

Energy Accounting of Irrigated Wheat Production to Post Production (Baking Bread) in Doroodzan, Fars Province, Iran

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ABSTRACT

The total energy input (TEI) of irrigated wheat in Fars province, Iran, was estimated at 901 liter diesel oil equivalent per hectare (LDOE ha⁻¹) (423 LDOE or 4819 Mcal, (47%) and 478.14 LDOE or 5454 Mcal, (53%) for wheat production and post production, respectively. The TEI for 1 ton wheat was estimated at 200 LDOE and for 1 ton of bread at 181 LDOE (wheat bread at 28% moisture). The direct use of fossil fuel oil in land preparation, planting, harvesting and transportation was estimated at 106 LDOE ha⁻¹. The applications of fertilizer and pesticide contributed about 40% of the total energy bill in production while it was larger in baking the bread at 72.3 LDOE ton⁻¹ or 75% of the energy costs of post production. At 4515 kg ha⁻¹ average yield of irrigated wheat in Fars province, Iran, the energy output was estimated at 15848 Mcal for raw wheat, 13409.55 Mcal for bread and 2895 Mcal for straw. The energy balance for raw wheat production (field level) was estimated at 3.3. Post- production (baking bread) consumed a lot of energy. The estimated energy balance was 1.3. Measures on how to reduce the energy bill for wheat production and for post-production (baking bread) are discussed.

Keywords: energy balance, energy input, energy output, liter diesel oil equivalent (LDOE), national average yield, organic farming

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DOI: 10.32945/atr3323.2011

Wheat (*Triticum aestivum* L.) is among the oldest and most extensively grown of all crops (Hung *et al.*, 2008). It is the main cereal cultivated throughout the world along with rice, barley, and maize. Wheat cultivar has been developed for different qualities in accordance with the development of genetic recombination (Hung *et al.*, 2008). It is also grown under irrigated as well as rainfed conditions. Under rainfed condition, the wheat crop is exposed to mild and severe drought stress at any stages of crop development (Singh *et al.*, 2005). In Iran, wheat is grown in both irrigated and rainfed conditions with a national production of 14.3 million tons in 2005. At least 40% of Iran's wheat is rainfed with an average yield of only 0.8 t ha⁻¹. However, even under the irrigated land, the average wheat yield in Iran rarely exceeds 3 t ha⁻¹, which is slightly higher than the world average of 2.6 t ha⁻¹ (<http://www.fao.org/docrep/007/J5051e/j5051e07.htm>). The average yield, however in Doroodzan dam, Fars province, Iran was at 4.5 t ha⁻¹.

There is a close relationship between agriculture and energy. Agriculture is an energy user (oil for tillage, farm input applications, irrigation, etc.) and energy supplier in the form of biomass (Alam *et al.*, 2005). Energy use in agriculture had increased due to increased energy inputs (fertilizer) to maximize yield and minimize labour intensive practices (mechanization) or both (Esengan *et al.*, 2007). Savings, reducing, or efficient use of energy in agriculture are needed for sustainable production (Blanco-Canqui *et al.*, 2006; Mendoza *et al.*, 2003; Mendoza, 2005; 2007; Samson *et al.*, 2001) for financial savings, fossil fuel resources preservation and air pollution reduction (Uhlin, 1998) and lesser greenhouse gas emission (Niggli *et al.*, 2009; West and Marland, 2002). Application of integrated production methods are recently introduced to reduce production cost, efficiently use of human labour and other inputs, and to protect the environment.

Accounting the energy budget of agricultural production and post production is the first critical step in identifying the energy intensive processes or stages of production. In the past, researchers have studied the use of energy for wheat production in Iran (Shahan *et al.*, 2008). In their study, they estimated that the total energy budget per hectare of wheat in Ardabil province was 10720.6 Mcal which is equivalent to

940 liter diesel oil. Wheat as the main food of the Iranian requires large volume of oil from production-to-post production. In US, 272 liters of diesel oil is consumed from production-to-post production of 1 ton wheat (Pimentel *et al.*, 2008).

Iran as an oil producing country can provide its own oil requirements at cheaper price. In 2007, Iran oil price was only half of the world price. The peak of world oil production (the time of maximum oil production) was in the year 2006 and now the world begin to experience shortage of oil supply which is expected to trigger an increase in oil price (Zittel *et al.*, 2007). Iranians will no longer enjoy cheap oil price in the near future. By year 2030, Iran oil stock will be limited and becomes most limiting by year 2050 (Zittel *et al.*, 2007).

The relationships between agricultural production and energy provides the clear signal to look at measures on how to efficiently use energy to help save oil and mitigate the possible oil shortage in the future. Knowing the processes or stages and the associated inputs for the particular stage or process are important in designing farm practices, or systems aimed at reducing the energy bill and in improving the energy use efficiency of that stage or the whole part of the production chain (Mendoza, 2007; Bony, 1993; Panesar and Fluck, 1993; Mudahar and Hignett, 1985). In this study, the energy consumed during the different stages of wheat production and post production in the province of Fars, Iran were estimated and the measures or practices which could reduce the energy costs are discussed.

MATERIALS AND METHODS

The Study Area

The study was done in Doroodzan dam farms, Fars province, Iran (Fig. 1). Fars province is located in the southern portion of Iran. Iran has three distinct climatic regions namely: 1, the mountainous area of the north and northwest with moderate cold winters and mild summers; 2, the central regions, with relatively rainy mild winters, and hot dry

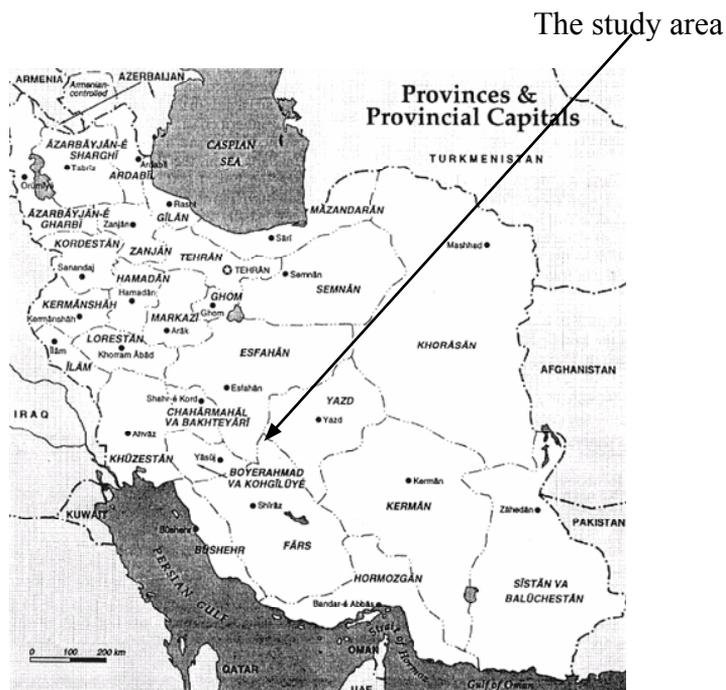


Figure 1. Map of Iran and the location of Fars province, the study area.

summers; and 3, the South and southeast, has moderate winters with very hot summers (http://en.wikipedia.org/wiki/Fars_Province). Doroodzan dam covers 110,000 ha of Fars irrigated land and it is located in first region of the northern part of Fars with average temperature of 16.8 °C (4.7° to 29.2 °C range) and an average precipitation of 485 mm (<http://www.frrw.ir/english/TarhhaDetails.aspx?id=38>).

Accounting of the Energy Bill of Wheat from Production to Post-Production

Energy Inputs for Wheat Production

Labour. The total labour incurred in growing 1 ha of wheat include land preparation (plowing and harrowing), seed preparation (seed mixing with fungicide and P fertilizer, and seed planting) and cultural

management practices (irrigation, N fertilization, herbicide, pesticide, care and maintenance and harvesting).

Machinery. The total time of machine used for growing a hectare of wheat which include plowing, harrowing, seed planting and harvesting operations.

Diesel Fuel. The amount of diesel fuel used for machine operations in a hectare of wheat for plowing, harrowing, seed planting and harvesting.

Material Inputs. The inputs include 92 and 87.2 kg ha⁻¹ N and P fertilizer respectively, 5L Fe, 2kg herbicide, 2 kg fungicide and 300 kg seeds.

Energy Usage for Irrigation. The energy uses for irrigating wheat include the energy inputs in dam and canal construction and the dam operation. For dam construction, the data were based in the construction of Hoover Dam (<http://www.usbr.gov/lc/hooverdam/faqs/damfaqs.html>) with the following specifications: Weight = 6,600,000 tons, concrete volume = 3333459 m³, steel weight = 83764.9 tons, construction period = 1806 days, number of labour = 3,500 / day. The density of normal concrete is 2400 kg/m³ (<http://hypertextbook.com/facts/1999/KatrinaJones.s.html>).

- Weight of concrete: $3333459 \times 2.4 = 8,000,301$ tons

- Number of man days = $3,500 \times 1806 = 6321000$ MD

Then, the ratio of concrete, steel and man day / weight of dam were estimated as follows; Concrete weight per weight of dam (ton): $8,000,301 / 6,600,000 = 1.212$; steel weight / weight of dam (ton): $83764.9 / 6,600,000 = 0.0127$; and the number of man day per weight of dam (tone): $6321000 / 6,600,000 = 0.957$.

Doroodzan dam in the Fars province, Iran, has the following features: Dam weight 11,300,000 tons and irrigation capacity of 110,000 hectares (<http://www.frrw.ir/english/TarhhaDetails.aspx?id=38>). Average dam lifespan is 150 years (<http://www.dcr.virginia.gov/documents/dsvadams.pdf>). Then, the above ratios were used in estimating the following data for Doroodzan dam: concrete weight, steel weight, number of man days, concrete weight ha⁻¹ year⁻¹, concrete energy ha⁻¹ year⁻¹, steel weight ha⁻¹ year⁻¹, steel energy ha⁻¹ year⁻¹, number ha⁻¹ year⁻¹, number of man hours

ha⁻¹ year⁻¹, man day energy ha⁻¹ year⁻¹, total energy consume for irrigation, energy compare to LDOE, percent energy of inputs in production, cost of inputs with average cost of US\$ 0.5 LDOE L⁻¹.

Canal construction energy consumed for excavation by machines is between 10-50MJ m⁻³ and average of 20MJm⁻³ or 4.78 Mcal m⁻³ (http://www.princeton.edu/~globsec/publications/pdf/8_1peterson.pdf). The length, depth and width of canal are 5,500,000 m, 1 m and 2m, respectively. The volume of excavation per meter length of canal was 2.4 m³ and the concrete per meter length of canal was 675 Kg (Pimentel *et al.*, 1980). The average life span of canal is 25 years (<http://www.dcr.virginia.gov/documents/dsvadams.pdf>).

Energy Inputs for Wheat Post Production

Labour. The total time of labour utilized for post production of wheat produced from one hectare irrigated area which include the following: temporary silo (transportation and seed elevator), permanent silo (transportation in, seed elevator in and seed elevator out), milling (cleaning, conditioning, grinding, sieving and purifying), packing, loading the packed flour in elevator, unloading the packed flour from elevator, loading the packed flour in track, transporting to bakery, preparing the paste and baking bread).

Machinery .The total time of machine used for post production of wheat produced from one hectare irrigated area included the following: temporary silo (transportation and seed elevator), permanent silo (transportation in, seed elevator in and seed elevator out), milling (cleaning, conditioning, grinding, sieving and purifying), packing, flour elevator, transportation to bakery.

Silo. Data of a wheat silo included: Inside diameter (4.24 m), inside height (22 m), capacity (278.3 m³), empty weight of silo (12.95 ton), weight of silage (178 ton) (<http://www.conairnet.com/product/documents/Material%20Storage%20Spec%20Sheets/Welded%20Silos.pdf>). The life span of silos was estimated at 50 years (<http://th2.mofcom.gov.cn/aarticle/supplydemandofchina/supply/200508/20050800335168.html>).

Diesel Fuel and Electricity. The amount of diesel fuel and electricity for post production of wheat produced from one hectare

irrigated area included: transportation (to temporary silo, to permanent silo and to bakery), seed elevator (temporary silo, permanent silo in, permanent silo out and flour), milling (cleaning, conditioning, grinding, sieving and purifying), packing and baking.

a. Elevator capacity was 250 kg h⁻¹ and power of ½ HP or 0.32 Mcal (<http://www.sehda.org/docs/wheat%20milling.pdf>).

b. Milling included cleaning, de-stoning and conditioning with capacity of 250 kg h⁻¹ and power of 5.5 HP or 3.5 Mcal (<http://www.sehda.org/docs/wheat%20milling.pdf>) and grinding, sieving and purifying with power of 33 kWh t⁻¹ or 28.37 Mcal (<http://www.ums.dk/Brochure%20PDF/Short%20Mill/ShortMill.pdf>).

c. Baking- 18% of wheat is lost when it is processed into flour. (<http://www.ums.dk/Brochure%20PDF/Short%20Mill/ShortMill.pdf>).

1. The moisture content of bread is 28% (<http://www.foodforlife.com/gluten-free-wheat-free-breads.html>).

2. Baking cost by gas per kg of bread was US \$ 0.059 when the price of gas was US\$ 39.20 per 50 kg cylinder. Baking cost by electricity per kg of bread was US\$0.047 when price of electricity was US\$ 0.39 kWh⁻¹. Baking cost by wood per kg of bread was US\$ 0.04 when the price of wood was US\$ 47 per 1000 kg (<http://cigr-ejournal.tamu.edu/submissions/volume9/EE%2007%20002%20Jekayinfa%20final%2012June2007.pdf>).

The energy consumed for the production of 1kwh electricity is 2.004 Mcal and the energy of 1 kwh is 0.859 Mcal and thus, the total energy for electricity is 2.863 Mcal (Pimentel, 1980).

Calculating the Total Energy Cost of Production to Post Production of Wheat

The various stages of wheat production-to-post production and the inputs used for each stage were accounted for. The specific energy used for each operation and inputs were estimated as per energy coefficients used by various researchers (Table 1) and the energy consumed for the various operations were converted to litter diesel oil equivalent (LDOE) to have easier grasp of their energy usage.

Table 1. The energy coefficients used for wheat.

| Input | Unit | Energy (Mcal) | Reference |
|---------------------|-------|---------------|---|
| Labour | Hour | 0.468 | Ozkan <i>et al.</i> , 2004 |
| Machinery | Hour | 14.975 | Erdal <i>et al.</i> , 2007 |
| Diesel fuel | Liter | 11.4 | Pimentel <i>et al.</i> , 1980 |
| LPG | Kg | 10.96 | http://www.shellgas.gr/site.html?page=16&lang=en |
| Wood | Kg | 4 | http://www.alibaba.com/company/100251168 |
| Electricity | KWh | 2.863 | Pimentel <i>et al.</i> , 1980 |
| Fertilizer N (Urea) | Kg | 14.3 | Pimentel <i>et al.</i> , 1980 |
| Fertilizer P | Kg | 2.97 | Esengun <i>et al.</i> , 2007 |
| Fe | Kg | 2.36 | Esengun <i>et al.</i> , 2007 |
| Seed | Kg | 3.51 | Ozkan <i>et al.</i> , 2004 |
| Straw | Kg | 1.37 | Ozkan <i>et al.</i> , 2004 |
| Bread | Kg | 2.7 | http://en.wikipedia.org/wiki/Bread |
| Chemicals | Kg | 28.66 | Canakci <i>et al.</i> , 2005 |
| Concrete | Kg | 0.365 | Thompson <i>et al.</i> , 1998 |
| Steel | Kg | 15.465 | Thompson <i>et al.</i> , 1998 |

The formula used in estimating the energy costs were as follows:
Equation 1. Inputs ha⁻¹ × Energy used (Mcal) = energy consumed ha⁻¹

Equation 2. Energy consumed ha⁻¹ / 11.4 Mcal/LDOE = LDOE ha⁻¹

Equation 3. LDOE ha⁻¹ × 0.5\$ L⁻¹ of Oil (LDOE) = cost of energy ha⁻¹

Equation 4. Man day (md) ha⁻¹ × US\$10 md = labour cost ha⁻¹

Equation 5. Output Mcal ha⁻¹ / input Mcal ha⁻¹ = energy balance

RESULTS AND DISCUSSION

The total energy cost per of wheat from production to post production was estimated at 901 LDOE ha⁻¹ or 10271 Mcal ha⁻¹ (Table 2). The energy cost in the field production of wheat was estimated at 422.7 LDOE ha⁻¹ or 4819 Mcal ha⁻¹ (47% of the total energy used, Fig.2)

Table 2. Energy (LDOE) consume for one hectare irrigated wheat in Fars province (Doroodzan Dam)

| PRODUCTION (47%) | Total | Total | Coefficient | Mcal | LDOE | LDOE | % | US\$ | US\$ |
|---------------------------------------|-------|-------|-------------|------------------|------------------|-----------------|--------|-------|---------|
| | day | hours | Mcal | ha ⁻¹ | ha ⁻¹ | t ⁻¹ | | unit | total |
| Labour | 39.8 | 318.4 | 0.468 | 149.03 | 13.07 | 2.89 | 3.09% | 10/d | 398 |
| Machinery | 2.5 | 20 | 14.975 | 299.51 | 26.27 | 5.84 | 6.21% | 0.5/l | 13.1 |
| Diesel fuel | | | | 638.4 | 56 | 12.45 | 13.24% | 0.5 | 28 |
| Input | | | | 2775.5 | 243.46 | 54.1 | 57.6% | 0.5 | 122 |
| Irrigation | | | | 956.31 | 83.88 | 18.64 | 19.8% | 0.5 | 44 |
| Total | | | | 4818.7 | 422.7 | 93.62 | | | 605.1 |
| Energy Balance | | | | 3.29 | | | | | |
| POST PRODUCTION (53%) | | | | | | | | | |
| Labour | 82.80 | 662.4 | 0.468 | 310.1 | 27.2 | 6.05 | 5.69% | 10 | 828 |
| Machinery | 1.41 | 11.28 | 14.975 | 169 | 14.82 | 3.29 | 3.1% | 0.5 | 7.4 |
| Silo | | 6.14 | 15.465 | 95.04 | 8.33 | 0.96 | 1.74% | 0.5 | 4.16 |
| Diesel fuel and electricity | | | | | 427.79 | 94.74 | 89.46% | 0.5 | 222 |
| Total | | | | 5454 | 478.14 | 106 | | | 1061.56 |
| TOTAL of production & post production | | | | 10271 | 901 | 200 | | | 1664.33 |
| Energy Balance | | | | 1.30 | | | | | |

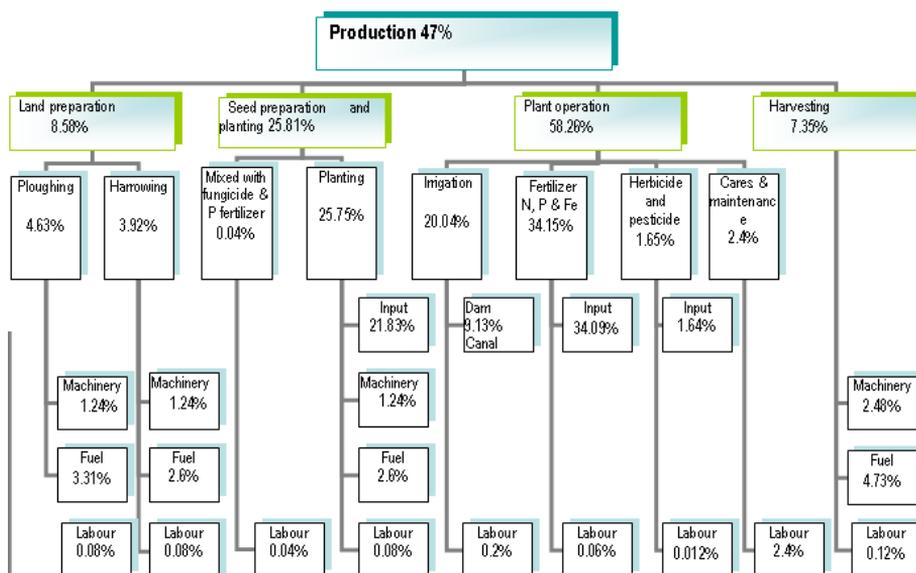


Figure 2. Energy consumed (%) for producing 1 hectare irrigated wheat in Fars province, Iran.

and 478.14 LDOE ha⁻¹ or 5454 Mcal ha⁻¹, for post production (54% of the total energy used). It is quite close to the estimated energy used in wheat production in US at 45% and post production at 55% (Pimentel, 2008). The total energy cost of 1 ton wheat from production-to-post production was estimated at 200 LDOE while the total energy cost for 1 ton bread was estimated at 181.4 LDOE. In U.S, it is 272 LDOE/ton as reported by Pimentel (2008). The energy cost of 1 ton wheat in the production level was equivalent to 93.62 LDOE (input 54 LDOE, irrigation 18.64 LDOE, fuel 12.45 LDOE, machinery 5.84 LDOE and labour 2.89 LDOE) and in the post production level at 106 LDOE (fuel 94.78 LDOE, labour 6.05 LDOE, machinery 3.29 LDOE and silo 0.96 LDOE).

At production level for one hectare wheat (Fig 2), planting operations consumed the highest energy estimated at 58.26% of production. Fertilizer N, P and Fe 34.15% consumed the highest followed by irrigation at 20.04% (dam-9.13%, canal-10.71%, and labour-0.2%), maintenance 2.4%, herbicide and pesticide at 1.65% (inputs 1.64% and labour 0.01%). The next group of energy consumer was seed preparation and

planting at 25.81% of production which included planting 25.75% (seed 21.83%, fuel 2.6%, machinery 1.24% and labour 0.08%) and mixing seed, fungicide and P fertilizer 0.04%. Land preparation consumed

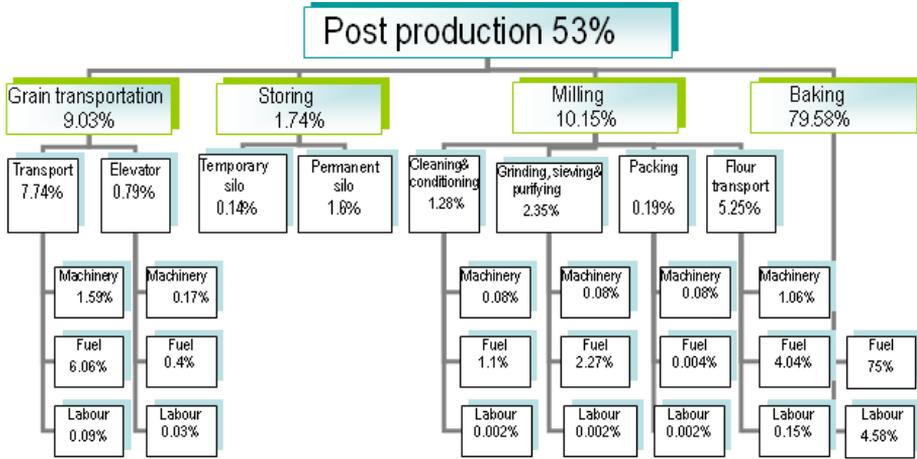


Figure 3. Energy consumed (%) for post production 1 hectare irrigated wheat in Fars province, Iran.

8.58% of the total energy bill in production which included ploughing at 4.63% (fuel 3.31%, machinery 1.24%, labour 0.08%) and harrowing at 3.92% (fuel 2.6%, 1.24% and 0.08%). The lowest energy consumed was in harvesting at 7.35% of the total energy bill of production (fuel 4.73%, machinery 2.48% and labours 0.12%).

For the post production stage (Fig. 3), baking was the highest energy consumer at 79.58% (fuel 75% and labour 4.58%) followed by milling at 10.15% of the total post production energy bill. This included flour transportation at 5.25% (fuel 4.05%, machinery 1.06% and labour 0.15%), grinding, sieving and purifying at 2.35% (fuel 2.27%, machinery 0.08% and labour 0.002%), cleaning and conditioning 1.28% (fuel 1.1%, machinery 0.08% and labour 0.002%) and packing 0.19% (machinery 0.08%, fuel 0.004% and labour 0.002%). Grain transportation consumed 9.03% of post production energy bill which included transportation 7.74% (fuel 6.06%, machinery 1.59% and labour 0.09%) and grain elevator 0.79% (fuel 0.4%, machinery 0.17% and labour 0.03%). The lowest energy consumer was storing bread at 1.74% of post production

energy cost (permanent silo 1.6% and temporary silo 0.14%).

The total expenses for wheat production were estimated at US\$1664.33 ha⁻¹ (Table 2). The most expensive input in irrigated wheat from production-to-post production was labour which consumed 66% of production and 78% of post production expenses. The difference in energy cost between production and post production was only 8% but the expenses increased in post production by 1.76 than production because the latter required more labour cost.

Energy Balance

Table 3. Energy balance for 1 hectare irrigated wheat in Fars province (Doroodzan Dam)

| PRODUCTION | Kg ha ⁻¹ | Efficiency of output Mcal | Output Mcal ha ⁻¹ | Input Mcal ha ⁻¹ | Energy balance |
|-----------------|---------------------|---------------------------|------------------------------|-----------------------------|----------------|
| Raw wheat | 4515 | 3.51 | 15847.65 | 4819 | 3.29 |
| Straw | 2113 | 1.37 | 2895 | 4819 | 0.6 |
| POST PRODUCTION | | | | | |
| Bread | 4966.5 | 2.7* | 13409.55 | 10271** | 1.30 |

* 2.7 Mcal/kg (<http://en.wikipedia.org/wiki/Bread>), ** production + post production = 10,271 Mcal

The energy output for production of grain and straw was estimated at 15847.65 Mcal ha⁻¹ and 2895 Mcal ha⁻¹, respectively (Table 3). The energy input of production was 4819 Mcal ha⁻¹ and the energy balance of production for grain and straw was estimated at 3.29 and 0.6, respectively. For post production, the bread produced per hectare production level was estimated at 4966.5 kg ha⁻¹, the energy requirements at 13409.55 Mcal ha⁻¹ and the input energy at 10,271 Mca ha⁻¹. The energy balance for bread (post production) was estimated at 1.30.

The energy cost of wheat production in Fars province, Iran (4819 Mcal ha⁻¹) was slightly higher than in the US (4239 Mcal ha⁻¹) (Pimentel *et al.*, 2008). The total energy consumed by fuel, labour, irrigation and machinery have no significant differences with that of the US, but the volume of seeds required for planting is 5 times higher in Iran. The average yields in Fars province is 4.5 t ha⁻¹ while only 2.9 t ha⁻¹ in US.. The energy cost ratio (production:post production ratio) for 1 kg wheat

in Fars province, Iran is about 47:53 while it is 45:55 in US (Pimentel *et al.*, 2008). Iranians are buying their breads directly from bakeries and they use their own fabric bags for packaging and thus no energy costs for packaging were included in the estimations. The energy cost for milling in Iran was 50% lower than in the US but the energy cost of baking in the former was 100% higher than the latter.

To reduce the energy incurred in production and post-production of wheat, it is necessary to look into all the energy requiring processes as follows:

1) The energy cost of production is related to inputs at 57.60% where 27.53% of the energy cost of production was N fertilizer. Nitrogen and other fertilizers and chemicals could be reduced by crop residues recycling (Badgley *et al.*, 2007, Mendoza , 2003; Samson *et al.*, 2001) or by returning wheat straw to the field and spraying them with microorganisms to facilitate decomposition (Parr *et al.*, 1994; Higa, 1991); planting of alfalfa in rotation to wheat (alfalfa with association of Rhizobial bacteria is able to absorb the N from the air and store in the root nodules) can decrease N requirements, planting of resistant varieties to pest and diseases to minimize pesticide use .

2) Water is the most limiting factor for agriculture and 20% of the energy cost of production is related to irrigation. Savings in water lost through seepage in the irrigation canal can be achieved by covering the canal by concrete .This could save water up to 80% and decrease the energy cost of irrigation as pointed out by many researchers (Singh *et al.*, 2007; and Shahan *et al.* 2008). It is correct that the initial costs would be high but the return in terms of lower energy cost of irrigation could more than offset the initial costs. Besides, water will soon be the limiting factor not only in wheat but other crops which should be grown also for balanced nutrition.

3) The embedded energy from machinery and fuel used to operate them consumed 6.21% and 13.24% of production cost, respectively. The average life span of machine in Iran is only 6 years but in countries where preventive maintenance and care of the machines are being done, the life span of machine reached up to 15 years or more. Using machine longer reduces the energy cost for their manufacture. Proper machine preventive maintenance will reduce the energy cost of machine and

fuel.

4) Labor is only 3.09% of the energy cost in wheat production but it is the most costly, monetary wise, as 66% of wheat production expenses are related to labour. Most of the labour cost (75.37%) is incurred for guarding their crops against animal intrusions. Unity of farmers in tending their animals shall decrease the labour cost.

5) The post-production energy bill was estimated at 53% of the total. But 79.58% of this was consumed in baking bread. The energy consumed for baking 1 kg bread with electricity was at 0.344Mcal while it was 0.824Mcal with LPG. Using of electricity instead of LPG can decrease the energy cost of baking by 2.4 times.

6) Construction of post production facility near the farm can generate substantial fuel savings because wheat has some secondary products (7% bran, 1% ash and 10% impurities) which can be used in the farm. After flour production, bran can be fed to livestock and other residues (ash and impurities) can be left in the farm and thus reducing the cost of energy in transporting them back in the farm. Every year, 18% of the gross yields are unnecessarily delivered to the cities. Iran produced 14.3 million tons of wheat in 2005. From these amounts, 2.5 million tons comprise the secondary products. At 4 L diesel oil required for delivery of 1 ton of wheat, the total oil used for transporting of 2.5 million tons secondary product was estimated at 10 million L diesel oil. Transportation to and from the city would consume about 20 million L of diesel oil to free the cities with these secondary products. This could have been avoided and savings are generated if factories are situated near the farms. It is important that the government should issue policy directives that future factories will be built near the farms.

CONCLUSION

The total energy input for irrigated wheat from production to post production in Fars province, Iran, was estimated at 901 LDOE ha⁻¹ or 10271 Mcal ha⁻¹. The energy cost in the production of wheat was equivalent to 422.7 LDOE or 4819 Mcal (47% of the total energy used) and 478.14 LDOE or 5454 Mcal (53% of the total energy used) for

post production. From production-to-post production, the energy bill was estimated 200 LDOE per ton of irrigated wheat and total energy cost for 1 ton bread was estimated at 181.4 LDOE. One tone of wheat produced consumed 93.62 LDOE and while post production consumed 106 LDOE.

The energy balance for production and post production was estimated at 3.29 and 1.30, respectively. The associated energy bill in the manufacture of production inputs led to their highest energy cost at 57.6% of production cost (nitrogen fertilizer 27.53%, seeds 21.83%, fertilizer P and Fe 5.62% and other chemicals 2.83%).

Fuel, the highest energy cost of post production contributed 89.46% of post production cost which included baking (76%), transportation (10.1%) and others (3.77%).

The most expensive input in irrigated wheat from production to post production was labour with 66% of wheat production and 78% of post production expenses. The difference between energy cost of production and post production was only 8% but the expenses in the latter were 1.76 times higher than the former because post production had higher labour cost.

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