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Life Cycle Analysis of the Processed Food versus the Whole Food – (Potato)

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Abstract—

The following report compares the energy inputs required for the processed food and whole food. The energy values are calculated considering many sectors and obtaining the energy equivalent of the each sector. Total energy is obtained by summing up the energy value of the individual sector. The value obtained is compared to the standard model value of the EIOLCA (d) model. Based on the model and its associated assumptions, the following conclusions can be drawn:

1. The processed food consumes 2.3% energy more than natural food production.

2. The major portion of energy consumption is due to electricity and the energy consumption can be reduced by judicial usage of electricity.

3. The study shows the correctness between EIOLCA and analytical model.

Key words: Processed food, whole food, EIOLCA, Energy

INTRODUCTION

There are two categories of foods: whole foods and processed foods. A healthy balanced diet should be primarily whole foods with restricted consumption of processed foods. There are numerous ways to differentiate between these two.

- Canned foods with large amounts of sodium or fat.
- Breads and pastas made with refined white flour instead of whole grains.
- Packaged high-calorie snack foods such as chips and candies.
- Frozen fish sticks and frozen dinners that are high in sodium.
- Boxed meal mixes that are high in fat and sodium.

Considering the nutrition values, whole food scores over the processed food.

Processed Foods

Generally speaking, processed foods are produced using manufacturing methods to transform raw ingredients into neatly packaged goods, which have a longer shelf life. Some of the artificial ingredients used include monosodium glutamate (MSG), flavors, preservatives, hydrogenated oil, fillers, and artificial sweeteners. Usually, consumers can prepare them quickly allowing immediate intake. Disappointingly, they don't offer much in nutritional value. This food category is well funded by government subsidies.

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Whole Foods

On the other hand, whole foods are grown in orchards, gardens, or greenhouses, are unprocessed and unrefined, and have a shorter shelf life. These foods are authentically flavorful, have vibrant colors, and rich textures. Moreover, they are full of the micronutrient vitamins, minerals, antioxidants, photochemical, and fiber. Typically, they require longer preparation times. In contrast, they receive very little media advertising, and are not well funded with government subsidies.

In this article vegetable has been considered as the area of focus and for analysis Potatoes has been considered, fresh potatoes and frozen potatoes.
As a potato does not go on with the bill of materials, I have classified my work into three sectors.

1) Production of crop
2) Material transport and preservatives
3) Consumer usage

1) Production of crop:

The potato is a cool season crop and it is grown through the spring months and harvested in early summer. Fall potato production usually results in poor plant stands and low production, due to high soil temperatures at planting and during early crop development. Potatoes grow best in fertile, well-drained, sandy loam soils. Planting on poorly drained soils usually results in a poor plant stand, due to seed piece decay and poor quality potatoes at harvest. Soils which blow or have poor water holding capacity should be avoided.

The factors effecting the production can be given as:

a) Effect of climate
b) Effect of soil
c) Effect of irrigation

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d) Effect of pesticide, fungicide

The energy calculations can be carried for the same by considering the production cost and raw materials used for manufacturing.

Material transport and processing:

Many stages in processing cause changes in flavor, color, texture and nutritive value. Heat treatment destroys enzymes and physical properties of the materials. However, modern methods involve the preservation of succulent peas by canning, freezing and dehydration. The blanching process is also an effective means of preservation. In the U.S., western states account for approximately 65% of production, central states account for 25%, and eastern and southern states account for the remaining 10%. With 90% of all potatoes being harvested in the fall, a majority of the crop is not sold immediately but rather stored and sold throughout the remainder of the year. Potatoes have the physical characteristics that make them ideal for long term storage in specialized sheds. As a result consumers have access to high quality potatoes year-round.

The transportation process can be layered into two types,

a) The transport from the producer to the market through road.

b) The storage process in the consumer market.

The energy usage in this can be calculated as in the fuel consumption in travelling and the energy utilized for the refrigeration in the consumer market.

2) Consumer usage:

The consumer usage covers the choice of the consumer of the processed or the whole food. The processed food uses energy for the storage and the nutrient value decreases on heating and reheating. The whole food has relatively less energy usage but the freshness in prone to reduce during long distance transportation. However the nutrition value of the whole food is more, hence the body requires less amount of food! This may not be the case with processed food.

I. RELATION BETWEEN ENERGY AND AGRICULTURE

The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio-energy. The size of the population engaged in agriculture, the amount of arable land and the level of mechanization are the most important factors on the energy utilization in the agricultural sector. A wide range of energy forms are used directly such as diesel fuel, water pumping and water for irrigation, and indirectly such as fertilizers and pesticides. Other energy inputs are required for post harvest processing in food production, drying, packaging, storage, and transportation and cooking. Energy use in agriculture has been intensified in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labor-intensive practices or both. Effective use of energy in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction [f]

Production of crop:

U.S. Potato Production and Value, 2002 (b)

- 0.51 million hectares of potatoes were harvested
- 20.84 billion pounds of potatoes were produced (grown)
- $3.15 billion was the value of U.S. potato production

The energy required for the production of the potatoes can be given as mentioned below.
Firstly, the amount of inputs used in the production of potato (chemicals, human labor, machinery, seed, manure, fertilizers, fuel, electricity and irrigation water) were specified in order to calculate the energy equivalences in the study. The amounts of input were calculated per hectare and then, these input data were multiplied with the coefficient of energy equivalent. The previous studies were used to determine the energy equivalents' coefficients. The energy equivalences of unit inputs are given in Mega Joule (MJ) unit (table 1). The total input equivalent can be calculated by adding up the energy equivalences of all inputs in MJ.

Table 1 . Energy equivalent of inputs

Particulars	Unit	Energy equivalent (MJ unit−1)	References

Particulars	Unit	Energy equivalent (MJ unit−1)	References
A. Inputs			
1. Human labor	H	1.96	1
2. Machinery	H	62.7	1
3. Diesel fuel	L	56.31	1
4. Chemical fertilizers	Kg	89.73	1
(a) Nitrogen (N)		66.14	1
(b) Phosphate (P2O5)		12.44	1
(c) Potassium (K_2O)		11.15	1
5. Farmyard manure	Kg	0.3	1
6. Electricity	kWh	11.93	1
7. Chemicals	Kg	555.2	1
(a) Insecticides		101.2	1
(b) Herbicides		238	1
(c) Fungicides		216	1
8. Water for irrigation	m3	1.02	1
9. Seeds (potato)	Kg	3.6	1

The total land area for the potato vegetation is .51 billion hectare. The results from various research works are considered and scaled up to the factor of 20 to manage the land usage.
This gives the quantity per unit area which is multiplied with the energy equivalent and the total energy input is obtained by summing up the energy values.
The sample calculation is shown below:
The energy equivalent for the human labor can be calculated as the product of Energy equivalent and the quantity per unit area. The total energy can be obtained the summing up the individual energy of the inputs. The value obtained is compared to the energy value of the Economic Input-Output Life Cycle Assessment (EIO-LCA) US 2002 (428) model. The Sector looked upon is 111200 -Vegetable and melon farming. The sector is however a broader one and comprises of 111211- potato farming. Hence the values obtained from the manual calculations and the EIOLCA differ a little. The values for the other inputs are calculated. Below shown is the formula which is used for the energy required for the tractor. In order to make an energy analysis it is necessary to consider the use of human and animal power in agricultural processes. For the estimation of gross energy input for agriculture, working days of agricultural workers are taken as 210 days assuming an average of 8 h of work a day, and the number of working hours of animals in Agricultural production is taken as 360 h annually.
To calculate the energy used in agricultural production or repair of machinery, the following formula was used.

$$ME = (G^* E) / (T^* Ca) \qquad (e)$$

Where ME, machine energy (MJ/ha); G, weight of tractor (kg); E, constant that is taken 158.3 MJ/kg for tractor; T, economic life of tractor (h); Ca, effective field capacity (ha/h).
For calculation of Ca, the following equation was used.

$$Ca = (S^* W^* Ef) / 10 \qquad (e)$$

Where Ca, effective field capacity (ha/h); W, working width (m); S, working speed (km/h);
Ef , field efficiency.
The equivalent energy values are tabulated (table 2). The total energy value is obtained as 5.30TJ. The above value is compared to the value obtained from the Economic Input-Output Life Cycle Assessment (EIO-LCA) US 2002 (428) model.

Table2: Amounts of inputs with their equivalent energy

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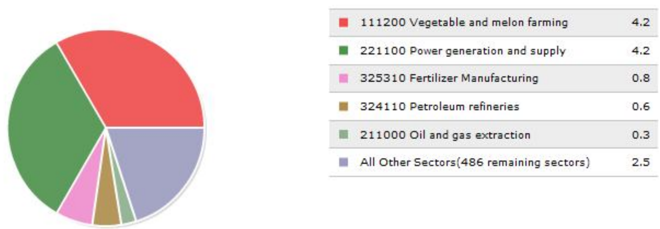
Quantity (inputs)	Unit	Quantity per unit area (ha)	Total energy Equivalent (MJ ha−1)
A. Inputs			
1. Human labor	H	10699	20970.04
2. Machinery	H	944.8	59238.96
3. Diesel fuel	L	10099.6	568708.47
4. Fertilizers (a) Nitrogen (N)	Kg	18,360 9963.2	658966.048
(b) Phosphate (P205)		4985.2	62015.88
(c) Potassium (K2O)		3411.6	38039.34
5. Farmyard manure	Kg	208234	62470.2
6. Chemical	Kg	88.6	
(a) Insecticides		29.8	3015.76
(b) Herbicides		28.8	6854.4
(c) Fungicides		30	6480
7.water for irrigation	M3	149407.4	152395.548
8.electricity	kWh	93920.2	3361403.958
9. seed	Kg	83811.6	301721.76
Total energy input	MJ		5.30*10^6

Table3: Economic Input-Output Life Cycle Assessment (EIO-LCA) US 2002 (428) model

	Sector	Total Energy TJ	Coal TJ	NatGas TJ	Petrol TJ	Bio/Waste TJ	NonFossElec TJ
	Total for all sectors	*12.6*	*3.22*	*2.94*	*4.27*	*0.323*	*1.88*
111200	Vegetable and melon farming	4.20	0	0.281	2.71	0	1.21
221100	Power generation and supply	4.20	3.06	0.894	0.148	0	0.098
325310	Fertilizer Manufacturing	0.774	0.003	0.692	0.017	0.010	0.052
324110	Petroleum refineries	0.594	0.000	0.159	0.385	0.029	0.021
211000	Oil and gas extraction	0.314	0	0.256	0.027	0	0.031
325190	Other basic organic chemical manufacturing	0.311	0.039	0.119	0.043	0.094	0.017
484000	Truck transportation	0.284	0	0	0.281	0	0.003
486000	Pipeline transportation	0.110	0	0.083	0	0	0.026
531000	Real estate	0.097	0.005	0.014	0.002	0	0.076
322130	Paperboard Mills	0.091	0.008	0.019	0.004	0.054	0.006

From the above table, adding values of (111200+325310+325190), we get total input energy as 5.25TJ which is close approximation to the calculated value.

Graph1: Economic Input-Output Life Cycle Assessment (EIO-LCA) US 2002 (428) model is shown below:



PROCESSED FOOD PRODUCTION:

The processed food had additional energy requirement for cooling which is 1800Kcal / kg (b).

Hence the total energy required for the frozen food is given as:

Potato Utilization Methods

34% frozen

28% fresh

12% chip

10% dehydrated

15% potato seed and on farm consumption

1% canned

Hence the additional energy required for cooling

= .34*20.84*10^9*.45*.004187*1800

= .0238TJ (C)

Hence the total energy input is increased to 5.328*10^12 J.

Comparing this value to the value obtained from the Economic Input-Output Life Cycle Assessment (EIO-

LCA) US 2002 (428) model [Internet]. The tabular value is shown below (table4).

Table 4: Economic Input-Output Life Cycle Assessment (EIO-LCA) US 2002 (428) model [Internet].

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HOME >> USE THE TOOL >> BROWSE US 2002 (428) MODEL >> DISPLAYING...

Sector #311410: Frozen food manufacturing
Economic Activity: $1 Million Dollars
Displaying: Energy
Number of Sectors: Top 10

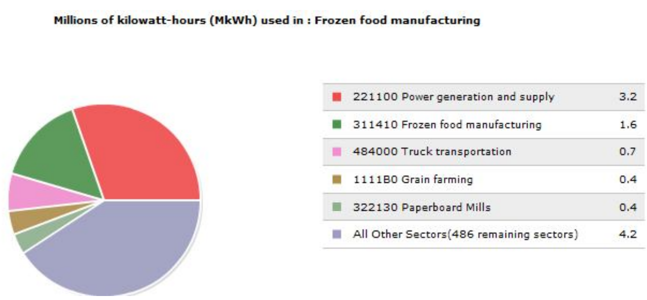
Documentation:
The sectors of the economy used in this mo
The environmental, energy, and other data
Frequently asked questions about EIO-LCA

Change Inputs (Click here to view greenhouse gases, air pollutants, etc...) **This sector list was contributed by Green D**

	Sector	Total Energy TJ	Coal TJ	NatGas TJ	Petrol TJ	Bio/Waste TJ	NonFossElec TJ
	Total for all sectors	*10.4*	*2.56*	*3.02*	*2.71*	*0.584*	*1.50*
221100	Power generation and supply	3.16	2.30	0.672	0.112	0	0.074
311410	Frozen food manufacturing	1.57	0.050	0.939	0.058	0.051	0.477
484000	Truck transportation	0.653	0	0	0.647	0	0.006
1111B0	Grain farming	0.413	0	0.041	0.315	0	0.058
322130	Paperboard Mills	0.361	0.033	0.074	0.015	0.213	0.025
324110	Petroleum refineries	0.295	0.000	0.079	0.191	0.015	0.011
322120	Paper mills	0.265	0.036	0.054	0.018	0.131	0.027
4A0000	Retail trade	0.254	0.002	0.039	0.057	0	0.157
211000	Oil and gas extraction	0.187	0	0.153	0.016	0	0.018
482000	Rail transportation	0.165	0	0	0.163	0	0.003

The values of 311410+221100+484000 are added to give total input value as 5.83TJ.

Graph 2: MkWh used in frozen food manufacturing



Hence the calculated value and the value derived from the software are in accordance with each other.

The energy consumption of the frozen potatoes is more than the fresh ones by 2.3%.

Differences between the working of both the models: As there is no build of materials the amount of inputs used in the production of potato (chemicals, human labor, machinery, seed, manure, fertilizers, fuel, electricity and irrigation water) were specified in order to calculate the energy equivalences in the study. The inputs included in the manual calculations which have several fields like water for irrigation, human labor, machinery, which is not considered in the EIOLCA model. Hence the value obtained in the analytical model is not same as the value shown in EIOLCA model. Also there is not separate sector for the potato farming, Hence the value is higher for the energy input.

The following are the summarized key notes comparisons:

1) The EIOLCA model has very less or no weight-age for several input fields I have considered for the calculations such as human labor, machinery etc.

2) The EIOLCA generalizes the field as vegetable and melon farming. However it says the sector vegetable farming melon farming comprises of potato farming.

3) However the values can be changed by multiplying by a correction factor for both whole food and processed food. The values can be obtained by knowing the percentage potato growth with respect to other vegetables.

Conclusions:

Based on the model and its associated assumptions, the following conclusions can be drawn:

1. The processed food consumes 2.3% energy more than natural food production.

2. The major portion of energy consumption was due to electricity and the energy consumption can be reduced by judicial usage of electricity.

3. The differences in the EIOLCA and other model were compared.

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