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Energy Consumption and Greenhouse Gases Emission form Canned Fish Production in Iran a Case Study: Khuzestan Province

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Abstract: Energy is a fundamental ingredient in the process of economic development, as it provides essential services that maintain economic activity and the quality of human life but intensive use of it causes problems threatening public health and environment. The aim of this study was to evaluate energy consumption and greenhouse gases emission from canned fish production in the Khuzestan province, Iran, to determine the losing energy factors and pollutant emission. In this research, canneries, consuming human labor, electricity and diesel fuel energy sources were investigated. Total input energy was 22681.8 MJ/t that diesel fuel had the biggest share in the total energy up to 98%. Energy of labour was a small amount of total input energy, but it is the most expensive input in the canned fish production. Primary cooking and sterilization operations are most consumers of input energy in canning fish production with 21202.6 MJ/t. Manual operations of fish cleaning and transferring, includes the lowest energy and this stage includes 43.33% of total human labour. Amount of greenhouse gas and air pollutant emissions from diesel fuel is much greater than electricity in fish cannery. Emission of CO_2, NO_X and SO_2 are the most gas emission with 1071.282, 7.264 and 6.52 Kg/t, respectively. Productivity of labour and electricity, diesel fuel and labour energy were 0.025 t/L_a 1h and 2.2, 0.044 t/GJ and 0.056 t/MJ, respectively. Using agitating retorts in steed of still retorts and reform path of transferring vapor will decrease the diesel fuel consumption and greenhouse gas emission.

Key words: Canned fish, energy, greenhouse gas, Iran

INTRODUCTION

The total amount of seafood consumed is growing due to international sourcing of raw material, advances in food processing technology and healthy properties (Abad *et al*., 2009). Due to their nutritional value, fish and canned fish products are high quality foods that are beneficial to human health. Fish and canned fish are sources of protein rich in essential amino acids, micro and macro elements (calcium, phosphorus, fluorine, iodine), fats that are valuable sources of energy, fat-soluble vitamins, and unsaturated fatty acids that, among other benefits, have a hypocholesterolic effect (anti-arteriosclerosis) (Usydus *et al*., 2008; Ismail, 2005). Fish is high in lysine and sulphur amino acids which make it particularly suitable for complementing the high-carbohydrate diet prevailing (Kent, 1987) and it provide a healthful source of dietary protein, and are relatively low in cholesterol and high in omega-3 (n-3) fatty acids (Steffens, 1997; Burger and Gochfeld, 2004; National Research Council, 2000) that reduce cholesterol levels and the incidence of heart disease, stroke, and preterm delivery (Patterson, 2002; Burger, 2005). Epidemiological studies on heart disease consistently indicate a protective role for fish and seafood consumption as opposed to land animal fats. Fish consumption is claimed to be associated with a reduced risk from all-cause, ischemic heart disease and stroke mortality at the population level (Torres *et al*., 2000). In fact consumption of fish is an essential part of a healthy and well balanced diet (Sazaki and The Fukuoka Heart Study Group, 2001; Moya *et al*., 2008). Several studies have documented the long-term cardio protective benefits for adults as well as the reproductive benefits of eating fish (Burger and Gochfeld, 2004). In comparison to the meat of slaughter animals, that of fish is rich in phosphorus, potassium and magnesium, and the calcium content of small-boned fish is also high. Marine fish and products made from them are the primary natural source of dietary iodine. They are also rich in microelements, such as selenium, fluorine and zinc (Usydus *et al*., 2008). Since fish, including its meat, bones and organs, contains good amounts of vitamin A, iron and iodine, it may be useful in combating the specific nutritional deficiencies, which can result in nutritional blindness, anaemia and goitre. Fish also has value as an energy source. Fish bones, which may be eaten in small

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fish such as sardines are particularly rich in calcium and phosphorus. On a unit weight basis, fish is relatively expensive in comparison with vegetables and grains, but it is frequently less costly than alternative animal protein sources. In relation to its nutritional value, it can be quite inexpensive, even compared with vegetable protein sources (Kent, 1987).

Global production of aquaculture products more than doubled during the 1990s, reaching around 45 million tons in 2000, while captured fisheries had a total of 96 million tons in 2000 (Tuominen and Esmark, 2003).

In 2006, the amount of Iran's fish production was equal to 563.9 tons and per capita consumption of marine products was 7.7 Kg (Anonymous, 2006b). The major of adverse factors in this situation is its high perishability (Kent, 1987). Research was conducted in 2002 indicated that about 45.7% of households interested in taking the form of fish are packaged (Anonymous, 2006a).

Canning is one of the common methods to preserve fish (Kent, 1987). The purpose of cannery is using heat alone or with other conserve materials to disable or remove all harmful microbes and canned the product so that this is preserved against contamination (Footitt and Lewis, 1995). Due to proximity to the Persian Gulf, Oman Sea, Caspian Sea, domestic water and ponds of fish, Iran has very high potential in fish production.

Energy has an influencing role in the development of key sectors of economic importance such as industry, transport and agriculture. This has motivated many researchers to focus their research on energy management (Singh, 1999; Baruah and Bora, 2008). Energy is a kind of strategic resource and an important substantial basis for economic increase and social development (Arevalo *et al.*, 2007; Shao and Chu, 2008). Per capita energy consumption is an index of growth of any nation in all forms of inputs. Different forms of energy like fuel for cooking, motive power for transport and electricity for modern communication are very important factors for growth of present- day- civilization (Singh, 2002). Energy is considered a prime agent in the generation of wealth and a significant factor in economic development (Demirbas, 2003).

Energy is essential to economic and social development and improved quality of life in world and the global economy has depended largely upon fossil energy such as coal, petroleum, and natural gas. These energy sources have been consumed throughout the world, seriously degrading the Earth's environment (Dickmann, 2006; Shao and Chu, 2008). There are many immediate adverse effects to the environment such as greenhouse gases and pollutants emissions from the burning of fossil fuels (Li *et al.*, 2009). Environmental problems growing dramatically caused by significant increase of consumption of fossil fuel energy and greenhouse gas emissions. Fossil fuel burning causes a significant pollution of CO_2, SO_2, NO_x and other gases (Kalogirou, 2004). They have very bad influence on environment such as acid rain, air pollution, destruction of ozone layer and land and global earth warming (Haralambopulos and Spilanis, 1997). However, intensive use of energy causes problems threatening public health and environment (Demirbas and Arin, 2002; Dickmann, 2006) that it has made a direct threat to world peace and development, becoming a common problem in any part of the globe (Demirbas, 2006; Grennan, 2006).

Therefore, both the natural resources are rapidly decreasing and the amount of contaminants is considerably increasing. Use of energy has been discussed due to its effect on the concentration of greenhouse gasses and consequently global warming. The best way to lower the environmental hazard of energy use is to increase the energy use efficiency (Esengun *et al.*, 2007).

Energy consummation analysis in production operations of cannery would be result in determining energy overuse sectors and may act as a platform to improve production processes.

Considering the importance of energy in economic, environment and sustainable development, surveying energy consumption and greenhouse gas emission from fossil energy resources in fish cannery seems necessary. The aim of this study was to evaluate energy consumption and greenhouse gas and air pollutant emission in canned fish production in the Khuzestan province, to determine the energy losing factors and decrease air pollutants.

MATERIALS AND METHODS

The study was carried out in Khuzestan province of Iran in December 2009- February 2010. The province with an area of 64,055 Km^2 is located in southwest of Iran (within 29º 58′ and 33º 04′ North latitude and 47º 41′ and 50º 39′ East longitude). In 2006 the populations of Khuzestan province were over 4.2 million (equivalent to 6.07% of the Iran's population) (Anonymous, 2006b). The main value-added sectors of economic activities of Iran are belonging to this province as in 2006, 15.6% of the gross domestic production value belongs to this province (Anonymous, 2009). Because of Persian Gulf, existence of internal waters and artificial lakes, the fish production potential in this province is very high. In 2006, the amount of fish hunting in different fishing waters of Khuzestan is equal to 33406 tons that between the coastal provinces of the Iran had the second rank. In this year, domestic aquaculture production of province is 25066 tons, which has the second rank. Number of fishing vessels in Khuzestan province is 2446 (Anonymous, 2006b).

Processing of canned fish: Figure 1 shows the Flow chart of production processes of canned fish. Preparing

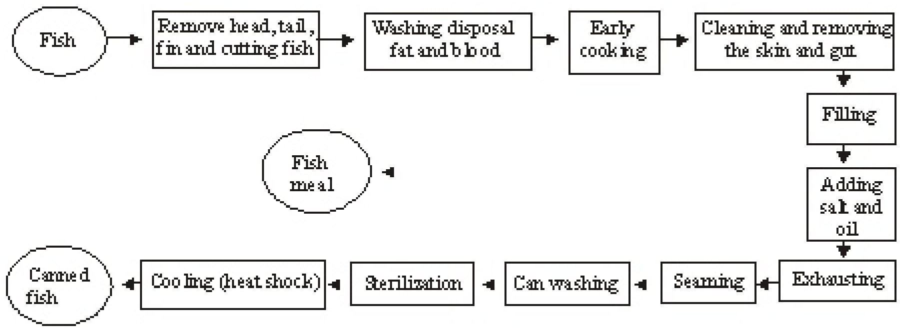

Fig. 1: Flow diagram of processes of canned production

fish for the cannery process includes removing the head, tail, fin and the paunch. A machine that is controlled by labour does removing head and tail and cutting fish. Waste (head, tail, etc.,) in this stage is used for animal feed (fish meal). After this stage, fish is washed with water and detergent. Preliminary cooking of fish is done by steam. This process in the Khuzestan province is accomplished in the steel boilers. The purposes of the primary cooking are removing the fats, comfortable making skin, sifting tissue of fish and making it ready for filling cans. Diesel fuel is burning to heat water and produce steam at this stage. In the next stage, fish placed on the metal tables and then is cleaned and bone, gut and materials with low quality is removed manually ranked first as the most labor consuming operation in canned fish production. Waste materials in this section are used as a animal feed ingredient.

Fish is transported among different stages of production by special cart and labor force just before cleaning tables. Filling is one of the important stages in the cannery which qualitative and quantitative aspects of it must be considered. Cans should be filled uniformly. Filling the cans in this province is done manually or semi-automatic. The main purpose of adding salt is adjusting and stabilizes flavor of fish in the product. Salt addition also is done manually. Oils are the one of the most important materials in canned fish formulation. Oils, which added automatically, must be stable and free from undesirable flavors and constitute 18% of the total amount of product. One of the important steps in cannery is exhausting air and gases from cans before the seaming operation do. Exhausting tunnel length is 6 m and located in 3 rows that are above other. At this stage due to high temperature of exhausting tunnel and creating steam, oxygen and air are exhausted from cans. Seaming in cannery is very important because main success of cannery industry is in creating a suitable Seaming. Seaming operations in the province are performed by automatic seamer machine. After this stage, cans are washed with detergent and hot water. After washing, the cans are placed in the retorts for sterilization. In Khuzestan, steel retort is used for food sterilization. After this stage, the cans are cooled by water so that Thermal shock to them to be given. Thermal shock is done in the retorts.

Calculated energy includes energy fuel, electricity and labor energy consumed in different stages of production. Electricity and other none operational energy consumption such as energy for ventilation and lighting, heating and cooling the canned fish factory weren't calculated. Diesel fuel, electricity and human labor were energy resources of input energy. Table 1 shows the types of input energy in each operation of canned fish production.

Diesel fuel is consumed in steam boilers to create hot steam. Hot water steam is transferred through pipes and fittings to the retorts (autoclave) for primary cooking, sterilization, and for washing. After filling stage, cans are transferred by conveyor.

Energy equivalents in Table 2 were used for estimation. Using the method of dimensionless analysis, it was found that for all operations utilizing energy, energy demand in *i* operation (E_{ei}) is directly proportional to the electrical power consumed in $_i$ operation (P_i) and the time taken to complete the *i* operation (t_{hi}), that is,

$$E_{ei} = \sum P_i t_{hi} k_{ei} \tag{1}$$

Where k_{ei} is the constant of proportionality, which represents the power factor of electric motor used (Jekayinfa and Bamgboye, 2007). Equation 2 was used for calculate energy of diesel fuel consumption.

$$E_{fi} = \sum f_i k_f \tag{2}$$

where, E_{fi} is the energy of diesel fuel, f_i is the quantity of diesel fusil consumption in *i* operation and K_f is the heat value of diesel fuel. Because the steam is transferred through the common tunnel to retorts, energy of diesel fuel for each stage of heating fish was not calculated

Table 1: Different stages of production of canned fish and type of input energy

Stages of production	Type of input energy
Transfer fish to the early preparation hall	Human labor
Remove head, tail, fin and cutting fish	Electricity+ human labor
Transferring, washing, disposal fat and blood and primary cooking	Diesel fuel+ human labor
Cleaning and transferring	Human labor
Filling and transferring	Electricity+ human labor
Adding salt	Human labor
Adding oil	Electricity+ diesel fuel
Exhausting	Electricity
Seaming	Electricity
Cans washing a transferring	Electricity+ human labor + diesel fuel
Sterilization and cooling	Diesel fuel

Table 2: Energy equivalents of input

Input	Unit	MJ/unit	Reference
Diesel fuel	L	56.31	(Erdal *et al*., 2007; Mohammadi *et al*., 2008)
Electricity	kWh	12	(Kitani, 1999)
Labour	h	2.2	(Pimentel and Pimentel, 1979)

Table 3: Factor of greenhouse gas and air pollutants emissions

Item	NO_x	SO_2	CO_2	SO_3	CO	CH	SPM
Diesel fuel (g/L)	18.3	16.4	2647.98	0.19	4.37	13.36	8.39
Electricity (g/kWh)	0.894	1	572.603	0.015	0.001	0.034	0.108

Source: (Anonymous, 2006a)

separately and total energy consumption for baking process (initial cooking and sterilization) was calculated. For calculating energy of labor, Eq. (3) was used:

$$E_{1i} = \sum k_1 L_{ai} t_{hi} \qquad (3)$$

Where E_{1i} is the input energy of labour in *i* operation and k_1 is the energy equal of labour that for female is equal 0.8 the energy of male (Singh and Mittal, 1992). La_i is number of labour in *i* operation.

The total energy expenditure in producing a given quantity of canned fish is the sum of the energy components involved in each process operation. Thus the total energy, E_T, becomes:

$$E_T = \sum E_{ei} + \sum E_{fi} + \sum E1_{ai} \qquad (4)$$

To calculate emissions of greenhouse gases and air pollutants, emissions factor (gases emission from unit energy consumption) were used. Factor of greenhouse gas and air pollutants emissions of diesel fuel and electricity are shown in Table 3.

Amount of greenhouse gas and air pollution emissions be caused by diesel fuel were calculated from the Eq. (5):

$$D_j = \sum \frac{c_j f}{1000} \qquad (5)$$

where, D_j is amount of *j* greenhouse gas or air pollutant emission (kg), c_j is index of greenhouse gas or air pollutant emission from diesel fuel (g/L) and *f* is amount of diesel fuel consumption (L).

There is a lot loss in Production, transferring and distribution of electricity that must be considered. To calculate the amount of greenhouse gas and air pollutant emission from electricity consumption conversion coefficient of electricity consumption equivalent to its production was accounted whit equal 6.

$$b = 11 + \frac{L_T}{100} \qquad (6)$$

b is the conversion coefficient of electricity consumption equivalent to its production and L_T is the total electricity loss that including domestic consumption of power plants, transferring and distribution losses. Amount of greenhouse gas and air pollutant emissions was calculated with Eq. (7):

$$D_j = \sum \frac{k_j b E_e}{1000} \qquad (7)$$

Where; k_j is the index of greenhouse gas or air pollutant emission from electricity (g/kWh) and E_e is the electricity consumption (kWh).

That partial productivity shows that per unit input, how much product is produced which is useful for comparing input in different production units. Partial productivity is calculated by Eq. (8):

$$Pertial\ productivity = \frac{Output}{Input} \qquad (8)$$

Partial productivity of labour and electricity and diesel fuel energy was calculated.

RESULTS AND DISCUSSION

The input energy values used in each metric ton of canned fish production are illustrated in Table 4. Total input energy was 22681.8 MJ/t. The most energy consumption was diesel fuel with 98% (22227.6 MJ/t) of the total input energy that shows the production of canned fish is severely depended on the diesel fuel in this type of cannery. Efficiency of still retorts is low and loss of water steam in them is high. Using agitating retorts (high efficiency) may decrease the diesel fuel consumption. Reducing even a few percent of diesel fuel consumption in production will significantly decrease the total input energy. Electricity includes 1.92% of total input energy. Energy of labour was a small amount of total input energy but it is the most expensive input in the cannery, therefore managing and increasing productivity of it is very important. Mechanizing and using of conveyer to transfer fish, will increase the use of electric energy but will decrease the labour force that compared to the electric energy is much higher cost. Women were 71% of total human labour in fish cannery because most of the manufacturing process is delicate and need accuracy. More of male labor force is used in heavy manufacturing operations such as transferring and cutting fish. Stage of cleaning, removing skin and viscera of fish are the most consumer of labor force.

Table 5 shows the energy inputs used in each operation of canned fish production. Initial cooking and sterilization operations are most consumers of input energy in canning fish production with 21202.6 MJ/t. Energy consumption in this process is including diesel fuel energy. After those operations, washing operation due to use of warm water for washing is other high-energy consumption operation whit 883.33 MJ/t in canned fish production. In adding oil operations due to heating oil, energy consumption is also higher than other stages. Input energy in adding salt and oil operations was 254.43 MJ/t. Operations of cleaning fish and transferring with labour force includes the lowest energy (7.44 MJ/t). At this stage, labor force is only used that about 81% of them are women. This stage due to high labor cost is the most expensive stage of production. In this section can be reduce labour and costs with mechanizing operations (especially transmission). This stage includes 43.33% of total human labour in production.

Table 4: Input for canned fish production (MJ/t)

Input	(MJ/t)	(%)
Labour	17.9	0.08
Electricity	436.3	1.92
Diesel fuel	22227.6	98
Total	22681.8	100

Table 5: Energy inputs in each operation

Operation	Input energy (MJ/t)
Transfer fish to the early preparation hall	89.1
Cleaning and transferring	7.44
Filling and transferring	117.25
Adding salt and oil	254.43
Exhausting	51.15
Seaming	76.5
Washing and transferring	883.33
Initial cooking and sterilization and cooling	21202.6

Emissions of greenhouse gas and air pollutant are shown in Table 6. Amount of greenhouse gas and air pollutant emissions from diesel fuel is much greater than electricity in fish cannery. Emission of CO_2 gas is much more than the other gases. The amount of this gas emission from diesel fuel and electricity is 1045.26 and 26.03 Kg/t, respectively. One of the dangerous gas is NO_x that amount of its emission in canned fish production is high (7.264 Kg/t). Emission of NO_x is followed by the SO_2, CH and SPM emission which wear 6.52, 5.274 and 3.316 Kg/t, respectively. Emission of SO_3 gas is lowest.

Partial productivity of human labour, electricity energy, diesel fuel energy and total of energy are shown in Table 7. Labour productivity was calculated 0.031 that shows per each labour-hour (L_a h), 31 kg of canned fish is produced. Productivity of electricity, diesel fuel and labour energy were 2.2, 0.044 t/GJ and 0.056 t/MJ, respectively. Total energy productivity was 0.044 t/GJ.

CONCLUSION

The aims of this study were to evaluate energy consumption and greenhouse gas and air pollutant emission in canned fish production in the Khuzestan province, to determine the energy losing factors. In this research, canneries that consume only human labor, electricity and diesel fuel energy were investigated. Total input energy was 22681.8 MJ/t that diesel fuel had the biggest share in the total energy with 98%. Energy of labour was a small amount of total input energy, but it is the most expensive input in the canned fish production.

Table 6: Emission of greenhouse gas and air pollutant in canned fish production (Kg/t)

Input	NO_x	SO_2	CO_2	SO_3	CO	CH	SPM
Diesel fuel	7.224	6.474	1045.258	0.075	1.725	5.274	3.311
Electricity	0.04	0.046	26.024	0.000	0.000	0.001	0.005
Total	7.264	6.52	1071.282	0.075	1.725	5.274	3.316

Table 7: Productivity of input

Labour (t/L_a h)	Labour (t/MJ)	Electricity (t/GJ)	Diesel fuel (t/GJ)	Total energy (t/GJ)
0.025	0.056	2.2	0.0448	0.044

Initial cooking and sterilization operations are most consumers of input energy in canning fish production with 21202.6 MJ/t. Operations of cleaning fish and transferring with labour force includes the lowest energy and this stage includes 43.33% of total human labour. Amount of greenhouse gas and air pollutant emissions from diesel fuel is much greater than electricity in fish cannery. Emission of CO_2, NO_x and SO_2 are the most gas emission with 1071.282, 7.264 and 6.52 Kg/t, respectively. Productivity of labour and electricity, diesel fuel and labour energy were 0.025 t/L_a h and 2.2, 0.044 t/GJ and 0.056 t/MJ, respectively. Using agitating retorts in steed of still retorts and reform path of transferring vapor will decrease the diesel fuel consumption and greenhouse gas emission.

ABBREVIATIONS

E_e Electricity energy
E_f Fuel energy
E_L Labour energy
E_T Total energy
t_h Time
p Electrical power
k_e Power factor of electric motor
k_f Heat value of fuel
k_L Energy equivalents of labour
L_a Number of labour
i Stage of operation
L Liter
f Amount of fuel consumption
h Hour
t Metric ton
D_j Amount of *j* greenhouse gas
c_j Factor of greenhouse gas emission from diesel fuel
b Conversion coefficient of electricity consumption to its production
L_o Total electricity loss
k_j Factor of greenhouse gas emission from electricity

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