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Energy utilization and carbon dioxide emission during production of snacks

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ABSTRACT

Energy utilization and carbon dioxide emission during production of the roasted in-shell pistachio nuts, pitted dried apricots, pretzels, potato chips, chocolate, baklava and two different varieties of pastry is calculated. Production baklava requires the highest, 32,543 MJ/ton, and that of the pitted dried apricots, 3125 MJ/ton, requires the smallest energy utilization. Production of one joule of nutrient energy requires 0.34–2.44 J of production energy input; and 0.12–2.05 ton of carbon dioxide is emitted per ton of the snacks produced. About 1–4% of the total emissions occur during the transportation of the ingredients to the factory; up to 48% of the total emissions are caused by packaging. Energy allocated to the production of the snacks themselves varies between 81 and 96% of the total energy utilization and causes 51–99% of the total emission. The results of this study point the production of the food itself as the focus of the forthcoming research to make further energy savings and reduce the emissions.

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1. Introduction

In the food industry studies on energy efficiency began in the late 1970s, substantial improvement was achieved over the years and the efficiency approached to the theoretical maximum in some sectors, including chemical fertilizer production (Kongshaug, 1998; Anundskas, 2000). The energy efficiency was improving by about 1% every year in the Dutch food industry in the early 2000s (Ramirez et al., 2006a). The ratio of the energy utilization in the Taiwanese food industry to the gross domestic production of the country showed a continuous decline from 2006 to 2010 (Ma et al., 2012). It is estimated that about 5–15% of the energy utilized at each step of food processing is still being wasted (Klemes et al., 2008). Rigorous studies are being done in the food industry to enumerate the energy utilization (Masanet et al., 2008; Khan et al., 2009; Canning et al., 2010; Therkelsen et al., 2014). Emission of the greenhouse gasses is an inevitable consequence of the energy utilization as explained in the reports prepared by Foster et al. (2006); CIAA (2007) and Carlsson- Kanyama and Faist (2000) to convince the public to adapt sustainable methods for food production. During the electric power generation from natural gas CO_2 accounts for 99% of all the emissions by weight (Spath and Mann, 2000). This study focuses on the carbon dioxide emissions, like our previous papers (Karakaya and Özilgen, 2011; Özilgen and Sorgüven, 2011 and Sorgüven and Özilgen, 2012) and is expected to point the direction for the forthcoming research to reduce the energy utilization and the emissions in the food industry. Carbon dioxide emission factors are reported to be 5.83 g/MJ (EPA, 1997) with natural gas, 140 g/MJ (PAS, 2008) with electricity and 16 g/MJ with diesel, based on energy yield of 57.5 MJ/kg diesel and emission of 0.94 g CO_2/kg diesel as reported by Lal (2004). In the food industry most of the heating stages are carried out with natural gas, and the other stages are with the electric power, e.g., with the energy source creating the highest emission.

In most countries, progress toward clean environment is achieved only with the support of the public, which comes only after informing the people. In this study, the energy utilization and the carbon dioxide emission during production of the snacks (roasted in-shell pistachio nuts, pitted dried apricots, pretzels, potato chips, chocolate, baklava and two different varieties of pastry) are assessed. Environmentally conscious consumers are expected to benefit from this study when they evaluate the impact of the alternative products on the environment.

2. Methodology

Energy utilization during the agriculture of the plant raw materials is summarized in Fig. 1 and Table 1. It is assumed that 5%

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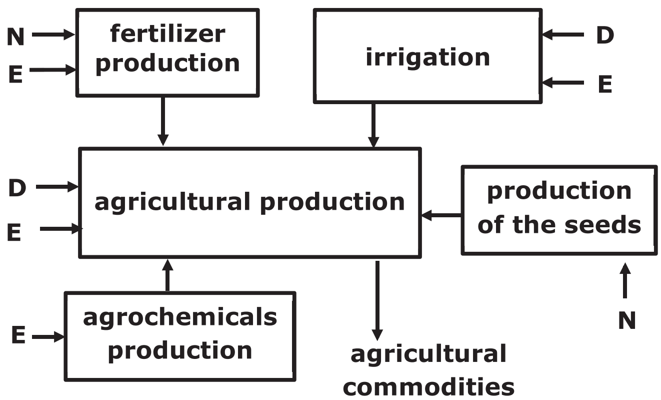

Fig. 1. Schematic description of the agricultural process.

of the lemons, apricots, potatoes and pistachio nuts were not suitable for processing and discarded; 70 kg of flour or semolina and 30 kg bran is produced after grinding 100 kg of wheat; half of the irrigation pumps were running with diesel and the rest with electricity, 85% of the energy needed to manufacture the chemical fertilizers were provided by natural gas and the remaining by electricity, and the farmland diesel was not used for transportation. Energy needed to produce the chemical fertilizers is 60.6 MJ/kg nitrogen fertilizer, 199 MJ/kg P_2O_5, 99 MJ/kg K_2O (Ören and Özturk, 2006) and 10 MJ/kg CaO (Canadian Lime Institute, 2001). Natural periclase (MgO) is used in the cocoa agriculture (Jadin and Snoeck, 1985) at a negligible energy cost. The word agrochemicals refer to the pesticides, insecticides, herbicides and fungicides. The commodities are assumed to be transported in 10 ton capacity heavy-duty trucks, traveling with the velocity of 90 km/h and utilizing 0.287 L/km of diesel (density 0.832 kg/L, energy equivalency of 57.5 MJ/kg of diesel) as reported by Roy et al. (2008) and Banaeian (2011), the refrigerated trucks are utilizing 20% more energy than the others (Tassou et al., 2009).

In Table 2, the energy utilization data for the production of the eggs by caged chicken is adapted from Wiedemann and McGahan (2011) and the data for the production of the eggcups is adapted from Table 3 of Zabaniotou and Kassidi (2003). The eggcup packages are made of recycled paper by using natural gas. An average egg weighs 60 g, six eggs are put in a 12 cm × 18 cm × 6 cm eggcup, and 120 eggcups are placed in a 50 cm × 56 cm × 62 cm carton. The energy cost of palletizing is negligible when compared to those of the production of the eggs and packaging in the eggcups and cartons. The raw milk production data is adapted from Table 2 of Sorgüven and Özilgen (2012), 75% of the energy of raw milk production is provided by diesel and the rest by electric power. The milk processing data is the average of the values reported in Figure 3 of Eide and Ohlson (1998). Energy utilization in the butter processing plant is adapted from Table 7 of Xu and Flapper (2011) after averaging the consumption in Australia and the USA. The butter is transported in 25 kg blocks in the LDPE bags (size 0.65 m × 0.40 m, thickness 0.5 mm) placed in 0.38 m × 0.25 m × 0.29 m cartons; 40 boxes, with one ton of butter inside, are transported in cooled trucks on one pallet after shrink wrapping. The production of the baked unpacked pistachio nuts is described in Fig. 2. Their shells are inedible and most of their water evaporates during roasting, only 48% of the harvested mass is actually edible (Kahyaoglu, 2008; Kallsen et al., 2009).

Energy utilization for the production of the ingredients is detailed in Table 2 for further use in the forthcoming tables. Data for sugar beet agriculture is adapted from Tables 7, 8 and A1, and Figure 5 of Sorgüven and Özilgen (2012); 7100 kg of sugar is produced from 47 tons of sugar beet. Crystal sugar is transported in sanitary powder trucks. The spices and the minced pistachio nuts are first filled in 5 kg HDPE bags (62 cm × 84 cm, thickness 0.02 cm), and then put in 60 cm × 50 cm × 75 cm cartons and shipped individually without palletizing. The juice constitutes 30% of the lemons, produced in the baklava factory and not pasteurized Table 8.

The flow diagrams for the production of dried apricots, pretzels and the potato chips are given in Figs. 3–5; 8.79 g of dried fruit is obtained from 30 g of fresh apricots and 25 kg of chips are produced from 100 kg of potatoes. Data regarding the manufacturing of the vegetable oil is adapted from Özilgen and Sorgüven (2011) after deducting the energy cost of the packaging; a sanitary oil pump is used for filling and emptying the tanks. It was assumed that twenty kg of spices are used while producing one ton of potato chips. The pretzels are made of 50% flour, 1% malt; 2% yeast, 45% water and 2% salt. The dough is dipped into caustic solution before baking, half of the water of the pretzels water evaporates in the oven; and natural salt is sprinkled on soon after the pretzels leave the oven. The salt is transported from 150 km of distance and ground in Jiangyin Baoli (China; Model JB-80 B) salt crusher (grinding 1000 kg/h, 46 kW). Spring water is transported for 100 km in a sanitary grade tank trailer as described in potato chips making process for the sunflower oil. The yeast and malt production data are adapted from Sorgüven and Özilgen (2012), and Özilgen (submitted for publication), respectively. Energy utilized for the manufacturing the caustic is assumed to be the same as that of the salt. The same kind of packaging is used with apricots, pretzels and potato chips. Sixty grams of apricots or potato chips or 200 g of pitted dried apricots or in-shell roasted pistachio nuts are packaged in a 18.5 cm × 15.5 cm 8.3 g LDPE pouch; 72 pouches are placed in a

Table 1
Energy utilization in agriculture of the raw materials.

Inputs	Energy utilization/ton of wheat (MJ/ton) (Ören and Öztürk, 2006)	Energy utilization/ton of potatoes (MJ/ton) (Pishgar-Komleh et al., 2012)	Energy utilization/ton of pistachio nuts (Saglam et al., 2012)	Energy utilization/ton of lemon (MJ/ton) (Özkan et al., 2014)	Energy utilization/ton of apricots (MJ/ton) (Gezer et al., 2003)	Energy utilization/ton of cocoa (MJ/ton) (Afrane and Ntiamoah, 2011)
Fertilizer	2417 (N) 427 (E)	864 (N) 153 (E)	4226 (N) 746 (E)	761 (N) 134 (E)	224 (N) 40 (E)	10,071 (N) 1778 (E)
Diesel	2582 (D)	285 (D)	2192 (D)	554 (D)	375 (D)	3473 (D)
Irrigation	209 (E) 209 (D)	285 (D)	–	–	–	–
Seeds	439 (N)	498 (N)	–		–	–
Agrochemicals	67 (E)	21 (E)	200 (E)	49 (E)	203 (E)	893 (E)
Electricity	–	–	–	213 (E)	–	317 (E)
Total	2856 (N) 703 (E) 2791 (D)	1362 (N) 338 (E) 285 (D)	4226 (N) 946 (E) 2192 (D)	761 (N) 396 (E) 554 (D)	224 (N) 203 (E) 375 (D)	10,071 (N) 2988 (E) 3473 (D)

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