LCI DATA FOR ENERGY CONSUMPTION IN FOOD PROCESSING

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Introduction

- Foods are essential for the sustenance of life.
- Food industry is one of the world's largest industrial sectors and taken together makes up for a sizeable portion of energy demand.
- Interest in communicating the environmental impact of foods to consumers.

Introduction

- Inventories of food processing comprise data on:
  - Raw materials from agriculture
  - Energy consumption in food processing
  - Water consumption in food processing
  - Packaging materials

Introduction

- The number of food products and the operations involved in their production are great.
- Food processes can be divided into common operations, called unit operations.
- For each unit operation different technologies are available

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Goal

Goal

- To provide an estimation tool for the energy demand of a range of food process unit operations
- This toolbox shall be a basis to perform LCA studies of processed food and provide decision support for process optimization and product selection to the food industry, retailers and consumers

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General approach

General approach

- Bottom up approach
- Data on process unit operations which are used in many production chains are being elaborated.
- To calculate the energy consumption three information modules are needed

General approach

PRODUCTION DATA

- Recipes

BASE DATA

- Thermophysichal properties of ingredients
- Specifications of the apparatuses

CALCULATIONS

- Calculation of energy consumption

General approach

- Blanching
- Evaporation
- Dehydration
- Freezing
- Pasteurization
- Pumping (liquid circulation)
- Mixing
- Frying
- Baking

Example: blanching

- Blanching implies exposing a vegetable to a heat source during a predetermined time at a specified temperature to inactivate enzymes causing food quality loss during storage.
- The commercial blanching equipments use saturated steam or a bath/shower of hot water.
- The energy consumption comprises thermal energy consumption (steam or hot water) and electricity for the belt and other mechanical devices.

Example: blanching

Thermal energy consumption:

$$Q_B = Fc_F(T_B - T_F) + Q_{loss}$$

$$Q_{loss} = Q_{conv} + Q_{rad} + Q_{other}$$

$$Q_{conv} = A \cdot h(T_s - T_a)$$

$$Q_{rad} = \varepsilon\,\sigma\,A\,(T^4 - T^4)$$

F: flow of vegetables (kg/h)

c_F : specific heat (kJ/kg °C)

T_F T_B : vegetable and blanching temperature (°C)

Q_L : heat loss from the blancher (kJ)

Q_{conv}: convection losses

Q_{rad}: radiation losses

Q_{other}: other heat losses

Electricity consumption depends on power and efficiency of the motor.

Example: blanching

	No end seals	Water courtains	Hydrostatic water seals	Hydrostatic water seals + nozzels
Energy required	2.12 MJ/kg	1.56 MJ/kg	0.95 MJ/kg	0.91 MJ/kg
Energy consumed by product blanching	13.2 %	19%	27.2%	30.9%
Energy lost by convection	0.5 %	0.5%	0.7%	1.1%
Energy lost by radiation	0.2 %	0.4%	0.3%	0.6%
Energy lost by conveyor belt reheating	4.4%	6.8%	-	-
Energy lost in steam condensate effluent	2.2%	10.9%	16.7%	16.2%
Other energy losses	79.7%	62.2%	55.1%	51.2%

Adapted from Scott et al. (1982)

Electricity consumption 1.5% of total energy consumption

Example: freezing

- Food freezing is the preservation process in which the temperature of the product is reduced to levels below the temperature at which ice crystals begin to form within the food, normally to -10 or-20 °C.
- Main freezing technologies: batch air-blast, continuous air-blast, plate freezers, cryogenic freezers.

Example: freezing

- Freezing time: $$t_f = \frac{1}{E}\left[\frac{\Delta H_1}{\Delta T_1} + \frac{\Delta H_2}{\Delta T_2}\right]\left[\frac{R}{h} + \frac{R^2}{2kf}\right]$$

$$\Delta H_2 = \rho L + \rho c_f\left(T_{fm} - T_{fin}\right)$$

$$\Delta H_2 = \rho c_u\left(T_i - T_{fm}\right)$$

$$\Delta T_1 = 0.5\left(T_i - T_{fm}\right) - T_a$$

$$\Delta T_1 = T_{fm} - T_a$$

$$T_{fm} = 1.8 + 0.263 T_{fin} + 0.105 T_a$$

- Product heat load:

$$Q_{pr} = \frac{W_{pr}}{t_f}\left[c_u\left(T_i - T_{if}\right) + L + c_f\left(T_{if} - T_{out}\right)\right]$$

Example: freezing

Typical Component Heat Load Percentages for Well-Designed Food Freezers
(Cleland and Valentas, 1997)

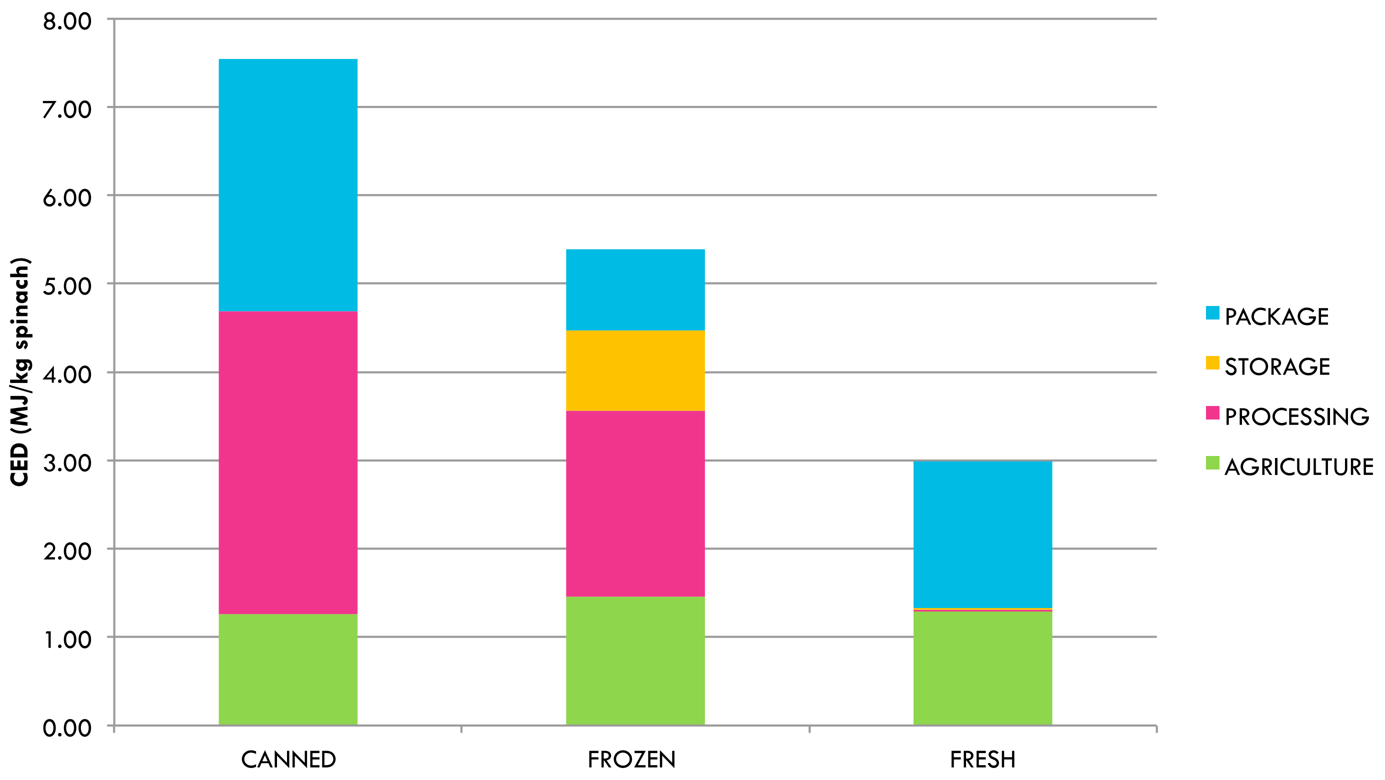
Freezer type	Product	Fans/pumps	Pull-down	Defrost	Other
Batch air-blast	50-80%	10-40%	<10%	<5%	<5%
Continuous air-blast	50-80%	10-40%	0%	10-20%	5-10%
Plate	85-95%	5-10%	<5%	<5%	<5%
Cryogenic	85-95%	<10%	<5%	0%	<10%

Case study

Case study: spinach

- Production of spinach in Switzerland.
- Processing:
  - Fresh (10 days storage)
  - Canned
  - Frozen (1 year storage)
- Not considered:
  - Waste
  - Cooking at home

Case study: spinach



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Remarks

Final remarks

- Difficulty in quantifying total energy consumption (eg. losses): empirical relationships.
- In case the technology is not known, we recommend using a production weighted average value.
- Models or measured data? Validation of some case studies

General approach: production data

- The production data module corresponds to the recipe of the product:
  - type and amount of raw material/ingredients
  - description of the process units and apparatuses used, including temperature, processing time, etc.

General approach: base data

- Thermophysical properties of foods allow to estimate the energy demand in unit operations related to heat transfer.
- key thermophysical properties: heat capacity, thermal conductivity, density, freezing temperature…
- Data sources: literature or models based on the food composition (water content, protein, fat, carbohydrates, fiber, and ashes)

General approach: base data

- Specifications of the apparatuses:
  - power
  - external surface
  - motor efficiency …

General approach: calculation

- The calculation procedure is based on three types of data sources:
  - process models
  - physical or empirical relationships
  - published data