Chapter 9
Food Process Economics

George Saravacos and Zacharias Maroulis

9.1 Importance of Economics in Food Processing

Food processing is a large industry consisting of several small or medium size plants and a few large installations. It produces a variety of food products that satisfy the nutritional and sensory needs of consumers. Economics plays a very important role in the efficient design of food processes and the production of sufficient quantities of food products for an ever expanding world population (Maroulis and Saravacos 2007).

The design and optimization of food processes is based on the principles of food science and the established techniques of chemical process design, and simplified computer spreadsheet techniques have been applied to the design of various food processes (Maroulis and Saravacos 2003). For example, heat and mass transfer food processes, such as heating, cooling, freezing, evaporation, dehydration, extraction, and membrane separations, can be designed and optimized using transport properties and other engineering data of foods, as published in the literature (Saravacos and Maroulis 2001; Rao et al. 2005; Rahman 1995). On the other hand, mechanical processes involving solid and semi-solid food materials, such as grinding, mixing, and mechanical separations or forming, are designed empirically using specialized processing equipment provided by equipment manufacturers and suppliers (Saravacos and Kostaropoulos 2002).

Food plant design is the integration of process design and process engineering economics (Lopez-Gomez and Barbosa-Cánovas 2005). Food processing plants are characterized by strict hygienic (sanitary) and food safety requirements, which should be satisfied in any economic analysis. However, recent worldwide demand for fresh processed foods at affordable prices stresses the importance of process economics.

G. Saravacos (✉) and Z. Maroulis
School of Chemical Engineering, National Technical University of Athens, 15780 Athens, Greece
e-mail: gsaravac@otenet.gr, maroulis@mail.ntua.gr

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9.2 Process Engineering Economics

Process engineering economics is based on the estimation of capital and operating costs, on which plant profitability can be estimated. It is applied in designing new processing plants, and in process and product improvement of existing installations (Clark 1997; Holland et al. 1997; Peters et al. 2003; Couper 2003). Safety and environmental requirements of the process should be considered.

9.2.1 Capital Cost

The capital cost is based on the equipment cost (C_{eq}), which is estimated from material and energy balances on the process flowsheet. Cost of food processing equipment is estimated from equipment size (surface area, volume, weight) using empirical correlations or the suppliers' data (Maroulis and Saravacos 2007). Sizing of food processing equipment is based on material and energy balances of the process flowsheet, using simplified design equations and engineering property data (Saravacos and Kostaropoulos 2002). Empirical correlations (diagrams) of cost versus equipment size (Guthrie charts) can be used for engineering calculations. Cost quotations of specialized food processing equipment can be obtained from equipment suppliers.

Typical cost: capacity diagrams of food processing equipment include fluid transport-power (kW); vessel-volume (m^3); conveyor belts-surface area (m^2); heat exchanger-surface area (m^2); dryers-surface area (m^2); filters-surface area (m^2); size reduction-capacity (kg/s); mechanical processing-capacity (kg/s); and utilities-kW (Maroulis and Saravacos 2007). Increases in cost of processing equipment (inflation) over the years are taken into account using the Marshall and Swift (M&S) cost index, published periodically in the journal *Chemical Engineering*, e.g., M&S Index: (1990) = 915, (2005) = 1,261.

9.2.2 Operating Cost

The operating cost includes the direct cost of raw and packaging materials, labor, and utilities, and various indirect costs such as maintenance, quality assurance, and office personnel.

9.2.2.1 Raw Food Materials and Packaging Materials

The cost of raw food materials is estimated with data obtained from US government organizations such as the Bureau of Labor Statistics (http://www.bls.gov) and the

National Agricultural Statistics Services (http://www.nass.usda.gov). Typical farm prices in the US (2003) for food materials are ($/kg): wheat 0.13, corn 0.09, potatoes 0.14, milk 0.27, beef 1.61, chicken 0.72, hogs 0.78, store-bought fresh tomatoes 0.76, tomatoes for processing 0.10, oranges 0.10, grapes 0.40, peaches 0.40, and apricots 0.65. Both retail and farm prices, or retail to farm price ratios (r), should be considered. Typical (r) values in the US are: eggs 1.7, milk 4, sugar 5, wheat flour 5.5, margarine 10, potato chips 15, bread 25, corn flakes 28, and corn syrup 35.

The cost of packaging materials may run from relatively low in bulk packing of fruit products in plastic-lined drums to very high in plastic cups for dairy products (Maroulis and Saravacos 2007). Intermediate costs include using metallic cans, glass bottles, and paper/plastic bags. The packaging cost per unit mass of food products ($/kg) increases substantially as the package size is reduced (e.g., plastic cups 0.80, glass bottles 0.20, metallic cans 0.12, plastic bags 0.10, and 208 L plastic drums 0.09).

9.2.2.2 Labor

Labor requirements include production and nonproduction workers, and amount to about 20% of the manufacturing cost. The process labor required can be estimated from the process flowsheet and the material and energy balances. The supporting labor is usually estimated using empirical correction factors and the total personnel is approximately equal to three times the process labor. A labor cost model (as in following example) has been proposed for estimating the total labor cost, using correction factors for the country (i.e., cultural) effect, skilled personnel, supervision, social benefits, and overtime work.

The annual operating time (hours) is estimated as the product of (hours per shift) × (shifts per day) × (days per week) × (weeks per year). Food plants can be operated for one or more seasons. The annual operating time for one season can vary from 500 to 2,100 h, with workers employed 12.5 weeks a year and 5–7 days a week, 1–3 shifts a day. A two-season operation (25 weeks) amounts to 1,000–4,200 h a year, while an all-year operation (50 weeks) amounts to 2,000–8,400 h a year. Food preservation plants usually operate 2–4 months per year, due to seasonal availability of agricultural raw materials. Some food manufacturing plants may operate 12 months a year, e.g., bakeries. Food ingredients plants may operate several months a year, depending on the availability of raw materials. Bulk storage of large volumes of raw materials (e.g., wheat, corn, and oilseeds) near a food plant can extend its operating time substantially.

The manpower requirements of a food processing plant can be estimated analytically by summation of the requirements for each processing equipment or operation (Maroulis and Saravacos 2007). Approximate personnel requirements for various food processing plants can also be estimated from the following empirical equation developed by regression analysis from published data (Bartholomai 1987).

$$M = 10F^{2/3} \tag{9.1}$$

where M is the manpower (number of personnel) and F is the plant product capacity (t/h).

The cost of labor primarily depends on the country and the degree of specialization. Labor rates are found in government publications such as the US Bureau of Labor Statistics. The average hourly rate for production workers in the US was $15 in 2008. Higher rates are found in some European countries, such as Germany and Norway, but substantially lower rates are observed in the rest of the world, with very low rates in underdeveloped countries. The cost of skilled operators, mechanics, technicians, foremen, and plant managers is normally estimated as 2, 3, 3.5, 4, and 5 times, respectively, the cost of unskilled labor.

9.2.2.3 Utilities

The main public utilities used in food processing plants are energy and water. Energy includes fuel (oil, gas) and electricity, and it is conveniently expressed in kWh/kg product (1 kWh = 3.6 MJ). Water is used as process water, and in cleaning operations, cooling, refrigeration, and steam generation; it is also involved in wastewater effluents. The cost of fuel ($/kWh) is a function of the cost of crude oil ($/barrel (bbl) = 159 L oil). The cost of crude oil is affected strongly by international political crises and wars (e.g., increasing from $60 to $100/bbl between the years 2007 and 2009). An empirical model was developed for the estimation of various energy forms from the price of crude oil (Maroulis and Saravacos 2007). Typical diagrams of energy cost of crude oil at $100/bbl and $60/bbl are shown in Figs. 9.1 and 9.2.

Typical energy cost (US 2008) follows: electricity – $0.10/kWh; steam – 10 bar $08/kWh ($40/t); fuel oil – $1.30/L; and natural gas – $0.80/m^3. The cost of food processing water (cleaning of or adding to food products) is about $0.50/m^3, while boiler water is more expensive ($2.50/m^3) due to its pretreatment. Waste disposal costs are about $50/t, while wastewater treatment (primary and secondary) costs about $1.00/t.

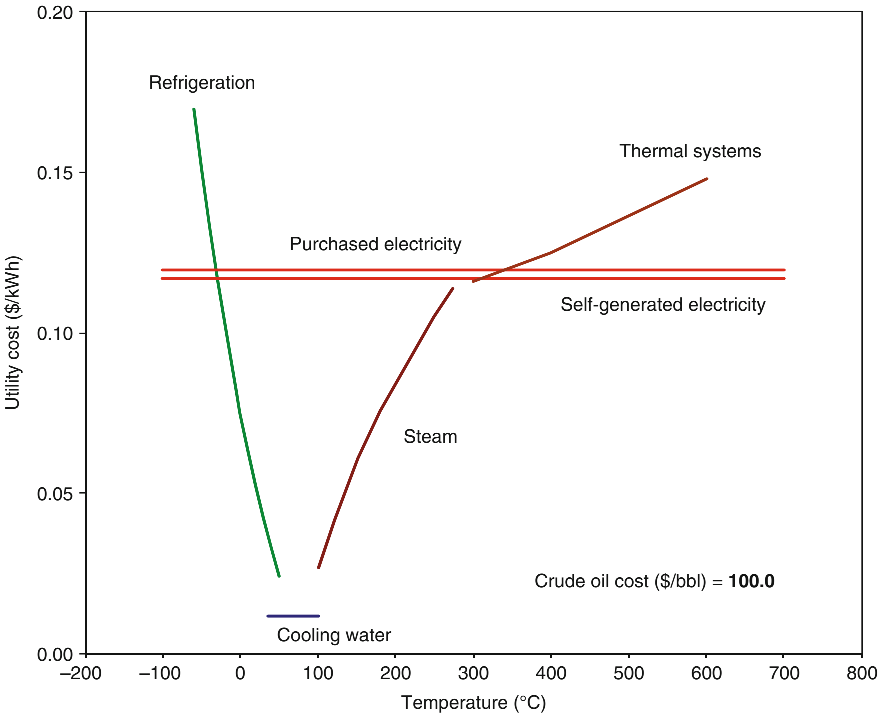
9.2.3 Process Profitability

9.2.3.1 Capital Cost

The total capital cost C_T is covered partly by the investor's own capital C_O and partly by a bank loan C_L:

$$C_T = C_O + C_L \tag{9.2}$$

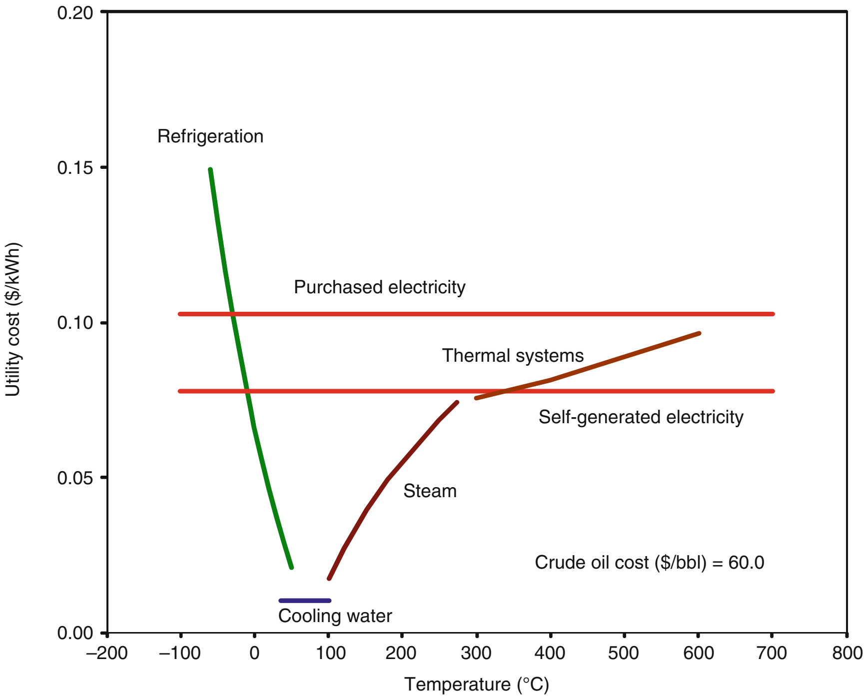
The loan is expressed as a fraction (leverage, λ) of the total capital ($\lambda = C_L/C_T$). A typical leverage in food processing is $\lambda = 0.50$. The total capital cost C_T invested



Utility	Description	$/kWh	$/Common unit
Electricity	Purchased	0.117	
	Self-generated	0.120	
Crude			100.0 $/bbl
Fuels	Fueloil	0.096	0.96 $/L
	Natural gas		0.64 $/m3
	Coal		65.0 $/t
Thermal systems	300°C	0.116	
	400°C	0.125	
	600°C	0.148	
Steam	40 bar	0.105	52.5 $/t
	10 bar	0.076	37.8 $/t
	5 bar	0.061	30.4 $/t
	1 bar	0.027	13.3 $/t
Cooling water	tower	0.012	0.271 $/m3
	river or sea		0.231 $/m3
	well		0.312 $/m3
Refrigeration	5°C	0.081	
	–20°C	0.102	
	–50°C	0.150	

Fig. 9.1 Energy cost of oil priced at $100/bbl

in a processing plant consists primarily of the fixed capital cost C_F and, secondly, the working capital C_w:



Utility	Description	$/kWh	$/Common unit
Electricity	Purchased	0.103	
	Self-generated	0.078	
Crude			60.0 $/bbl
Fuels	Fuel oil	0.062	0.63 $/L
	Natural gas		0.42 $/m^3
	Coal		65.0 $/t
Thermal systems	300°C	0.076	
	400°C	0.081	
	600°C	0.096	
Steam	40 bar	0.068	34.2 $/t
	10 bar	0.049	24.6 $/t
	5 bar	0.040	19.8 $/t
	1 bar	0.017	8.7 $/t
Cooling water	tower	0.010	0.238 $/m^3
	river or sea		0.203 $/m^3
	well		0.274 $/m^3
Refrigeration	5°C	0.072	
	–20°C	0.089	
	–50°C	0.132	

Fig. 9.2 Energy cost of oil priced at $ 60/bbl

$$C_T = C_F + C_w \tag{9.3}$$

The fixed capital cost C_F includes the cost of processing equipment C_{eq}, installation, piping, instrumentation and control, electrical installations, buildings, land and site improvements, office facilities, engineering, and contingency. The working capital C_w consists of the total amount of money invested in raw materials and supplies in stock, finished and semi-finished products, accounts receivable and payable, and cash kept on hand. The working capital amounts to 15–50% of the total cost. In general, food manufacturing plants require higher proportions of working capital than food preservation operations. The fixed cost C_F is estimated from the equipment cost, using the empirical equation,

$$C_F = f_L C_{eq} \tag{9.4}$$

where f_L is the Lang factor. The empirical Lang factor f_L in older plants (Bartholomai, 1987) is approximately $f_L = 2$, but in recent installations, using more instrumentation, process control and computers, values are $f_L = 3$ for main plants and $f_L = 4$ for grassroots plants (including off-site facilities) (Maroulis and Saravacos 2007).

9.2.3.2 Manufacturing Cost

The manufacturing cost C_M of a processing plant consists primarily of the variable cost of raw and packaging materials, labor, and utilities. It also includes the fixed cost of maintenance, insurance, taxes and royalties, and the indirect cost of sales and general expenses. The total manufacturing cost C_{MT} or total annualized cost *TAC* includes the effect of capital cost, as given by the following equation:

$$C_{MT} = C_M + eC_T \tag{9.5}$$

where C_T is the total capital cost, and e is the capital recovery factor, as calculated from the following equation:

$$e = i \Big/ \left[1 - (1+i)^{-N}\right] = i(1+i)^N \Big/ \left[(1+i)^N - 1\right] \tag{9.6}$$

The capital recovery factor is a function of the discount (interest), rate i, and the lifetime of the investment N (years).

9.2.3.3 Discounted Cash Flow

The annual gross profit before taxes P_G is the sales income S minus the manufacturing cost C_M:

$$P_G = S - C_M \quad (9.7)$$

The cumulated cash flow (*CCF*) or annual cash flow is defined by the simplified equation,

$$CCF = -C_O + N\,P \quad (9.8)$$

where C_O is personal capital and P the annual profit after taxes and loan payment, assumed to be constant over the operating time N (years). The investor's own capital is the total capital minus the bank loan. The discounted cash flow or the net present value (*NPV*) is lower than the *CCF*, because it includes the interest rate i of the money:

$$NPV = -C_O + P/e \quad (9.9)$$

where e is the capital recovery factor, defined in (9.5). In the simplified (9.7) and (9.8), the annual profit after taxes and loan payment P is assumed to be constant over the years. When P varies over time, the following summation equations, similar to (9.8) and (9.9), are used to estimate *CCF* and *NPV*:

$$CCF = -C_O + \sum_{n=1}^{N} P_n \quad (9.10)$$

$$NPV = -C_O + \sum_{n=1}^{N} \frac{P_n}{(1+i)^n} \quad (9.11)$$

9.2.3.4 Measures of Plant Profitability

The following measures are used to evaluate plant profitability:

(a) Cash: *CCF* (non-discounted) and *NPV* (discounted)
(b) Time: simple payback period, $SPB = C_T/P$ (non-discounted)
    Discounted payback period, $DPB = ln((1 - iSPB)^{-1})/ln(1 + i)$
(c) Rate: return on investment, $ROI = 1/SPB = P/C_T$ (non-discounted)

Internal rate of return, *IRR*: $ROI = IRR/(1 - (1 + IRR)^{-N})$ (discounted)

The results of profitability analysis are presented in diagrams of *CCF* and *NPV* versus time (years), and break-even analysis of (annual income or sales) and (manufacturing cost or expenses) versus annual operating time. The latter diagram shows the optimum operating time for maximum profit for the specific food plant (Maroulis and Saravacos 2007). The values of *SPB* and *DPB* can be estimated from the cash flow diagrams as the intersection of the *CCF* and *NPV* curves with the time axis, respectively.

9.3 Food Processing Plants

For the purpose of economic analysis, food processing plants can be categorized as follows: food preservation, food manufacturing, and food ingredients plants. Food engineering is mainly concerned with food preservation and food manufacturing plants, while food ingredients plants are more related to chemical engineering. Application examples of some typical plants are presented in this section from process data in the literature (Maroulis and Saravacos 2007).

9.3.1 Food Preservation Plants

Food preservation processes include concentration, dehydration, freezing, and thermal processing (pasteurization, canning). Most plants are located near the production of raw materials (fruits and vegetables, animal products) and usually operate only for one season (e.g., 2–3 months a year). Application examples of two typical food plants are presented in this section, from process data in the literature (Maroulis and Saravacos 2007).

The economics of an orange juice concentrate (*OJC*) is summarized here as an application example. Figure 9.3 shows a block diagram of the process with material and energy balances based on 1 kg of 65% *TS* (total solids) *OJC*, using literature data on fruit composition and process technology. The requirement for raw material is 10.35 kg oranges of 13.6% *TS*. Figure 9.3 shows the material and energy balances of the orange juice concentrate *OJC* processing plant.

The extracted juice is concentrated from 12% to 65% TS, using a four-effect falling film evaporator. The *OJC* is packed in plastic drums and stored at 0°C. The orange peels are used to produce press oil and then dehydrated in an air dryer to produce animal feed with 10% moisture. The theoretical energy requirements for the process are 8 MJ/kg of product. Assuming a thermal efficiency of 75%, the actual energy requirement is about 10.7 MJ/kg or 3 kWh/kg of product.

The plant operates seasonally when ripe oranges are available for processing, which is 16 weeks (or about 4 months) a year. The annual operating time is assumed to be 1,280 h/y and the annual production 1,280 t/year OJC (16 weeks/year × 5 days/week × 2 shifts/day × 8 h/shift). Table 9.1 shows the annual material balances for the orange juice concentrate plant based on a production rate of 1 t/h *OJC*.

The *OJC* product is packed in 5,565 plastic drums of 230 kg capacity, amounting to 5,565 × 0.23 = 1,280 t/year OJC. The required processing equipment, including cleaning of oranges, juice extraction and finishing, juice evaporation, aseptic packing, and peel drying, were sized and priced following simplified engineering procedures (Saravacos and Kostaropoulos 2002). The equipment cost was $1.62 million. Table 9.2 shows the capital cost components of the *OJC* plant. The working capital is assumed to be 25% of the fixed.

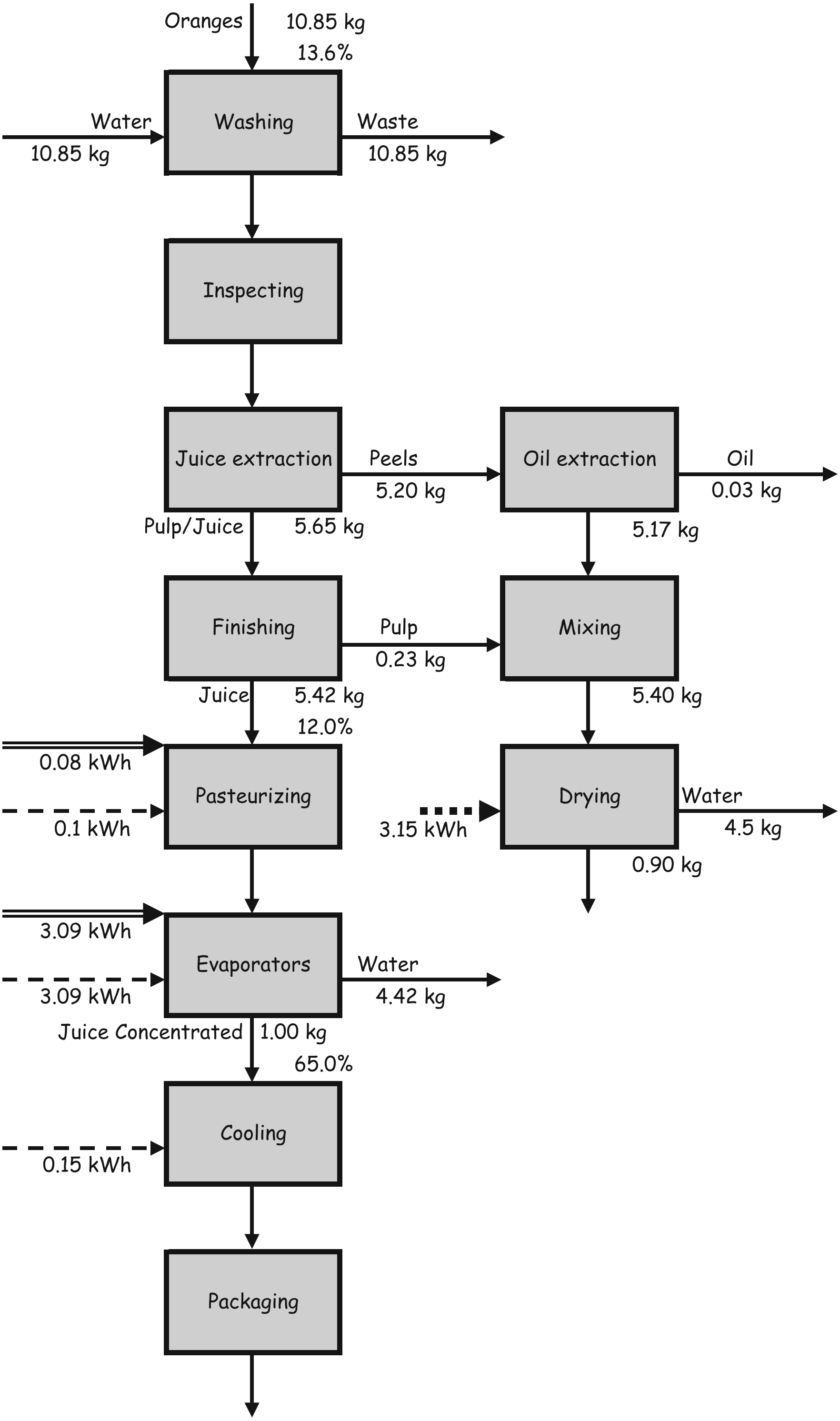


Fig. 9.3 Block process diagram of the *OJC* plant

Table 9.1 Annual material balances of the *OJC* plant

Oranges	13,890 t/year
OJC	1,280 t/year
Dried peels	1,150 t/year
Peel oil	38 t/year

Table 9.2 Capital cost of the OJC plant

Process equipment, C_{eq}	1.62 M$
Lang factor, f_L	3
Fixed capital, C_F	4.86 M$
Working capital, C_W	1.21 M$
Total capital, C_T	6.07 M$

Table 9.3 Annual operating cost of the *OJC* plant

Raw materials (0.12$/kg oranges)	1.67 M$
Labor	0.72 M$
Packaging materials (20$/drum)	0.11 M$
Utilities	0.65 M$
Waste treatment	0.07 M$
Variable manufacturing, C_{MV}	3.22 M$
Fixed manufacturing, C_{MF}	0.49 M$
Overheads, C_{over}	0.23 M$
Manufacturing cost, C_M	3.94 M$
Capital recovery factor, e	0.083 ($i = 0.07, N = 27$)
Capital charge, eC_T	0.50 M$
Total annualized cost, $C_M + eC_T$	4.44 M$

The annual operating cost of the *OJC* plant was calculated from material balances, cost data, and empirical correlations, as shown in Table 9.3 (2006 prices). It is assumed that the discount (interest) rate is $i = 0.07$ and the lifetime of the plant is $N = 7$ years.

Table 9.4 summarizes the plant profitability data for the *OJC* plant. The investor's own capital C_0 is assumed to be 50% of the total C_T. The capital return ratio is defined as $CRR = NPV/C_0$.

The annual sales income is based on an *OJC* product price of $3.60/kg, which it is assumed includes the income from the dried peels and peel oil. Figure 9.4 shows the cost components of the orange juice concentrate. The raw material (oranges) is the main cost item (36%), followed by labor (20%) and utilities (15%). Food manufacturing (equipment) cost is about 19% of the total, while bulk packaging in large containers is a relatively low cost. Overheads and capital charge amount to 18% of the total cost.

The relatively high cost of utilities in the *OJC* plant is due to the removal of large amounts of water by evaporation and dehydration, requiring large amounts of steam and fuel gas. Figure 9.5 shows the cash flow, the cumulative cash flow (*CCF*), and the net present value (*NPV*) of the *OJC* plant as a function of operating time N (years). The values of depreciation period ($N_D = 7$ years), loan period ($N_L = 15$ years), salvage period ($N_S = 20$ years), and project lifetime ($N_E = 27$ years) are also shown. The *ROI* value is estimated from the relation $ROI = 1/SPB$.

Table 9.4 Plant profitability of the *OJC* plant

Annual sales income, S	4.61 M$/year
Manufacturing cost, C_M	3.93 M$/year
Gross profit, P_G	0.68 M$/year
Net present value, *NPV*	1.30 M$
Own capital cost, C_0	3.01 M$
Capital return ratio, *CRR*	0.43
Internal Rate of Return, *IRR*	0.12
Return On Investment, *ROI*	0.16
Simple payback period, *SPB*	6.3 years
Discounted payback period, *DPB*	10 years

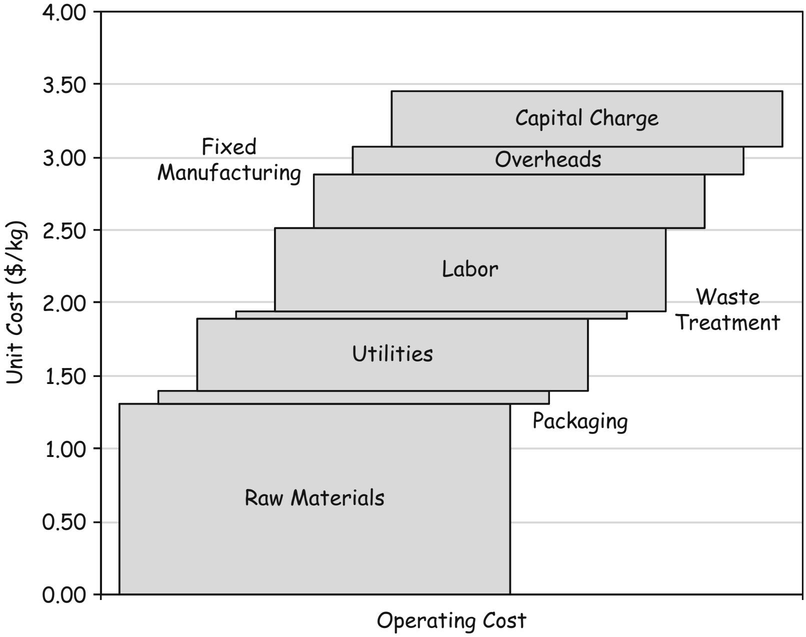


Fig. 9.4 Operating cost of the *OJC* plant

Figure 9.6 shows a break-even analysis of the *OJC* plant. For the process system analyzed here, the optimum operating time (maximum annual profit) is about 1,000 h/year.

9.3.2 Food Manufacturing Plants

Food manufacturing plants typically produce several food products packaged in small consumer units, using agricultural raw materials or semi-finished food

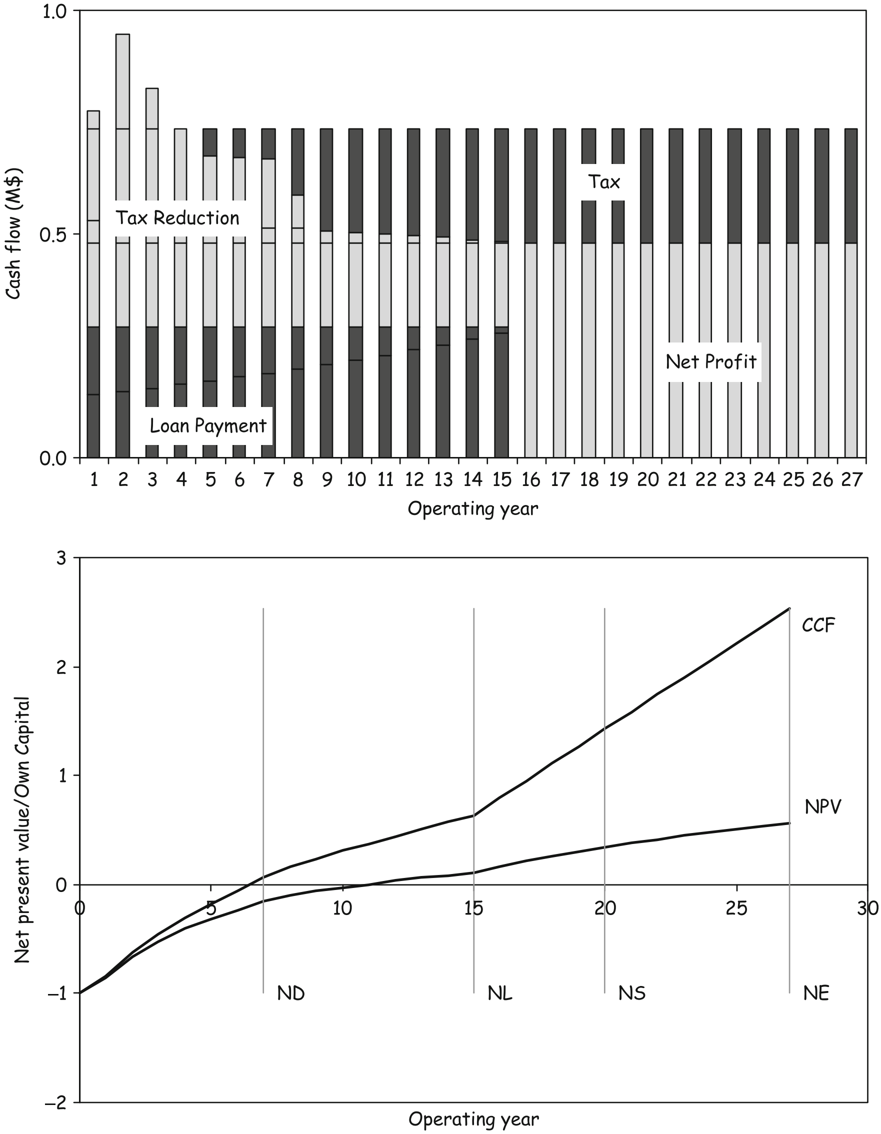


Fig. 9.5 Cash flow and *NPV* of the *OJC* plant

materials and food ingredients. The plants are preferably located close to large consumer centers, operate several months a year, and require more labor and packaging materials than food preservation plants. Food manufacturing plants are characterized by strict hygienic and food safety regulations, due to the sensitivity of food products to microbial and chemical spoilage. Thus, they require special quality control and compliance with government and international regulations. Products

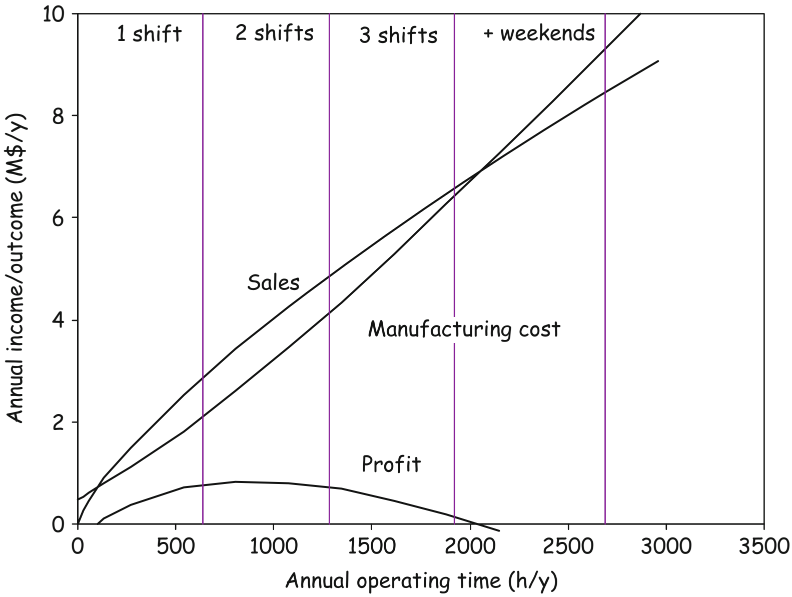


Fig. 9.6 Beak-even analysis of the *OJC* plan

produced in food manufacturing plants include cereal, dairy, fruit and vegetable, animal, and prepared food products. It should be noted that these plants may use some food preservation technology during processing and storage.

As a typical application example, the economics of yogurt manufacture in producing consumer packages is discussed in this section. Figure 9.7 shows the process block diagram and the material and energy balances for the manufacture of dairy yogurt.

The material and energy balances in this example are based on the raw materials, 1,000 kg of milk and 40 kg of nonfat dry milk (*NFDM*). The yogurt plant operates 48 weeks a year, 5 days a week, with two shifts per day and 8-h shifts, amounting to 3,840 h/year. Table 9.5 shows the annual material balances for the yogurt manufacturing plant, producing 4,000 t/year yogurt.

The yogurt product is packaged in plastic cups of 0.250 kg capacity, resulting in 15,976,000 cups/year. The theoretical energy requirement for the process is 0.73 MJ/kg product. Assuming a thermal efficiency of 75%, the actual energy requirement is about 1 MJ/kg or 0.3 kWh/kg product. The required processing equipment, including for milk storage, mixing, homogenization, heat treatment, culture inoculation, and aseptic packaging, was sized and priced, following simplified engineering procedures (Saravacos and Kostaropoulos 2002). The equipment cost was $2.49 million. Table 9.6 shows the capital cost components of the yogurt plant. The working capital is assumed to be 25% of the sales.

The annual operating cost of the yogurt plant was calculated from material balances, cost data, and empirical correlations, as shown in Table 9.7 (2006 prices).

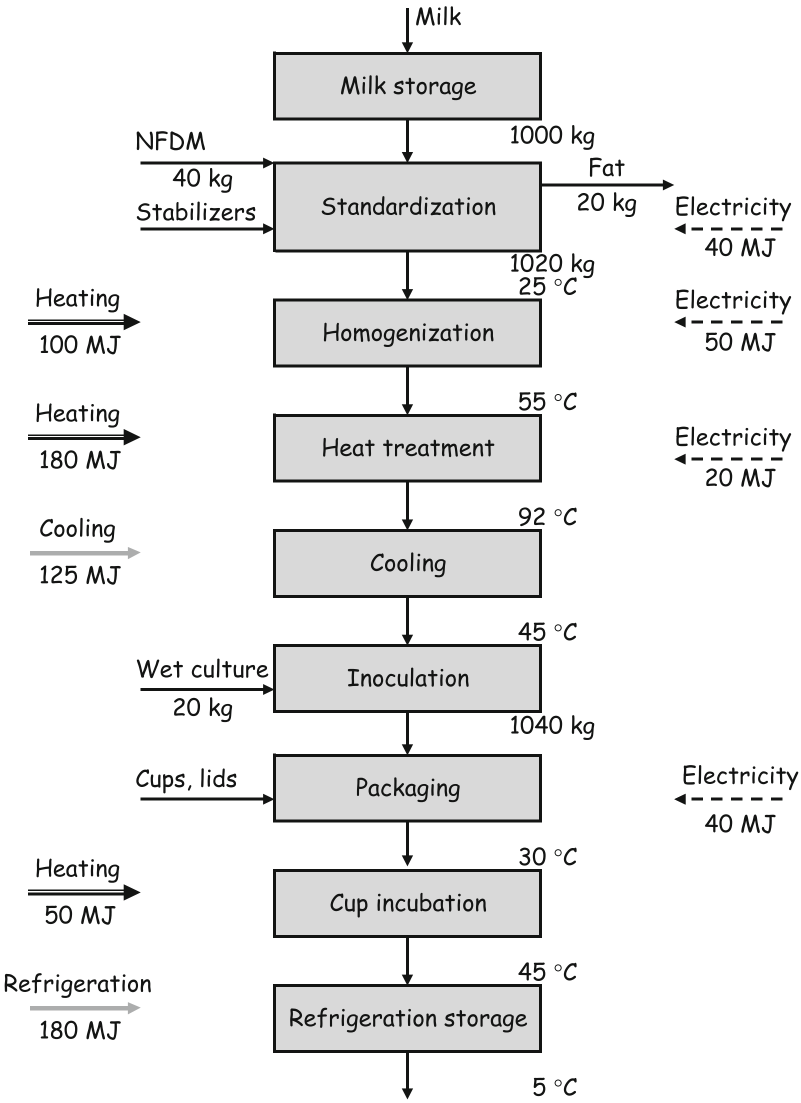


Fig. 9.7 Process block diagram of the yogurt manufacturing plant

Table 9.5 Annual material balances of the yogurt manufacturing plant

Material product rate	t/year
Milk	3,840
NFDM	156.3
Stabilizer	76.8
Fat removed	76.8
Yogurt	3,994

Table 9.6 Capital cost of the yogurt manufacturing plant

Process equipment, C_{eq}	2.49 M$
Lang factor, f_L	3
Fixed capital, C_F	7.47 M$
Working capital, C_W	5.05 M$
Total capital, C_T	12.52 M$

Table 9.7 Annual operating cost of the yogurt manufacturing plant

Raw materials (0.35 $/kg milk)	7.68 M$
Labor	3.24 M$
Packaging materials	(0.04$/piece) 3.84 M$
Utilities	0.32 M$
Variable manufacturing, C_{MV}	15.09 M$
Fixed manufacturing, C_{MF}	0.75 M$
Overheads, C_{over}	1.01 M$
Manufacturing, cost C_M	16.85 M$
Capital recovery factor, e	0.083 ($i = 07, N = 27$)
Capital charge, eC_T	1.04 M$
Total annualized cost $C_M + eC_T$	17.89 M$

Table 9.8 Plant profitability of the yogurt manufacturing plant

Annual sales income, S	20.18 M$/year
Manufacturing cost, C_M	16.84 M$/year
Gross profit, P_G	3.34 M$/year
Net present value, *NPV*	16.99 M$
Own capital cost, C_0	6.26 M$
Capital return ratio, *CRR*	2.72
Internal Rate of Return, *IRR*	0.32
Return On investment, *ROI*	0.40
Simple payback period, *SPB*	2.5 years
Discounted payback period, *DPB*	3 years

It is assumed that the discount (interest) rate is $i = 0.07$ and the lifetime of the plant is $N = 27$ years.

Table 9.8 summarizes the plant profitability data for the yogurt plant. The investor's own capital C_0 is assumed to be 50% of the total C_T.

The annual sales income is based on a yogurt product price of $1.25/kg. Figure 9.8 shows the cost components of the yogurt manufacturing plant. The raw material (milk) is the major cost item (43%), followed by packaging materials (23%), labor (18%), and processing equipment (5%). Utilities, overheads, and capital charge amount to about 11% of the total cost.

The cumulative cash flow (*CCF*) and the net present value (*NPV*) plots of the yogurt plant are similar to the diagrams of the *OJC* plant. Break-even analysis of the yogurt plant resulted in a diagram similar to Fig. 9.6, indicating a higher optimum operation time (maximum annual profit) of about 2,500 h/year.

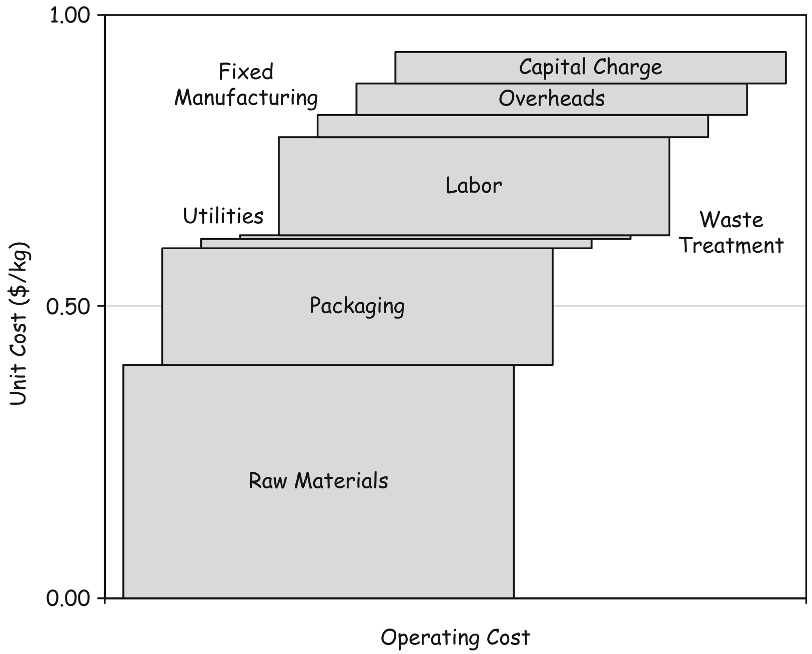


Fig. 9.8 Operating cost of the yogurt manufacturing plant

9.3.3 Food Ingredients Plants

Food ingredients plants utilize agricultural and natural raw materials to recover valuable components, which are then used in food manufacturing. Typical products are wheat flour, vegetable oils, starch, pectin, sugar, and proteins. Special food components used in smaller quantities include flavorings, vitamins, coloring materials, sweeteners, preservatives, and antioxidants.

9.4 Conclusions

Applying the principles of process economics to food processing can lead to useful information on the economics of food processes. Simplified procedures based on material and energy balances, sizing of process equipment, and cost data on raw materials, labor, and utilities result in new food process designs and economic evaluation of existing processing operations. Raw materials, followed by labor, are the major cost items in most food production processes. Packaging cost also may be important for some food manufactured products. Food products manufactured from raw food materials and food ingredients are generally more profitable than products of food preservation plants.

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