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Economic study of tomato paste production

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Summary

Statistics of tomato production and utilization have been reported to show the recent development of the tomato industry in the EEC countries. In particular, the profitability of tomato paste production has been evaluated and then analysed to assess the influence of the operating costs, EEC payments and market price of tomato paste. The economic balance for a plant capacity of 14 tons of raw tomatoes per hr and 2880 operational hr per year shows profitability of 22% in 1979 and 16% in 1980 owing to inflation and decrease in product demand. The annual cost of raw materials is not only more than 75% of production costs, but is also double the total capital invested. For this reason the tomato industry is compelled to resort to high-interest, short-term loans which further reduce net earnings. Mechanization of crop harvesting, automation of sorting, optimization of evaporation and packaging units and flexibility of plants are needed to maintain interest in tomato paste production in industrialized areas.

Introduction

The recent evolution of tomato paste production has seen the growth of large-scale and capital-intensive enterprises, even though a large number of production units are still of small or medium size.

More effective co-operation between the farmer and the processor and between the agricultural engineer and the food engineer has also exerted a deep influence on food industrial activities.

In this paper statistics of tomato production and utilization in Italy and in the EEC countries have been used to characterize the economics of the tomato

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paste industry by carrying out a profitability analysis. As production costs are affected by the size of the operation, our analysis has been referred to a plant of medium size (working capacity 14 tons of raw tomatoes per hr).

Production and utilization of tomatoes

The tomato is a plant species of the genus *Lycopersicon* belonging to the plant family *Solanaceae.* Its fruit consists of an outer peel; an intermediate part containing pale straw-coloured juice, insoluble pigments (lycopene, carotene, xanthophyll and chlorophyll), pectic substances and pectic enzymes; and a central placenta containing many small, oval seeds. The composition of tomatoes and tomato products is affected by such factors as growing, seasonal and climatic conditions, maturity, varieties, etc. Table 1 gives an indication of the range of physical and chemical composition of raw tomatoes (Guastalla, 1968). The sugars in tomatoes are practically all reducing sugars, i.e. glucose (0.88–1.25%), fructose (1.08–1.48%), etc. (Lamb, 1977). The pH of raw tomatoes is 4.2–4.6 and is mainly due to citric and malic acids (Lamb, 1977). Although the nutritional value of tomato is rather low, the large amount of tomatoes consumed in any meal of the day, raw or cooked, makes it quite valuable in standard and special diets.

The development of many new tomato varieties in order to improve yield, crack resistance, quality of fruit, etc. makes it difficult to consider all the varieties currently in use. The harvesting season depends on the climatic conditions: in Italy, it lasts from July to the end of September.

The leading countries in terms of acreage are the U.S.A., Italy, Mexico, Egypt and Brazil. Table 2 shows tomato production in the EEC and other countries from 1978 to 1980: Italian production, being the highest in Europe, ranged from 57 to 67% of that of the U.S.A. in 1979 and 1980.

The evolution of tomato production, acreage and yield per hectare in Italy from 1970 to 1980 is shown in Table 3.

Table 1. Physical and chemical composition of tomatoes (Guastalla, 1968)

Component	(%)
Juice	94–96
Seeds	1–1.5*
Peel and fibres	1.5–2.5*
Water	95
Carbohydrates	2.8–4.1
Protein (N×6.25)	0.6–0.8
Acid (expressed as citric acid)	0.3–0.5
Ash	0.4–0.5

*Moisture content 66%

Table 2. Crop estimates (1000 tons) for tomatoes as reported in OECD. report (1979)

Country	1978	1979	1980*
Belgium	114.8	117.5	—
Denmark	18.3	17.0	16.5
France	802.1	824.7	826.7
Germany	28.0	29.3	25.8
Ireland	28.8	28.0	26.0
Italy	3850.0	5130.0	4660.0
Netherlands	371.6	405.1	380.0
United Kingdom.	129.0	139.0	—
Spain	2223.0	2049.8	2056.0
Greece	1718.0	1750.0	1750.0
Portugal	950.0	970.0	—
Austria	28.0	37.0	35.0
Turkey	3300.0	3500.0	—
Canada	477.7	466.5	—
U.S.A.	6780.6	7699.1	—
Japan	887.8	941.1	—

*Estimate as at 6.5.80

Table 3. Tomato production, acreage and yield per hectare in Italy from 1970 to 1980 (IRVAM, 1980)

Year	Production (1000 tons)	Acreage (ha)	Yield (t/ha)
1970	3617.9	129 967	27.84
1971	3423.6	120 190	28.48
1972	3050.4	111 026	27.47
1973	3310.4	109 988	30.10
1974	3637.4	116 999	31.09
1975	3511.96	113 178	31.03
1976	2968.65	98 938	30.01
1977	3299.91	107 317	30.75
1978	3820.5	112 970	33.82
1979	5132.1	132 002	38.88
1980*	4810.0	125 930	38.20

*Estimates from IRVAM

Table 4. Supply balance sheet for fresh tomatoes (1000 tons) in the EEC countries in 1976/77 and 1977/78, as reported in Eurostaf (1981)

	Germany		France		Italy		U.K.		EEC	
Utilization (1000 tons)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
(a) Sales by professional producers	30	29	573	573	2517	2711	187	180	3875	4036
(b) Imports	339	343	188	185	2	2	130	149	364	378
Intra EEC	227	240	57	49	—	—	36	51	—	—
(c) Resources = uses (a+b)	369	372	761	758	2519	2713	317	329	4239	4414
(d) Exports	1	—	5	8	21	24	5	8	54	53
Intra EEC	1	—	3	4	16	20	4	8	—	—
(e) Total domestic uses (c−d)	368	372	756	750	2498	2689	312	321	4185	4361
Losses	37	37	82	79	204	—	—	—	339	128
Animal feed	—	—	—	—	1	—	—	—	4	2
Processing	—	—	218	225	1518	1897	—	—	1737	2122
Human consumption	331	335	456	446	775	792	312	321	2017	2109

(1) From 1 April 1976 to 31 March 1977
(2) From 1 April 1977 to 31 March 1978

In 1976–77 and 1977–78, the last years for which statistics are available, the general aspects of the tomato sector in the main EEC countries and in the EEC as a whole are summarized in Tables 4 and 5, which report the supply balance sheets for fresh tomatoes and processed tomatoes respectively (Eurostat, 1981). From these tables it is possible to derive that the imports of fresh tomatoes are about 9% of total EEC uses, while those of processed tomatoes are approximately 30% of total EEC consumption.

Table 5. EEC supply balance sheet for processed tomatoes expressed in fresh product weight (1000 tons) in 1976/77 and 1977/78, as reported in Eurostat (1981)

	Germany		France		Italy		U.K.		EEC	
Utilization (1000 tons)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
(a) Usable production	—	—	218	225	1518	1897	—	—	1737	2122
(b) Imports	627	556	322	364	100	129	569	494	864	830
Intra EEC	459	464	184	201	2	5	243	228	—	—
(c) Resources = uses (a+b)	627	556	540	589	1618	2026	569	494	2601	2952
(d) Exports	22	20	37	47	1062	1155	—	—	36	155
Intra EEC	19	12	8	9	618	581	—	—	—	—
(e) Final stocks	—	—	—	—	60	—	—	—	—	—
(f) Change in stocks	—	—	—	—	−290	−10	—	—	−290	−10
(g) Total domestic uses	605	536	503	542	846	881	569	494	2855	2807
Losses	—	—	—	—	—	—	—	—	—	—
Human consumption	605	536	503	542	846	881	569	494	2855	2807

(1) From 1 April 1976 to 31 March 1977
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The tomato industry can be described by two different types of culture, that is, glasshouse or greenhouse and open field. All greenhouse-grown tomatoes are marketed fresh, while a high proportion of the tomatoes grown in open fields is processed. Table 6 deals with the utilization of tomatoes grown in open fields in Italy and shows that more than two-thirds of the crop are processed. About 45% of fresh tomatoes are canned as peeled tomatoes, 53% as tomato paste at 28–30% natural tomato soluble solids (NTSS) and the remainder as chopped peeled tomatoes and tomato juice (INCA, 1979).

In all probability the EEC Common Agricultural Policy (CAP), involving a system of production grants, may have been particularly significant in encouraging the recent expansion (126% increase from 1977 to 1980) in tomato concentrate production in Italy, although in the same period a remarkable 20% increase in tomato yield per hectare was obtained (Table 3). Certainly, the introduction of common policies for all agricultural products has been

Table 6. Utilization of tomato in Italy from 1974 to 1980

Utilization (1000 tons)	1974*	1975†	1976†	1977‡	1978§	1979§§	1980**§§
Industrial processing	1850	1480	1240	1550	2300	3730	3500
Fresh market	940	1011.4	942	1000	828	895	918
Market surplus	5.2	124.6	10	14	13	163	70
Waste and losses							
Production and self-consumption	325	330	371	300	198	262.1	240
Distribution	114	105	75	86	50	64.5	62
Export	15.8	19	15	20	19	17.5	20
Total	3250	3070	2653	2970	3408	5132.1	4810

*IRVAM (1975)
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§IRVAM (1979)
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**Estimates at 31st July, 1980

responsible for the operation of a scheme of contractual systems between the growers and the processing industry, thus representing a stabilizing element in the EEC market against the large variations of world market prices for raw materials. In fact, the competitive position of EEC producers and manufacturers can be greatly affected by the importation of processed fruits and vegetables from non-EEC countries.

For this reason, the CAP introduced a support system for a large number of products (such as stewed or frozen fruits with or without sugar addition, dried fruits, citrus peels, pectic substances, fruit purées, fruit pastes, fruit juice and grape juices with a sugar addition greater than 30%) by establishing no internal trade barriers between the member states and common external tariffs against the non-EEC producers (EEC regulatory n. 516, 1977). Furthermore, the importations of products containing sugar substitutes like glucose and/or glucose syrups, which are less expensive than sucrose were submitted to import tariffs to maintain the competitiveness of the European industry (EEC regulatory n. 516, 1977). On the other hand, the exportation of products requiring sugar addition to non-EEC countries was supported by the granting of aids, proportional to the addition of sucrose, glucose, or glucose syrups (EEC regulatory n. 516, 1977), while that of the other products mentioned above was helped by grants covering the difference between the EEC and world market prices.

As far as the production of tomato products is concerned, the contracts regulating intra-European trade between tomato suppliers and tomato manufacturers for each type of product in 1979–80 are summarized in Table 7 (EEC regulatory n. 1346, 1980).

Table 7. Contracts regulating the intra-EEC trade between growers and manufacturers, as reported in IRVAM (1980): minimal raw tomato price to be paid to growers and rewards to be given to processors according to the type of final product

	Payments to			
	Producer (L./kg of fresh tomatoes)		Manufacturer (L./kg of packed product)	
Final product	(1979)	1980)	(1979)	(1980)
Peeled tomato				
type 'Roma'	110.44	127.70	148.31	147.39
type 'S. Marzano'	146.42	169.38	186.17	185.01
Chopped peeled tomato	91.25	105.59	72.68	72.25
Tomato juice				
3.5—5% NTSS	91.25	105.59	69.33	68.89
5 —7% NTSS	91.25	105.59	106.67	105.94
7 —8% NTSS	87.58	101.31	146.84	145.88
8 —10% NTSS	87.58	101.31	167.81	166.72
10 —12% NTSS	87.58	101.31	199.28	197.98
Flakes	110.44	127.70	1562.77	1675.09
Frozen peeled tomato	110.44	127.70	148.31	147.39
Tomato paste 28–30% NTSS	87.58	101.31	400.87	429.54

In general, every year a European committee lays down the minimum selling prices for fresh tomatoes to be transformed into tomato products and the aids to the processors. The former are evaluated by taking into account the average market prices during the previous harvesting season and the increase in the cultivation costs, while the latter depend on the mean processing costs in the EEC and the average CIF (Cost Insurance Freight) selling prices for each tomato product imported from Third Countries (EEC regulatory n. 516, 1977).

Finally, the contracts mentioned above also guarantee a certain income to farmers who have not sold their crop by withdrawing the surplus for other uses such as industrial utilization or animal feeding. For instance, in 1979 about 168 000 tons of fresh tomatoes were withdrawn by the government association (AIMA).

A typical tomato paste production process

Of the various technological lines actually used to process fresh tomatoes the economics of tomato paste production has been studied because of its high

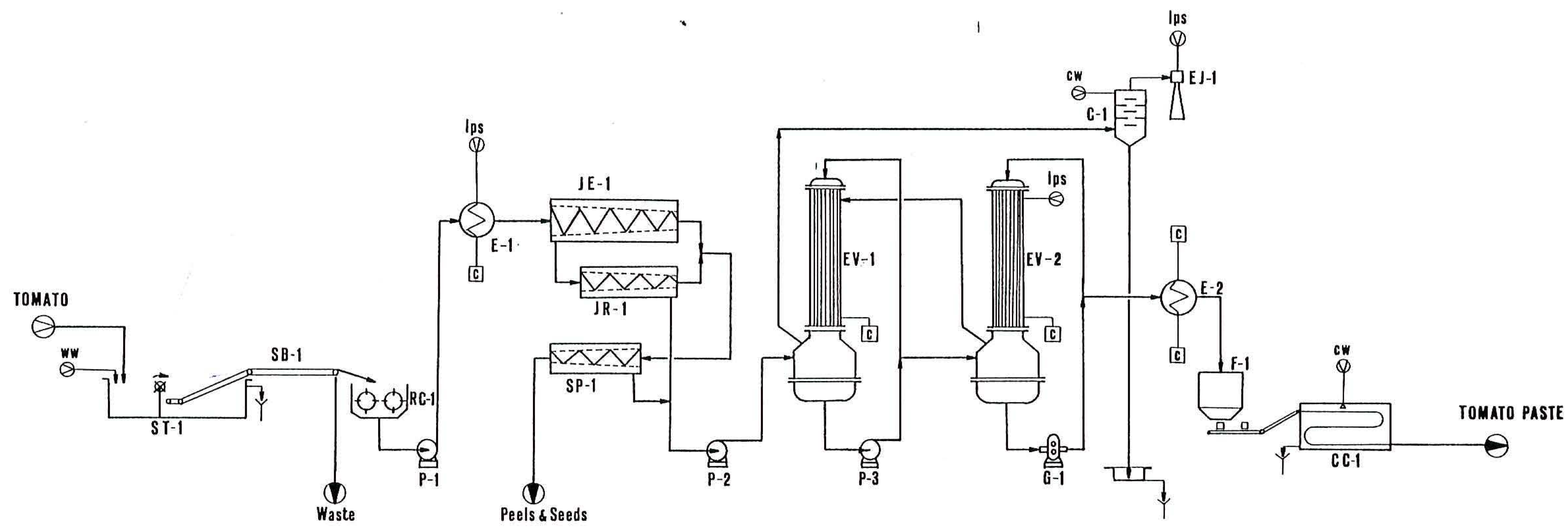

Figure 1. Flow diagram for tomato paste process.
Equipment identification Items: C, Condenser; CC, Container cooler; E, Heat exchanger; EJ, Ejector; EV, Long-tube falling-film evaporator; F, Filler; G, Rotary gear; JE, Juice extractor; JR, Juice refiner; P, Centrifugal pump; RC, Rotary comb chopper; SB, Sorting belt; SP, Screw press; ST, Soaking tank.
Utility Identification Items: c, Condensate; cw, Cooling water; lps, Low pressure steam; ww, Washing water.

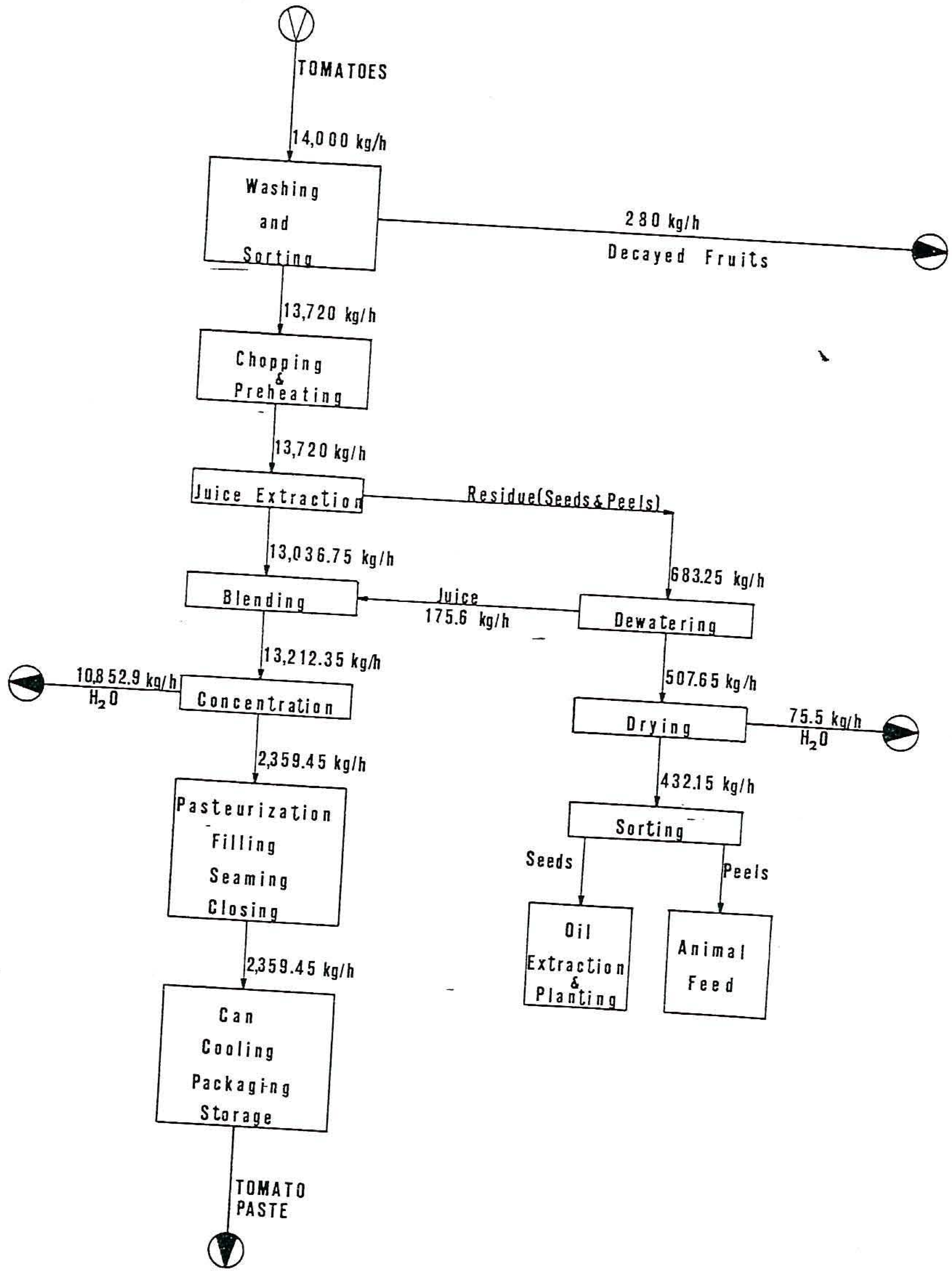

Figure 2. Material balance flow sheet for the flow scheme of Fig. 1.

output (INCA, 1979), by considering a medium size plant with a working capacity of 14 tons of fresh tomatoes per hr and operating for 120 days per year.

The process flow diagram and material balance flow sheet are shown in the Figs 1 and 2, respectively. The process may be described as follows.

Washing and sorting

Fruit is generally brought to the concentration plant in bulk form or polyethylene tubs by trucks. Storage should be no longer than 48 hr to limit bacterial contamination which modifies the chemical and nutritional characteristics.

Two soaking tanks are commonly used to remove all the adhering dirt; then the washed tomatoes are moved to the sorting belts by a conveyor.

Under optimal conditions of lighting and belt design (area, width and speed of the belt of about 0.07 m^2 per kg of tomatoes, 0.5 m and 5 m/min respectively) seasonal workers are usually employed to inspect 400–500 kg/hr per person (Guastalla, 1968). Decayed fruits are picked out by hand and discarded. Washing water is chlorinated (5–10 p.p.m.) to maintain sterility during operation. In our specific case, 1.43 m^3 of water was found to be sufficient for each ton of fresh tomatoes (Leoni, 1978); sorting required three sorting belts working in parallel and thirty men per shift.

Chopping and pre-heating

Washed tomatoes are first chopped into small pieces by a machine consisting of a rotating, cogged drum and a stationary comb, and then pre-heated to 90–95°C for 1–2 min ('hot-break' method) or to 60°C ('cold-break' method) to allow easier peeling (Guastalla, 1968; Tressler & Joslyn, 1961). The 'cold-break' treatment is actually more widely used because the 'hot-break' method inhibits pectic enzymes, giving highly coloured, thick and viscous juices and heavy fouling in heaters and evaporators (Morgan, 1959). Moreover, seed recovery for future planting is also possible (Fig. 2), although the commercial value of the seeds is rather low.

Extraction

Chopped tomatoes are pressed through various screens, the openings of which decrease from 1.5 to 0.4 mm. The residue is dewatered by a continuous screw press to improve the extraction yield and then sent to final disposal in a controlled discharge area. Other alternatives, such as seed recovery for oil extraction or future planting, and peel utilization as animal feed or fuel, involve a drying operation and are usually regarded as being uneconomic for a number of reasons (seasonal operation, high operating costs of drying, low commercial value of final products, etc.).

Concentration

This operation is carried out at sub-atmospheric pressures by using falling-film and scraped-film evaporators according to the viscosity of the final product. In this study tomato juice was concentrated from 5 to 28% NTSS by using counter-current two-stage falling-film evaporators. Material and energy balances solved by trial and error are shown in Table 8. Physical data (boiling-point rise, density and specific heat of tomato products) were derived from Liverotti (1980), and heat transfer coefficients from manufacturers' catalogues.

Table 8. Material and energy balances for the evaporation unit of the tomato paste process shown in Fig. 1

Parameter	First effect	Second effect	Unit
Internal pressure	55	196	mmHg abs.
Juice temperature	42	69	°C
Boiling-point rise	0.7	1.7	°C
Heat-transfer coefficient	2900	1980	W/m^2. °C
Temperature difference	29	35	°C
Heat-transfer surface	52	60	m^2
Input liquid flow-rate	13212	7927	kg/h
Input NTSS	5	8.3	%
Output liquid flow-rate	7927	2359	kg/h
Output NTSS	8.3	28	%

Pasteurization—

Continuous pasteurization at 90–92°C has been found to allow safe storage by preventing any spoilage by lactobacilli and avoiding any local superheating of the product (Guastalla, 1968; Tressler & Joslyn, 1961).

Filling and closing

Pasteurized juice is automatically filled into thoroughly cleaned and steam-treated lacquered tin cans; the cans are then seamed and cooled. Insufficient cooling is detrimental to flavour and often causes labelling difficulties.

Storage

Tomato products may be temporarily stored in 5–20 kg cans, 115–225 kg barrels (Cultrera & Giannone, 1965) or sterile tanks in an inert gas atmosphere (Menoret & Gautheret, 1962). The first two methods involve high packaging costs if further processing is required. The rate of deterioration increases rapidly with increase of temperature. Canned tomato products stored at 12–24°C retain their normal flavour and appearance for about 18 months if air humidity is kept low to avoid condensation and can rusting (Guastalla, 1968).

Waste disposal

Although the liquid wastes from processing and washing operations have a BOD ranging from 600 to 1000 p.p.m. (Degrémont, 1972), the small volumes arising during the seasonal operation of the tomato industry involve limited environmental contamination. Therefore, after screening to remove suspended solids wastewaters are usually disposed of as irrigation water or piped into existing sewers (Tressler & Joslyn, 1961), but this procedure may not be acceptable in future.

Cost estimates

The economic balance of the plant has been calculated as outlined below.

The capital investment C_i has been derived by using Chilton's method (1960), as summarized in Table 9. In particular, capital investment for the major items of equipment (Fig. 1) has been derived from recent data from manufacturers, while the minor items, such as decayed fruit and pallet conveyors, screw press, etc., have been assumed to represent 5% of the 'total purchased equipment cost' C_e.

Table 9. Capital investment estimate for the tomato paste process shown in Fig. 1: working capacity 14 tons of fresh tomatoes per hours; output level about 6800 tons of tomato paste at 28% NTSS

Unit		Investment cost (in millions L.)
Washing—extraction		100
Concentration		350
Pasteurization		20
Packaging		35
Cooling		100
Steam production		50
Pumps		3
Minor items		35
Total purchased equipment C_e		693
Ancillary process equipment and installations		
Piping and valves	$0.20\ C_e$	
Instruments and controls	$0.10\ C_e$	
Electrical	$0.15\ C_e$	
Equipment installation	$0.30\ C_e$	
Painting, insulation	$0.02\ C_e$	
	$0.77\ C_e$	534
Civil works and services	$0.55\ C_e$	381
Utility installation	$0.20\ C_e$	139
Total direct cost $C_d = 2.52\ C_e$		1747
Engineering	$0.10\ C_d$	175
Contractor fees	$0.05\ C_d$	87
Contingencies	$0.15\ C_d$	262
Total capital investment $C_i = 1.30 C_d$		2271

A summary of all the items contributing to operating costs C_o is set out in Table 10.

Table 10. Production costs for the tomato paste process shown in Fig. 1 for Italy in 1979 ($1 = 1000 Italian Liras)

Operating costs	Cost (in millions L.)
Investment-related costs	
Depreciation (10 years, 10% interest rate)	370
Maintenance (3% C_d)	52
Subtotal	422
Utilities	
Electricity: L.25/kWhr × 139 kWhr × 2880 hr	10
Cooling water: L.20/m³×158 m³/hr×2880 hr	9
Well water: L.80/m³×20 m³/hr×2880 hr	5
Fuel: L.165/kg×558 kg/hr×2880 hr	265
Subtotal	289
Raw materials	
Tomato: L.96·58/kg×14 000 kg/hr×2880 hr	3894
Lacquered tin eans: L.80/kg×2359·45 kg/hr×2880 hr	544
Chlorine:	2
Subtotal	4440
Labour	
Seasonal worker: L. 4500/hr×90 SW×960 hr/SW	389
Seasonal skilled worker: L. 14×10⁶/year×9 SSW×1/3 year/SSW	42
Permanent skilled worker: L. 16×10⁶/year×4 PSW×1 year/PSW	64
Administrative Worker: L. 16×10⁶/year×4 AW×1 year/AW	64
Supervisor: L. 20×10⁶/year×1 S×1 year/S	20
Subtotal	579
Total	5730

The economic balance of the concentration plant can be written as follows,

$$C_o + P = Q_P(c_P + c_{EEC}) \tag{1}$$

where Q_P and c_P are respectively the overall quantity and selling price of tomato paste, and c_{EEC} the EEC payments per kg of packed product. The plant profitability P is expressed as a percentage p of the 'total capital employed' C_T, which is made up of C_i and the fraction n of the operating costs related to 3 months of turnover:

$$C_T = C_i + nC_o \tag{2}$$

By combining equations (1) and (2) we have

$$p = \frac{Q_P(c_P + c_{EEC}) - C_o}{C_i + nC_o} \tag{3}$$

For 1979 the profit from the operation and the return on capital p have been calculated as shown in Table 11. A profitability of about 22% is usually considered satisfactory for a venture of this nature, depending on the risk relative to alternative utilization of capital within a company.

Table 11. Profitability analysis for the tomato paste process shown in Fig. 1 with reference to the operating costs shown in Table 10

Areas of profitability	10^6 L.	%
Gross profit		
Sales: L. 560/kg×2359.5/β kg/h×2880 hr	4181	
EEC payments: L. 400.87/kg×2359.5/β kg/h×2880 hr	2992	
Subtotal (a)	7173	
Operating costs (b)	5730	
Profit from operations (a−b)	1443	
Total capital employed (C_T)		
Original fixed capital invested	2271	
Turnover: 0.75×5730×10^6 L.	4297·5	
Total	6568·5	
Profitability (a−b)/C_T		21·97

β = filling degree of 5-kg container—0.91

To determine how p is influenced by several parameters, such as tomato transport, package and labour costs, the marked price of the packed product and EEC payments, equation (3) has first been modified by subsituting all the terms of the operating costs and then differentiated with respect to each parameter x_i at $x_{j \neq i}$ = const. Each partial derivative, $\delta p/\delta x_i$, has been finally used to determine the relative variation Δp of p at different degrees of variation of each factor as follows,

$$\Delta p = \sum_i \left(\frac{\delta p}{\delta x_i}\right)_{x_{j \neq i}} x_{io} \left(\frac{\Delta x_i}{x_{io}}\right) \qquad (4)$$

where x_{io} is the basic value of the generic parameter x_i. All the data useful for this analysis of sensitivity are presented in Table 12. A 10% variation of raw tomato and tomato paste market prices and EEC payments varies the return on capital by 29 and 21% respectively, while the same variation of the various other factors yields a mean effect on p less than 5%.

These results make the consideration of alternative investment extremely difficult, as the differences are of the same order of magnitude as the profit or loss. In the past year, owing to the effect of inflation, raw tomato costs increased by 15.7%, product prices by 11%, the EEC subsidies by 7.2%, transport costs

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Well water: L.80/m^3×20 m^3/hr×2880 hr	5
Fuel: L.165/kg×558 kg/hr×2880 hr	265
Subtotal	289
Raw materials	
Tomato: L.96·58/kg×14 000 kg/hr×2880 hr	3894
Lacquered tin cans: L.80/kg×2359·45 kg/hr×2880 hr	544
Chlorine:	2
Subtotal	4440
Labour	
Seasonal worker: L. 4500/hr×90 SW×960 hr/SW	389
Seasonal skilled worker: L. 14×10^6/year×9 SSW×1/3 year/SSW	42
Permanent skilled worker: L. 16 × 10^6/year × 4 PSW × 1 year/PSW	64
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Subtotal (a)	7173	
Operating costs (b)	5730	
Profit from operations (a−b)	1443	
Total capital employed (C_T)		
Original fixed capital invested	2271	
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Total	6568·5	
Profitability (a−b)/C_T		21·97

β = filling degree of 5-kg container—0.91

To determine how p is influenced by several parameters, such as tomato transport, package and labour costs, the marked price of the packed product and EEC payments, equation (3) has first been modified by subsituting all the terms of the operating costs and then differentiated with respect to each parameter x_i at $x_{j\neq i}$ = const. Each partial derivative, $\delta p/\delta x_i$, has been finally used to determine the relative variation Δp of p at different degrees of variation of each factor as follows,

$$\Delta p = \sum_i \left(\frac{\delta p}{\delta x_i}\right)_{x_{j\neq i}} x_{io} \left(\frac{\Delta x_i}{x_{io}}\right) \qquad (4)$$

where x_{io} is the basic value of the generic parameter x_i. All the data useful for this analysis of sensitivity are presented in Table 12. A 10% variation of raw tomato and tomato paste market prices and EEC payments varies the return on capital by 29 and 21% respectively, while the same variation of the various other factors yields a mean effect on p less than 5%.

These results make the consideration of alternative investment extremely difficult, as the differences are of the same order of magnitude as the profit or loss. In the past year, owing to the effect of inflation, raw tomato costs increased by 15.7%, product prices by 11%, the EEC subsidies by 7.2%, transport costs

Table 12. Sensitivity analysis of profitability referred to a +10% relative variation of each parameter contributing to the economic balance of the tomato paste process shown in Fig. 1.

Parameter x_i	Basic value x_{io}	$\left(\frac{\delta p}{\delta x_{io}}\right)_{x_{j \neq i}}$	$\left(\frac{\Delta p}{p_o}\right)^*$
Raw tomato cost	87.58 L./kg	-7.150×10^{-3}	−28.5%
Transport cost	9.00 L./kg	-7.150×10^{-3}	−2.9%
Tomato paste package cost	80.00 L./kg	-1.205×10^{-3}	−4.4%
Labour cost	579.00 10^6 L.	-1.773×10^{-10}	−4.6%
Tomato paste market price	560.00 L/kg	1.137×10^{-3}	+28.9%
EEC payments	400.87 L/kg†	1.137×10^{-3}	+20.7%

*Referred to a +10% relative variation ($\Delta x_i/x_{io}$) of each parameter x_i
†Packed tomato paste at 28% NTSS

by 33%, package costs by 25% and labour costs by 15%, thus yielding a lower return on capital (16.3% instead of 22%). If tax, duty, insurance, advertising investment and interest allowed are deducted from gross profit, profitability is further lowered.

The annual contribution of raw material costs (Table 10) is more than 75% of the overall operating costs and about twice the total capital invested. Therefore, tomato manufacturers may have to resort to high-interest, short-term loans to obtain working capital, thus drastically reducing net earnings.

Moreover, not only low, raw tomato prices but also low production costs have to be considered to understand why tomato products of first quality from Greece, Spain and Portugal are not so expensive as those from Italy. In fact, even if the EEC payments for tomato manufacturers were to reduce raw material costs from L. 87.58/kg to L. 29.02/kg the selling price (L. 560/kg) of 28% NTSS tomato paste, for instance, would still be higher than that (L. 450–500/kg) of a similar product from Portugal. This can be easily explained by taking into account the higher labour costs of the EEC industry in comparison with Third Countries like Spain, Greece, Portugal, Turkey, etc.

Therefore, it is virtually certain that the present CAP support system for the tomato processing sector should adopt drastic changes in its mode of operation in order to allow the EEC manufacturers to cope with increased levels of competition from non-EEC countries.

In fact, one of the main disadvantages of the CAP system is that the obligation for the EEC processors to purchase tomatoes at prices much higher than their competitors in the non-EEC countries lowers their competitiveness on EEC and export markets.

In a short-term period this might be guaranteed by increasing the import tariffs for tomato products from Third Countries or granting greater aids to the manufacturers, while a new market intervention activity should be introduced to favour a long-term reorganization of the EEC tomato sector, as its profitability cannot be improved only by optimizing tomato processing methods. In fact, the incidence of the actual processing equipment on the total capital invested is rather less than 31% (Table 9) and in the near future this proportion is likely to be reduced further following the installation of wastewater treatment plants to fulfil anti-pollution regulations.

In more specific terms, to support continuing interest in these processes in industrialized areas the following changes are necessary:

(1) The industry will need to develop new 'crack-resistant' varieties of tomato in order to favour the mechanization of crop harvesting, thus obtaining a substantial reduction in manpower and raw tomato costs.

(2) Automatic sorting will be required, although this has proved to be one of the most difficult operations to mechanize. However, we are certain to see a major drive in this area in the future, more than two-thirds of labour costs being associated with manual sorting.

(3) For the concentration of tomato juice 2-effect or 3-effect falling-film evaporators are most commonly used. However, dewatering costs for a water removal of about 10 ton/hr (Fig. 2) might be further reduced by increasing the number of effects up to 4 or 5 in accordance with Thijssen and van Oyen (1977). Further energy might be saved by expanding live steam through an exaust-steam turbine-engine to drive circulation pumps (Angeletti, 1979).

(4) The adoption of multi-purpose plants capable of treating different kind of fruits (such as tomato, grape, apple, orange, lemon, etc.) would increase the annual working period of the industry, thus reducing the contribution of amortization and permanent worker costs to the overall operating costs.

(5) Low interest government loans will also help industry to deal with the problem of delayed EEC payments and the burden of interest.

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References

Angeletti, S. (1979) *Modello matematico di una unitā di concentrazione a multiple effetto con evaporaton ā film cāolente,* Chem. Engng. Thesis, University of Rome, Italy.
Chilton, C. (1960) *Cost Engineering in the Process Industries.* McGraw-Hill, New York.
Cultrera, R. & Giannone, L. (1965) *Ind. Conserve,* **40**, 94.
Degrémont (1972) *Mémento Technique de l'Eau.* p. 746, Technique et Documentation, Paris.
EEC regulatory n. 516, 1977.
EEC regulatory n. 1346, 1980.
Eurostat (1981) *Crop Production,* **6**, 74.
Guastalla, M. (1968) *Le Conserve di Pomodoro.* Stazione Sperimentale per l'Industria delle Conserve Alimentari, Parma.
INCA (1979) *Produzione, Esportazione e Prezzi degli Alimenti Conservati Italiani nel 1979. Rilevazione e Dati Statistici.* Rome, Italy.

IRVAM (1975) Pomodoro – Consuntivo della Campagna di Produzione e Commercializzazione 1974, *Consuntivi.* June, p. 7.

IRVAM (1977) Pomodoro di Pieno Campo—Rapporto Consuntivo 1976 e Previsionale 1977, *Previsioni Consuntivi.* July, p. 16.

IRVAM INFORMAZIONI (1978) *Pomodoro – Consuntivo 1977 e Previsione 1978.* **12** (6 August), 11.

IRVAM INFORMAZIONI (1979) *Pomodoro – Consuntivo 1978 e Previsionale 1979.* **30** (2 August), 10.

IRVAM INFORMAZIONI (1980) *Pomodoro – Previsione 1980 e Consuntivo 1979.* **30** (31 July), 8.

Lamb, F.C. (1977) Tomato Products. *Bulletin 27-L.* p. 2. National Canners Association, Washington D.C.

Leoni, C. (1978) La Depurazione degli Effluenti nelle Industrie Conserviere Animali e Vegetali, Corso di Aggiornamento in *Depurazione degli Effluenti ed Economia dell'Acqua nell'Industria Alimentare',* University of Milan (Italy), Cernobbio.

Liverotti, C. (1980) *Progettazione di un impianto per la produzione di succo concentrato di pomodoro,* Chem. Engn. Thesis, University of Rome, Italy.

Menoret, Y. & Gautheret, R.J. (1962) *Ind. (Paris).* **79**, 419.

Morgan, A.J. (1959) *Food Technol. Champaign,* **13**, 232.

Thijssen, H.A.C. & van Oyen, N.S.M. (1977) Analysis and Evaluation of Concentrated Alternatives for Liquid Foods. *Seventh Eur. Symp. Food: Product and Process Selection in Food Industry,* Eindhoven (Netherlands).

Tressler, D.K. & Joslyn, M.A. (1961) *Fruit and Vegetable Juice – Processing Technology,* p. 247 & 970, AVI Publishing, Westport.

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An objective index for the evaluation of the ripening of salted anchovy

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Summary

Salted anchovies were conditioned in order to allow ripening in brine. A sensory panel procedure was developed to systematically follow the process.

This sensory evaluation was carried out for up to 328 days, and the results indicated 10 months as the minimum time required to obtain an adequately cured product.

Total ester index was determined at the successive stages of anchovy ripening. There was a close correlation between total ester index and sensory score between 100 days and 328 days of ripening. This relationship to storage time and to sensory assessment supports the use of total ester index as an objective method to follow and assess the later stages of this little known process.

Introduction

Salting and curing of anchovies is a traditional process used by Mediterranean fishermen to obtain a product with a tender consistency and specific pleasant aroma and taste as a result of enzymic activity on the fish flesh.

The reproduction of *Engraulis anchoíta* takes place all year round, but there are two principal periods of spawning, the main one taking place during October–November and the second during May–June (Bellisio, López & Torno, 1979).

From experience it has been observed that the desired ripening reaction takes place only in *E. anchoíta* caught during the October-November period and this fish is suitable as raw material for semi-preserves.

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