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SMALL/MEDIUM MULTIPURPOSE FRUIT AND VEGETABLE PROCESSING PLANTS

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SMALL/MEDIUM MULTIPURPOSE FRUIT AND VEGETABLE PROCESSING PLANTS

A B S T R A C T

The establishment of small/medium multipurpose fruit and vegetable processing plant could be an efficient and economic alternative while processing seasonal fruit and vegetable into similar end products. In fact, most of fruit and vegetable processing plants based on seasonal raw materials, are totally or partially of multipurpose nature and employ multipurpose equipment for similar processing operations.

Multipurpose fruit and vegetable plants could be of versatile types and combinations engaged with practically all different processing technologies and unit operations. This will oblige to examine and evaluate each case on its own merit.

The application of the multipurpose concept is only one of the factors and issues influencing the viability of the plant's operation. The pros and contras relative to the implementation of this concept should therefore be examined and evaluated within the full context of all factors influencing the feasibility of the project.

In this report an attempt has been made to present the principal factors and issues related with the definition and application of the "multi-purposeness" concept to small/medium fruit and vegetable processing plants including flow charts for different multipurpose processing operations and two case studies.

C O N T E N T S

APPENDIXES

S U M M A R Y

The "multipurposeness" concept applied in small/medium fruit and vegetable processing plants is an efficiency concept based on the utilization of the same assets and equipment of the plant for processing different raw materials and end products, by an adequate sequence of operations, that will lead to an economy in investments and production costs, compared with an independent execution of the same processing programme by separate means.

Small fruit and vegetable processing plants in developing countries are generally tended to operate with simple equipment and more manual work. Medium plants are more mechanized, therefore the application of the multipurposeness concept in these plants will be of a higher interest compared with small plants.

In certain cases compromises in the selection of the equipment and the processing programmes should be done in accordance with the different raw materials and/or end products to be processed.

The application of the multipurposeness concept may take place at different levels of the plant's operations being (a) installations and activities on whole plant's level; (b) equipment and operations concerning the assembly of raw materials and end products; (c) equipment and operations concerning the preparation of raw materials for processing; (d) equipment and operations concerning the conversion of raw materials and (e) equipment and operations concerning the treatment of end products.

Planning, evaluation and implementation methodologies and procedures concerning the establishment of small/medium multipurpose fruit and vegetable processing plants in developinng countries are generally conducted on the same lines as for all other agroindustrial projects, taking in consideration the effect of the multipurposeness nature of the plant on the project's results.

The multipurposeness characteristic of small/medium multipurpose fruit and vegetable processing plant is only part of the factors and issues influencing the viability of the plant's operations. These concepts should be examined

and evaluated within the context of the prefeasibility or feasibility study of the project and in relationship to the pros and contras associated and relevant to their application. The great number of versatile types and possible combinations existing in the establishment of small/medium multipurpose fruit and vegetable processing plants in developing countries oblige to examine and evaluate each case on its own merit.

In this industrial profile an attempt has been made to present the principal unit operations and processing technologies issues relevant to the establishment of small/medium multipurpose fruit and vegetable processing plants in developing countries including schematic flow charts for different processing alternatives, a mathematical and schematic graphical presentation of "multipurposeness" concepts, a discussion concerning planning issues and procedures and two case studies.

I. BACKGROUND AND CONCEPTS

1.1 Introduction

In many developing countries agricultural production of fruit and vegetable is progressively developed by volume and diversification. Processing of the outcoming crops is often needed and will generally start by small/ medium plants whose size will depend on the availability of adequate raw materials and marketing possibilites. In processing seasonal raw materials at different harvesting seasons into similar intermediate and/or end products multipurpose processing equipment is generally utilized justified by the economy obtained in processing more products by the same equipment units.

The term "multipurpose" processing plant for fruit and vegetable is generally referred to a plant that with the same installed equipment will process different types of fruit and/or vegetable. This against the term "single purpose" processing plant that will refer to a plant equipped to carry out only one type of processing operations, generally with one type of raw material. The "multipurposeness" of the plant will therefore express the flexibility and the capability of the plant to process by the same equipment a wider range of fruit and/or vegetable, at different times, into their respective end products.

The "multipurposeness" concept is a very common one, applied on a wide scale in many fields of action of our life. It is an efficiency concept which concerns with the utilization of the same assets for the execution of more activities at different times, by an adequate sequence of operations that will aim to be more economical, hence efficient, compared with an independent execution of each of the respective activities by separate means. For example: A food processor is considered cheaper and more efficient compared with the purchase of different kitchen utensiles for each of its duties.

Multipurpose fruit and vegetable processing plant could be of great versatile types and combinations. The multipurposeness characteristics of the plant is only one of the factors influencing its viability. Therefore each project should be examined on its own merit consideraing all economic and social factors involved.

The present industry profile has been prepared following the request of UNIDO, Industrial Information Section. In this profile an attempt has been made to summarize and discuss the principal issues and aspects concerning the "multipurposeness" concept and its application in the establishment of small/medium multipurpose fruit and vegetable processing plants in developing countries, including case studies, schematic flow charts for different processing alternatives and a mathematical and graphical presentation of the multipurposeness concept and its application.

1.2 "Multipurpose", "Single Purpose" and "Specialized" Processing Equipment

Processing of fruit and vegetable is generally done by successive steps of unit processing operations, represented schematically by a process flow diagramme, that could be considered as the "strategy" selected to reach the processing targets. The selection and the implementation of the appropriate processing equipment for each unit operation and the performance conditions of this equipment may be considered as the "tactics" by which this strategy is achieved.

Fruit and vegetable processing equipment is generally focused to execute a specific unit processing operation (washing, sizing, evaporating, dehydrating, etc.). Processing equipment manufacturers tend to construct multipurpose equipment that could respond to a wider range of raw materials or products to be processed by the same unit. The multipurposeness characteristics of the equipment are therefore advantageous to the manufacturers of this multipurpose equipment, enabling to expand the range of potential buyers. It could be also advantageous to the processing plant that may employ the same multipurpose equipment for processing different raw materials or products in the same plant, whenever the same processing unit operations are employed, hence reduce investment costs.

Different processing conditions are often required for different raw materials or products to be processed by the same multipurpose equipment unit. For this reason most multipurpose processing equipment units have adequate controls (variable speed motors, temperature controls, flow controls, etc.), or exchangeable parts (screens in finishers, knives in cutters, etc.), that could enable to shift the machine performance to respond to specific needs.

In many cases, different types and sizes of multipurpose equipment are manu actured and employed for the same unit processing operation, (different types of conveyors, washing equipment, sizing equipment, sterilization equipment etc.). Compromises are often required in the selection of the optimal alternative to fit all multipurposeness needs, which are generally done by evaluating the pros and contras of each case on its own merits.

From the equipment manufacturers stand point two categories of equipment are available being:

a. "Multipurpose" equipment adequate for the processing of different raw materials or products, as described above, and

b. "Specialized" equipment, being a processing equipment unit destined to process only one specific type of raw material or product, as for example the "Ginaca" employed only in the processing of pine-apple.

From the processing plant stand point two categories of equipment are also available being:

a. "Multipurpose" equipment, employed by the plant for the processing of different raw materials as products, as above, and

b. "Simple Purpose" equipment that is employed by the plant for processing only one type of raw material or product. This equipment could be a "specialized" type equipment, or also a multipurpose equipment from manufacturers stand point employed by the plant as a "simple purpose" equipment.

It is therefore obvious that any "specialized" equipment is always a single purpose equipment but not vice versa. A simple purpose equipment in one plant may act as a multipurpose equipment in another plant. For example a rotating dryer may be considered as a single purpose equipment in drying orange peels in a processing plant for processing orange products and as a multipurpose equipment unit while dehydrating citrus peels, apple pomace and/or grape pomace in the same plant into stock feed.

In this report the term "simple purpose" equipment will also refer to all "specialized" processing equipment units.

The "degree" or "level" of multipurposeness, expressed by the ratio between the cost of the multipurpose processing equipment to the total cost of the processing equipment, is not necessarily linked to the plant's size and/or the production volume. Small plants could sometimes be of a higher multipurposeness nature compared with medium or big processing plants. However, most small/medium fruit and vegetable processing plants, which process different types of raw materials in different seasons of the year, are in one way or another of a multipurpose nature.

1.3 Principal and Complementary Raw Materials and Processed Products

In small/medium multipurpose fruit and vegetable processing plants different raw materials and processed products may have different importance, or weight, in the production plan due to their higher yearly production volume, or sales value, or importance to farmers, or export, or because of other reasons. In such cases they are sometimes classified as "principal" and "complementary" or marginal raw materials and processed product.

The "principal" raw materials and processed products are expected to secure the feasibility, or at least the break even point, of the plant's processing operations. In this case all the plant's fixed cost will be charged on their account.

On the other hand the "complementary" raw materials and processed products will be evaluated on the basis of their contribution to the additional profitability to the plant's operations. For the calculation of their profit and loss balance only the variable costs and the additional fixed costs, if any, concerning their production will be considered.

The profit and loss balance of all raw materials and end products processed by the plant, will be calculated as the sum of the profit and loss balances of all principal and complementary raw materials and end products processed by the plant.

In multipurpose plants the division into "principal" and "complementary" products could be of interest while dealing with progressive development projects that will start with the principal products and will be extended in the coming years with more complementary processed raw materials and/or end products.

II. JUSTIFICATION AND FIELDS OF ACTION

2.1 Justification

The implementation of the "multipurposeness" concept for small/medium fruit and vegetable processing plant will be justified whenever an economy can be reached by the reduction in the investment level, cost of depreciation, better utilization of man power, saving in fixed and overhead costs or other factors. The "multipurposeness" concept will not refer to processing operations carried out in parallel, at the same time, that will necessitate independent production means. Conditions calling for the establishment of small/medium multipurpose fruit and vegetable processing plant are presented as follows:

2.2 Processing of Fruit and Vegetable of Different Picking and Harvesting Seasons

The degree of multipurposeness will be influenced by the annual division (seasonality) of the processed fruit and vegetables. A higher degree of the multipurposeness utilization of the equipment could be attained by processing raw materials having similar characteristics, to be processed by the same equipment, similar processing technology and production capacities into similar end products, during more months of the year.

2.3 Progressive Development of Agricultural and Agroindustrial Projects

New fruit and vegetable agroindustrial development projects, carried out by a progressive development path, will generally aim to reduce initial risks at the early stage of the project's life time, by limiting the number and volume of the initial new activities in which experience has not yet been gained. The industrialization of these raw materials will result less risky if started by a small/medium multipurpose processing plant designed for similar processing technologies and installed in accordance with the project's progressive development path. In these cases only the equipment needed for the initial stage may be installed.

Later with the increase and/or diversification of the production programme, complementary equipment that might be needed could be added. The stand-by equipment installed for security reasons, against equipment break-down, can be also utilized during the peak harvesting season to increase the plant's production capacity. Building and construction programme should be coordinated accordingly.

2.4 Diversification and flexibility in Supplying Market Demand

In small countries having a diversified demand for small quantities of processed fruit and vegetable products, the supply of the demand of the domestic and regional markets is often solved by the establishment of small/medium multipurpose fruit and vegetable processing plants, having simple multipurpose equipment that may allow an easy shifting from one product to another in accordance with the availability of raw materials and markets demand. These plants will generally process a wide range of end products, by small production lots for more frequent and regular deliveries to their buyers.

2.5 Investigations and Pilot Processing Operations

Multipurpose equipment is frequently utilized in the investigation of new and improved processing technologies and in pilot processing operations linked with the preparation of samples of end products to be tested for consumers acceptance for quality and price.

Multipurpose pilot processing equipment form an indispensable part of the equipment of investigation institutes or laboratories engaged in the study and development of fruit and vegetable post harvest, storage, processing, transportation and marketing operations. Due to their flexibility and multipurposeness a wider range of processing alternatives may be examined with the same equipment.

2.6 Utilization of Manpower

Multipurpose fruit and vegetable processing plants, operating with different raw materials, during different seasons of the year, will enable to reach a higher stability and output of the employed staff.

On the other hand, these plants may require a higher flexibility and skill in the performance of part of its staff when shifting from one processing operation to another one.

The increase of the production volume due to the multipurposeness characteristics of the plant will also affect, and will reduce, the average fixed costs per ton of the processed raw materials.

III. CHARACTERISTICS OF SMALL/MEDIUM MULTIPURPOSE FRUIT AND VEGETABLE PROCESSING PLANTS

3.1 Batch and Continuous Processing Operations

Small multipurpose fruit and vegetable processing plants are generally based on simple batch operation equipment. Continuous processing operations are more frequent in medium/big plants, for which a steady supply of raw materials will be needed.

Multipurpose batch and continuous operations may prevail in the same plant. In such cases the linkage between the batch and the continuous section may take place by storage or holding facilities for an intermediate product processed, for example, by a batch operation, that will be passed to a continuous operation section. Or alternatively by an intermediate product processed by a continuous operation that will be kept for further processing by a batch operation or by another continuous operation.

3.2 Combined Multipurpose and Singlepurpose Processing Operations

Multipurpose and single purpose fruit and vegetable processing lines may be installed and operate in the same processing plant. It might also occur that fruit and vegetable of different harvesting seasons may need different equipment for certain processing operations and the same multipurpose equipment for other unit operations and/or sections of the plant. For example processing of citrus, and apple juice and wine from grapes are done by different processing technologies and plants but their by-products may be processed into animal feed by the same multipurpose drying equipment.

Multipurpose processing equipment is sometime installed alongside a main processing line for fruits and vegetables, to enable the processing of small lots of specific raw materials and/or end products for which it will not be convenient to stop the main production line or put in operation a processing line of a higher production capacity.

3.3 Processing of Fruit and Vegetable of Overlapping Picking or Harvesting Seasons

With fruit and vegetable of overlapping picking or harvesting seasons, to be processed by the same multipurpose equipment, the following alternatives may be examined and evaluated.

I. Install and operate different and/or additional processing equipment for processing in parallel the overlapping raw materials, or

II. Operate an interchangeable processing programme that will enable an alternate processing by the same multipurpose equipment of the fruit and vegetable picked or harvested at the same season, or

III. By the storage, if possible and convenient, of one of the overlapping raw materials until finishing to process the other one. This alternative could also be of interest in solving the problem of fruit and vegetables surplusses obtained during the peak seasons and for regulating the production capacity whenever irregular deliveries of raw materials may take place.

The selection of the most appropriate alternative is generally based on its feasibility evaluation.

3.4 Production Capacity and Production Volume

Production capacity and production volume are linke by the production time, which will generally depend on the date and duration of the harvesting season.

The production capacity of a multipurpose equipment unit should therefore correspond to the maximal (or peak) production capacity of each of the raw materials or products processed by the same equipment unit.

The operational costs of a multipurpose processing equipment unit comprise three cost components:

- Costs to be considered on a yearly basis, (depreciation, management etc.), that form part of the fixed costs of the plant.

- Costs proportional to the production volume, (energy, packaging materials, etc.) that form part of the variable costs.

- Costs per work hour of the multipurpose processing equipment unit, being certain fixed costs depending primarely on the work time of the equipment (spare parts and repairs, energy involved in running the empty machine, minimum seasonal labour to control the operation, etc.). These costs could be related to the operational production capacity of the multipurpose equipment unit.

The cost per ton of a processed raw material related to a processing equipment unit will therefore decrease with the increase in the production volume (effect of the costs considered on yearly basis) and will also decrease with the increase in the production capacity (effect of the fixed costs per work hour basis). However, it will not be influenced by the variable costs (costs proportional to the production volume).

An increase in the production volume and the production capacity of a multipurpose processing equipment unit will contribute to an improvement in the feasibility results of its operation. This effect will be more marked with processing equipment units of smaller production capacity, hence small multipurpose processing plants compared with medium and big size processing equipment units generally installed in medium/big plants.

With multipurpose fruit and vegetable processing plants based on continuous operation an increase in the production capacity can be obtained by a reduction of the daily number of work hours, hence by operating the plant during less hours at a higher production capacity. With plants based on batch operations, an increase of the production capacity of the different multipurpose processing equipment unit, can be also obtained by the preparation of enough intermediate products that will enable to proceed with the desired production capacity of the respective batch operation.

In small/medium multipurpose fruit and vegetable processing plants in which marked differences in the production capacities of different raw materials or products will prevail, the solicited production capacity of one multipurpose processing equipment unit can be repalced by two or more units each of smaller production capacities. In this case the raw materials of the lower production capacity will be processed only by one of the smaller multipurpose processing equipment units, while all smaller units will be employed, in parallel, to process these raw materials of the higher production capacity.

In certain cases the production capacity of a multipurpose processing equipment unit can be controlled and regulated by changing the equipment performance by the utilization of variable speed motors or by other means.

When dividing the production capacity of one equipment unit between two machines the following factors should be evaluated.

a. For the same production capacity and type of equipment the cost of two smaller equipment units, each having half of the production capacity under consideration, will be about 25% more expensive compared with the cost of one equipment unit for the same production capacity.

b. The reduction (or increase) in the operational costs should be weighed against the increase (or reduction) in the equipment cost.

c. The installment of two units is often advantageous from machinery break down and mainteance stand point, offering a higher safety of operation.

The great number of versatile types and alternatives existing in the establishment of small/medium multipurpose fruit and vegetable processing plants, engaged in the processing of seasonal raw materials, oblige to examine and evaluate the pros and contras concerning the application of the multipurposeness concept for each case on its own merits.

A priori the pros and contras of the application of the multipurposeness concept should be compared with the alternative of applying independent processing equipment for the same processing programme. In this case

the impact of the following two principal economic factors should be compared:

- The impact of the differences in the investments costs, and
- The impact of the differences in the operational costs.

The application of the multipurposeness concept will be justified if the overall costs indicated above concerning the application of this concept will be lower than the respective costs applied to independent processing equipment for the same production programme. However, the overall feasibility of the multipurpose processing plant should be defined while considering all other economic and social factors influencing the project's results.

3.5 Progressive Development Projects

With newly established small/medium multipurpose fruit and vegetable processing plants, a progressive development programme could be more easy and convenient while starting the plant's processing programme with a limited number of end products of the same nature to be processed by the same multipurpose equipment and by similar processing technologies. This in order to reduce initial investments costs, reduce initial risks associated with the lack of production experience and reduce difficulties associated with the introduction of new products into new potential markets. Under certain circumstances starting exports to the extra-regional markets could be more convenient and simple by the production and export of semi-elaborated products, packed in institutional packaging.

In progressive development projects, with different levels of multipurposeness utilization of the processing equipment during the different years of the project's life time, the pros and contras relative to the implementation of the multipurposeness concepts should be defined and evaluated all over the years of the project's life time by calculating the respective yearly present values, as done in the financial analysis of feasibility studies. For this calculation the same rate of discount applied for feasibility study of the same progressive development project may be applied. Within this context the two following principal alternatives should be also examined.

- Install the multipurpose equipment for the full capacity of the project's processing targets as from the initial stage of the production operations, or

- Install the multipurpose equipment progressively, in more processing units, following the increase of the production volume.

No general rule can be anticipated for these alternatives and for this reason each case should be examined by its own merit.

3.6 Principal Unit Processing Operations

In this chapter a summarized list of the principal unit processing operations concerning small/medium multipurpose processing plants are presented. For all these unit operations multipurpose equipment is available.

Multipurpose Immobile Assets, Installations, Equipment and Operations on Whole Plant Level

In all small/medium multipurpose fruit and vegetable processing plants the application of the multipurposeness concept starts with the immobile assets of the plant and proceeds with the installations, equipment and operations established and conducted on whole plant level that will refer to the following duties.

I. Multipurpose immobile assets, such as:

- Site, fences, internal roads.
- Building and structures.
- Other immobile assets, if any.

II. Multipurpose installations for the supply of utilities, such as:

- Electricity supply and distribution system.
- Water supply, storage and distribution system.
- Fuels supply, storage and distribution systems.
- Steam generation and hot water supply and distribution systems.

- Generation and distribution of compressed air and/or other gases (CO_2 or N_2).

III. Multipurpose installations for the supply of supporting services, such as:

- Repair and maintenance workshop and services.
- Draining of fluid effluents.
- Disposal of solid wastes.
- Materials handling and transportation means.
- Fire fighting equipment.
- Ambient protection.
- Installations and services for the employed personnel and guests.

IV. Multipurpose management and production control facilities.

- Management and administration facilities.
- Production control on plant level facilities.
- Quality and health control laboratory.

Multipurpose Unit Operations Concerning the Assembly of Raw Materials and Auxiliary Products.

Securing a regular and adequate supply of raw materials and auxiliary products will remain a principal issue for a successful and efficient multipurpose operation, to which the following multipurpose facilities and operations will refer.

- Organization and facilities for the purchase and delivery to the plant of raw materials and auxiliary products.
- Facilities and equipment for the receipt, quality and weight (volume) control of the delivered goods.
- Storage and handling facilities until delivery for processing.

Multipurpose Unit Operations Concerning the Preparation of Raw Materials for Processing

This phase may comprise the following principal unit operations and multipurpose equipment.

- Cleaning: Dry cleaning (brushing), washing (wet cleaning), aerating (aspiration), filtering (clarifying).

- Separating: Sorting, grading, sizing, draining, trimming, peeling, pitting, coring and stone removal, stemming, silking (corn), centrifuging.

- Disintegrating: Cutting, grinding, breaking, pulping, homogenizing, spraying.

- Separating (continued): Filtering, screening (finishing), expressing, rendering, extracting.

- Pumping: Positive Displacement pumps, centrifugal pumps,sanitary pumps, fans, air (gas) pumps, sludge pumps.

Multipurpose Unit Operations Concerning the Conversion of Raw Materials

This phase may comprise the following principal unit operations and multipurpose equipment:

- Mixing: Mixing of different solid materials, ng of different liquids and/or pastes, mixing of soli d liquids and/or pastes.

- Heat processing: Blanching, High Temperature Short Time (H.T.S.T.) pasteurization and sterilization, exhausting, cooking, sterilizing, retorting or processing and cooling.

- Refirgerating: Pre-cooling, cold storage, freezing, refrigerated transporting, ice production and cooling.

- Evaporating and distilling.

- Dehydrating, drying and freeze drying.
- Controlling (regulating and measuring).

Multipurpose Unit Operations Concerning the Treatment of End Products

In the treatment of end products processed by small/medium multipurpose fruit and vegetable processing plants, the following unit operations and equipment should be considered:

- Coating, Forming and Decorating.
- Packaging equipment and materials such as: Dosing and filling machines, closing and seaming equipment, labelling machines, marking equipment, cans reforming equipment, cartons and/or boxes forming and closing equipment, carton filling equipment.
- Handling and storage equipment and facilities for end products.

Wastes Treatment and Utilization

The treatment and utilization of processing wastes of small/medium multipurpose fruit and vegetable processing plants may comprise the following principal unit operations and multipurpose equipment:

- Disposal of solid wastes: Waste bins and/or containers, waste removal containers, incinerator.
- Disposal of liquid effluents: Septic and decantation basins, filtering equipment, pumps and piping.
- Dehydration of wastes: Expelling on hydraulic presses, rotating driers, pelletizing equipment, storage silos.
- Recovery of specific products: Specific equipment selected according to the processed product (citric acid, papain, sugar syrup, etc.).

3.7 Characteristics of small/medium multipurpose fruit and vegetable processing plants of different processing technologies

In this chapter a brief summary will be presented concerning the characteristics of small/medium multipurpose unit and vegetable processing plants

of the following processing technologies:

- Multipurpose canning plants
- Multipurpose freezing plants
- Multipurpose dehydration plants
- Multipurpose preservation plants
- Multipurpose marmelades, jellies and candied fruit plants
- Multipurpose pickling plants
- Multipurpose extraction plants
- Multipurpose frying and toasting plants
- Multipurpose fermentation plants.

In Appendixes No. 1 to No. 14 and Nos. 19, 23 schematic flow chart concerning different multipurpose fruit and vegetable processing plants are reported.

Multipurpose Canning Plants

Canning is probably the most widespread preservation method for fruit and vegetables done on a wide range of raw materials, and products and packaging types and sizes. All these products are preserved under sterilized form in air-tight sealed packs that will prevent spoilage by microorganisms and/or contact with air.

Small/medium multipurpose fruit and vegetable canning plants are widely spread and installed in developing countries for processing seasonal fruit and vegetables during more months of the year. In fact, most of the fruit and vegetable canning plants installed and operating with seasonal raw materials, are in one or another way of multipurpose nature.

Multipurpose fruit and vegetable canning plants can be encountered with a very wide versatility of combinations of raw materials, end products, processing unit operations and packaging. The multipurposeness of the canning operations may refer to the different end products processed from the same raw materials (processing of pineapple into canned slices and cubes, crush, natural and concentrated juice) or to the processing of different fruit and vegetables during different seasons of the year. Other processing technologies may take place in the same canning plant

as for example pickling of vegetables by fermentation before being canned, or drying of citrus peels into animal feed as a by-product of the citrus canning industry.

Small multipurpose canning plants for fruit and vegetables are generally based on the same line operation for all processed raw materials and end products.

Middle multipurpose fruit and vegetables canning plants may comprise different processing lines and sections depending on the processed products and the processing technology. The multipurpose utilization of the installed equipment is regulated considering the production season, production volume and the adaptability and facility to incorporate this equipment in the different processing operations.

The principal end products processed by small/medium multipurpose fruit and vegetable canning plants are the following:

- Fruit and vegetables juices, natural, concentrated and nectars, wihtout and with the addition of sugar, flavouring materials, spices, etc.
- Fruit and vegetable pulps, natural and concentrated, with and without the addition of sugar, spices and flavouring materials.
- Whole and/or cut fruit and vegetable (solid parts), canned in water, or in syrup, or in brine, or in vinegar, or in their own juice etc., with and without other additives.

The outcoming by-products will depend on the characteristics of the processed raw materials, for example essential oils (citrus industry), pectine (citrus peels and/or apples pomace or animal feed from the resulting wastes of the plant.

Several examples presented by schematic processing flow charts of small/ medium multipurpose fruit and vegetable canning plants are given by the following Appendixes No. 1 to No. 5 annexed to this report.

In Appendix No. 1 a schematic flow chart is given concerning a multipurpose fruit canning plant for stone fruit (apricots, peaches, plums and deciduous fruits as apples, pears, quinces).

In Appendix No. 2 a schematic flow chart is given concerning a small/medium multipurpose fruit canning plant for sliced fruit (pineapple and mango), fruit juice (pineapple) and fruit coctails (pineapple, paw-paw, banana, melon and orange) to be packed in two different can sizes of 20 oz (sliced fruit and cocktails) and 5½ oz (for juices and nectars).

In Appendix No. 3 a schematic flow chart is presented concerning a small/medium multipurpose fruit canning plant for fruit purees and drinks (banana, mango, soursop, papaya, guava).

In Appendix No. 4 a schematic flow chart is given concerning a small/medium multipurpose section of a plant for citrus fruit and other fruit juice concentrates, (pineapples, apples, pears).

In Appendix No. 5 a schematic flow chart is given concerning a small/medium multipurpose vegetable canning plant (peas, carrots, sweet corn).

Multipurpose Freezing Plants

Multipurpose fruit and vegetable quick-freezing plants may be encountered d principally for vegetables and for combined canning and quick-freezing of fruit juices, concentrates and pulps. The quick-frozen end products may be packed as individual consumer's pack or as institutional packaging for sale and/or utilization in processing of other products in the same plant (regeneration and packing of canned juices and/or nectars from frozen concentrates, processing of fruit juice cocktails etc.).

Small multipurpose quick freezing plants are not frequent in developing countries due to the relatively high cost of these installations and the need to have an organized refrigeration chain all through the production, marketing and consumption of the frozen end products still not available in many places. Freezing, when needed and done by small plants is sometimes carried out in cold storage rooms, below $0^{o}C$, in which the product to be frozen (generally fruit pulps) is kept until further utilization. An example for this case is presented by Appendix No. 19 and the case study given in Chapter VI.

Small/medium multipurpose fruit and vegetable quick freezing plants may operate with different freezing technologies, refrigeration systems and

refrigerants in use. These plants are generally equipped with cold rooms and distribution means for the storage and marketing of the processed frozen products.

Combined small/medium multipurpose processing plants for canning and freezing can be encountered in the fruit juices and pulps processing industry, where fruit juice and/or pulp concentrates are firstly slush frozen and held in bulk (barrels) in low temperature cold storage rooms at $-18^{o}C$ and below, for further utilization in the same canning plants for processing of canned fruit juices, nectars and cocktails after the end of the fruit harvesting season, or for sale to other manufacturers in the country or for export. An example for a combined canning and freezing plant is given by Appendix No. 4.

The multipurposeness characteristics of a canning and quick freezing plant will depend on the raw materials and end products to be processed. In most of these plants multipurpose equipment will be utilized for most unit operations, however certain raw materials may necessitate additional specific equipment, such as ginacas for processing pineapple or viners for peas etc.

An example for a small/medium multipurpose quick freezing plant for vegetable is presented in Appendix No. 6 for the quick freezing of sweet corn, peas, pepper and other vegetable (onion, green beans, brocoli, okra, carrots).

Multipurpose Dehydration PLants

In developing countries the dehydration or drying of vegetables and fruit, including spices, is done on different production scales, as from cottage industries by sun drying up to medium and big plants operating with advanced dehydrating and drying technologies and equipment.

Small dehydrating units are quite common in developing countries, specifically for cottage operations in drying spices, or candied fruit prepared on a small scale with simple processing equipment and often by manual work. The multipurposeness concept relevant to an efficient utilization of the plant's equipment will be less marked in this case due to the low cost of the equipment, and high labour involved.

In medium processing plants for the dehydration of fruit and vegetables the multipurposeness characteristics of the plant are similar to these indicated for the quick-freezing industry. Also in this case the multipurpose sections of the plant will generally correspond to the initial steps of the receiving of raw materials and the last steps of dehydrating, packing and storage. The plant's section related with the preparation of the raw materials for dehydration may require additional specific equipment related to the characteristics of the processed produce.

Multipurpose dehydrating installations are also employed for the recovery of wastes and their transformation into animal feed (citrus or pineapple peels, grapes and apple pomaces, etc.). In small processing operations these by-oroducts are sometimes directly disposed as stockfeed or removed from the plant as waste. In medium processing plants multipurpose dehydrating equipment is generally utilized.

Several examples, presented by schematic processing flow charts, of small/medium multipurpose dehydrating plants are given by the following Appendixes No. 7 to No. 9 of this report.

In Appendix No. 7 a schematic flow chart is given concerning a small/medium multipurpose processing plant for sun dried fruit (apricots, peaches).

In Appendix No. 8 a schematic flow chart is given concerning a small/medium multipurpose vegetable dehydrating plant (potatoes, carrots, onion, leek).

In Appendix No. 9 a schematic flow chart is given for a small/medium multipurpose by-products installation for dehydrated fruit and vegetable processing residues (citrus peels, grapes pomace, pineapple residues).

Multipurpose Preserving Plants

Preserving or fruit juices and pulps by preserving agents and vegetables (cucumbers, peppers, etc.) by salt are often done as a cheap and simple preserving means for the preparation of intermediate products that will be kept until further processing.

Simple multipurpose processing equipment is generally implemented for the preservation of fruit and vegetable products which may consist of parafinated wooden or plastic barrels or plastic lined metal containers or coment lined basins etc. which could be repeatedly utilized for different raw materials and for repeated preserving operations.

The preservation of fruit juices and pulps, or salt preservation of vegetable such as cucumber or peppers for further utilization and processing during more months of the year will also contribute to extend production, with the same equipment, during a wider time interval. The selection of the preserving agents and the preserving technology will depend on the products to be preserved and the legislation prevailing in this respect.

Small/medium multipurpose fruit and vegetable preserving units are often employed in developing countries being operated with simple technology and equipment. An example for preserved concentrated citrus juices is described by the flow chart given in Appendix No. 4. Similar installation may be utilized also for the preservation of fruit pulps as indicated in Appendix No. 11 of this report.

Multipurpose Marmelades, Jams, Syrups and Candied Fruit Plants

In developing countries marmelades, jams, syrups and candied fruit are often processed by small/medium multipurpose fruit processing plants. Small plants generally operate by batch operation and manual work. Middle multipurpose processing plants are more mechanized. In many places it is also done as home or cottage industry, on small scale, with end products distined principally to domestic or the regional markets.

Cooking of marmelades on small production scale can be done with simple direct heating methods and equipment. More advanced plants employ multipurpose double jacketed steam heated cooking pans which enable a better control and better quality products.

In Appendix No. 10 a schematic flow chart is presented concerning a small/medium multipurpose marmelade processing installation based on fresh fruit (strawberries, paw paw, mango, apricots, peaches, plums). The same multipurpose installation can be also implemented for processing marmelades and jellies from frozen or preserved fruit pulps or frozen fruits products

(whole or cut fruit, pulps etc.).

In Appendix No. 11 a schematic flow chart is given concerning a small/medium multipurpose candied fruit processing installation (citrus peels, cumcuate, pears).

In Appendix No. 26 a schematic flow chart is presented concerning a small/medium fruit and tomato processing plant for fruit and tomato juices, concentrate nectars, pulps and marmelades.

Multipurpose Pickling Plants

Pickling of vegetables (cucumbers, tomatoes, eggplants, etc.) in brine by fermentation is generally done in multipurpose holding containers made of plastic or wood that can be repeatedly utilized. It is also performed at different processing scales as from home-made and cottage activities up to large and modern processing plants.

Small plants are generally based on batch and labour intensive operations. In middle plants continuous operations are more frequent in the washing and grading section of the arriving raw materials and after pickling in the filling, bringing deaeration, seaming and sterilizing sections. Multipurpose equipment is employed similar to the equipment used in caning of vegetable and fruit products. Processing of canned pickled vegetables in vinegar can be done with the same multipurpose equipment.

Examples describing two schematic processing flow charts for small/medium multipurpose vegetable pickling plants are presented in Appendix No. 12 and No. 13 as follows:

In Appendix No. 12 a schematic flow chart is given concerning a small/medium multipurpose vegetable processing plant for fermented pickles (cucumbers, green tomatoes, eggplants, turnips etc.), including the possibilities to incorporate in this plant also the processing of pickled vegetable by vinegar and vegetable preservation (cucumbers, pepper etc.) by salt pack.

In Appendix No. 13 a schematic flow chart is presented concerning a small/medium multipurpose vegetable processing plant for pickles in vinegar (cucumbers, pearl onions, baby corn, mixed pickles).

Multipurpose Extraction Plants

In developing countries, fruit and vegetable extraction activities will primarily refer to the following unit operations:

- Extraction of sugar and starch
- Extraction of oils and fats
- Extraction of essential oils
- Extraction of specific products (pectine, papain, citric acid, concentrated vegetable proteins etc.).

In small/medium plants extraction of sugars from fruit juice is generally done up to the stage of sugar syrup mainly employed for further utilization in the same plant. Production of crystalized sugar still remains a product of the sugar industry, extracted from sugar cane and/or sugar beet.

Starch extraction from roots and bulbs (cosava, potatoes, etc.) and fruit products (bread fruit etc.) is carried out in developing countries on a small scale by simple equipment and manual work as well as with modern processing plants. Multipurpose equipment can be utilized for the extraction and processing of starches from different raw materials (corn, potato, cosava, etc.).

Extraction of edible oils from certain fruit (olives, almond, avocado, etc.) is mostly done by the oil industry but also by small/medium oil extraction plants by pressure expelling or extraction by solvents.

The principal essential oils extracted from fruit are the citrus essential oils (orange, lemon, lime, etc.) recovered by multipurpose oil extraction and purification equipment, that form part of the citrus processing plant. Other essential oils from fruit (cardamon, nutmeg, etc.) are extracted in general by steam distillation and further separation by decantation and/or centrifugation or by fractional distillation of the extracted oils.

Multipurpose steam distillation equipment for essential oils is often used in many developing countries in small extraction plants, while the separation by centrifugation, which requires a more expensive and sophisticated equipment, is more practiced by the medium essential oils extraction plants and in the citrus industry.

Refining of extracted crude essential oils by fractional distillation is generally done by multipurpose equipment, utilized for more types of essential oils distilled in the same plant.

Extraction of specific products, such as papain (enzyme) from paw-paw (papaya), or citric acid from lime etc. is done by specific equipment adjusted to each product.

Multipurpose Frying and Toasting Plants

Oil frying of fruit, vegetable and root products (plantain, banana, casava, potatoes, etc.) can be done with different types of frying equipment as from simple frying pans operated on small production scale by batch operation and direct heating to continuous frying equipment with automatic controls of advanced types used in medium and big plants. Frying equipment is generally designed and operated as multipurpose equipment.

Toasting and/or roasting equipment for nuts (almonds, hazelnuts, cashew, nuts, etc.) also operate as multipurpose equipment for different kinds of raw materials. In small toasting units simple directly heated roasters of batch operations types are utilized. In medium plants more advanced roasters, with automatic controls, are more frequent.

In Appendix No. 14 a schematic flow chart is given for a small/medium multipurpose frying plant for sliced potatoes, cassava, banana, plantain.

Coffee roasting is probably the most extended roasting operation carried out with simple roasters as from kitchen utensile up to big automatic controlled roasters employed by the coffee processing industry.

Multipurpose Fermentation Plants

The two principal types of fermentation processes are performed in developing countries being:

- Fermentation of sweet fruit juices to produce cider, wines, wines distillates, alcohol and vinegar.
- Anaerobic fermentation of vegetables and some fruit to produce fermented pickled products.

Wine processing plants from grapes, including wine distillates, alcohol and yeast are common in grapes growing countries. Fermentation of apples into cider is common in apple growing countries.

Wine and wine distillates are also processed from other fruit grown in developing countries (pineapple, cashew apple, mango, etc.). These industries generally process seasonal surpluses of fruit. The processing of fruit wines and other distillates is done in great part by multipurpose equipment installed in the winery or distillary plants.

Processing of vinegar from fruit juices is done in developing countries by small/medium multipurpose installations for the fermentation, clarification, sterilization and bottling of the processed vinegar.

Yeast production is associated in many plants with the alcohol and wine industry.

Processing of pickled vegetable by fermentation has been described above.

Multipurpose Processing Plants of Combined Processing Technologies

Small/medium multipurpose fruit and vegetable processing plants, in which different processing technologies are employed, are quite frequent. Example: a fruit and vegetable complex for canning, freezing and dehydration of residual wastes into animal feed. In these plants the "multipurposeness" characteristics of the plant will refer to the plants installations and activities on whole plant level, and to the unit operations and activities common to the different raw materials and end products processed by the different processing technologies (receiving washing, sorting, sizing, packing, etc.).

IV. MATHEMATICAL AND GRAPHICAL PRESENTATION OF THE MULTIPURPOSENESS CONCEPTS

4.1 General Issues

The multipurpose characteristics of a small/medium fruit and vegetable processing plant may be related to the whole plant, or alternatively to specific sections or parts of the plant. In this chapter the multipurposeness characteristics will refer to the processing equipment of the plant. The evaluation of these concepts is based on the definitions, symbols and units indicated in continuation.

4.2

Symbol	Unit	Definition
j		An index for an arbitrary processing equipment unit.
jm		An index for an arbitrary multipurpose processing equipment.
N		Total number of all processing equipment units installed in the plant.
rj		An index for an arbitrary raw material processed by the plant.
r		An index for an arbitrary processing equipment unit which processes an arbitrary raw material j.
R		Total number of raw materials processed by the plant.
$C_j = \frac{M_j}{H_j}$	tons/hour	The average yearly production capacity of an arbitrary processing equipment unit j concerning all its processed raw materials. (Equation No. 1).

Symbol	Unit	Definition
E	US $	The total cost of all N arbitrary processing equipment units installed in the multipurpose plant. (Equation No. 3)
E_j	US $	The total cost of an arbitrary processing equipment unit j, installed in the multipurpose plant. (Equation No. 3).
E_{jm}	US $	The cost of an arbitrary multipurpose processing equipment unit.
E_m	US $	The total cost of all multipurpose processing equipment installed in the multipurpose plant. (Equation No. 4).
E_r	US $	Total cost of all processing equipment installed in an independent plant (or line) that will process an arbitrary raw material r following the same processing programme defined for the multipurpose plant. (Equation No. 11)
E_{rj}	US $	The cost of an arbitrary processing equipment unit j employed in processing of the arbitrary raw material r.(Equation No. 11).
ER	US $	Total cost of the processing equipment of all R independent plants to be installed for an independent processing of all R raw materials following the same production programme defined for the multipurpose plant. (Equation No. 10)
H_j	hours/year	Total number of yearly working hours of all raw materials processed by the same arbitrary processing equipment unit j. (Equation No. 1)

Symbol	Unit	Definition
$I = \frac{W}{E_m}$		The weighed cost ratio of the multipurpose processing equipment. (Equation no. 8)
$K = \frac{E_m}{E}$		The multipurpose processing equipment cost ratio. (Equation No. 5).
$L = \frac{E}{ER}$		The cost ratio of the processing equipment of a multipurpose plant versus the total cost of the processing equipment of independent plants for the same production programme. (Equation No. 9).
M_j	ton/year	Total yearly effective volume of all raw materials processed by the same arbitrary processing unit j. (Equation No. 1)
$P_j = \frac{C_j}{T_j}$		The yearly average coefficient of utilization of the production capacity of an arbitrary processing equipment unit while processing all R, raw materials. (Equation No. 8).
T_j	tons/year	The nominal production capacity of the arbitrary processing equipment unit j, as indicated by its manufacturers. (Equation No. 2)
W	US $	The weighed cost of all N arbitrary processing equipment units installed in the plant. (Equation No. 7).
W_j	US $	The weighed cost of an arbitrary processing equipment unit j, (Equation No. 6)

4.3 Nominal and Effective Production Capacity

In this report the term "nominal production capacity" T_j of an arbitrary processing equipment unit j, will refer to the production capacity indicated by the manufacturers of the same equipment unit.

The average production capacity C_j of the same arbitrary processing equipment unit will refer to the ratio obtained by the division of the total yearly volume M_j of all products (raw materials, semi-elaborated product and end products) effectively processed by the same equipment unit during the total yearly number of processing hours H_j employed, hence

$$(1) \qquad C_j = \frac{M_j}{H_j}$$

In plant operations the average production capacity will rarely reach the nominal production capacity. A full operational production capacity may be practically evaluated to about 70 to 80% of the nominal production capacity.

The coefficient of utilization of the nominal production capacity P_j of an arbitrary multipurpose processing equipment unit has been defined as the ration obtained by the division of the average production capacity C_j by the nominal production capacity T_j of the same processing equipment unit, hence

$$(2) \qquad P_j = \frac{C_j}{T_j}$$

4.4 The Cost Ratio of the Multipurpose Processing Equipment

The total cost E of all processing equipment units installed in a multipurpose processing plant will be the sum of the costs of all N arbitrary units E_j installed in the same plant, hence

$$(3) \qquad E = \sum_{j=1}^{j=N} E_j$$

And in a similar way the total cost E_m of all multipurpose processing equipment units E_{jm} installed in the same plant will be

$$(4) \qquad E_m = \sum_{j=1}^{j=N} E_{jm}$$

The cost ratio of the multipurpose processing equipment, denominated by the symbol K, has been defined as the ration obtained by the division of E_m by E, hence:

$$(5) \qquad K = \frac{E_m}{E}$$

This ratio represents the "degree" or the share of the cost of the multipurpose equipment in the total cost of the processing equipment installed in the plant. A ratio of K = 0 will mean that all processing equipment units are of simple purpose nature, while when K = 1 all the processing equipment units are of multipurpose utilization. An example for a calculation method for the value of K is given in chapter 5.11 in continuation.

4.5 The Average Weighed Cost Ratio of the Multipurpose Processing Equipment

The "weighed cost of a multipurpose processing equipment unit", denominated by the general symbol W, has been defined in this report as the product obtained by multiplying the cost E_{jm} of the same processing equipment unit by the coefficient of utilization of its nominal production capacity P_j, hence:

$$(6) \qquad W_j = E_{jm} \cdot P_j$$

The weighed cost W_j mey be considered as the portion of the cost E_{jm} of the multipurpose processing equipment unit j, fully utilized in the multipurpose processing operations of the plant.

The "weighed cost of all multipurpose processing equipment nits" of the same plant, denominated by the general symbol W, will be the sum of all individual weighed costs W_j of the installed multipurpose equipment, hence:

$$(7) \qquad W = \sum_{j=1}^{j=N} W_j$$

The weighed Cost W may be considered as the portion of the total cost of the multipurpose processing equipment E_m fully utilized in the plant's processing operations. Examples for the calculation of W_j and W are given in Appendix No. 17-A and in the case studies presented in continuation in chapters VI and VII of this report.

4.6 The Coefficient of Utilization of the Cost of the Multipurpose Processing Equipment

The "coefficient of utilization of the cost of the multipurpose processing equipment", denominated by the symbol I, has been defined in this report by the ration obtained by the division of the weighed cost W by the total cost of the multipurpose equipment E_m, hence:

$$(8) \qquad I = \frac{W}{E_m}$$

The coefficient I may be considered as the portion of the cost of the multipurpose processing equipment of the plant fully utilized in the processing operations.

A value of I = 0.7 to 0.8 (70 to 80%) will mean that the multipurpose equipment is practically fully utilized for its effective production capacity. A lower value of I will mean that for all or part of the multipurpose processing equipment an increase in the effective production capacity is still possible.

A calculation method for the value of I is given in chapter 5.11 in continuation.

4.7 The Cost Ratio of the Processing Equipment of a Multipurpose Plant versus the Total Cost of the Processing Equipment of Independent Plants for the same Production Programme

This co t ratio, denominated in this report by the symbol L, has been defined as the ration obtained by the division of the total cost E of all processing equipment units of a multipurpose plant, as indicated in equation (3) above, by the total cost ER of all processing equipment units installed in R independent processing plant to process the same R

raw materials following the same production programme, hence:

$$(9) \qquad L = \frac{E}{ER}$$

In this case the total cost ER will be equal to the sum of the costs of the processing equipment of all individual independent plants E_r, each for the processing of an arbitrary raw material r, hence:

$$(10) \qquad ER = \sum_{r=1}^{r=R} E_r = \sum_{r=1}^{r=R} \sum_{j=1}^{j=N} E_{rj}$$

as the cost E_r will be equal to the cost of all N arbitrary processing equipment units E_{rj} installed in this plant, hence

$$(11) \qquad E_r = \sum_{j=1}^{j=N} E_{rj}$$

In developing countries the definition of the value of L could be of interest in the comparison of the alternatives for establishment of different smaller processing plants in different locations or the centralization of the same production programme in one multipurpose plant, hence principally in the comparison of centralized and dis-centralized operations.

4.8 Calculation of the Multipurposeness Characteristics (Example)

In Appendixes 17-A and 17-B schematic tables are given as an example for the calculation of the characteristics of a multipurpose processing plant, as follows:

In column 1 of Appendix No. 17-A all N arbitrary processing equipment units j installed in the plant are listed.

In column 2 of Appendix No. 17-A a description of each of the j processing equipment units of the plant is respectively indicated.

In column 3 of Appendix No. 17-A the cost E_j of each of the installed equipment units is indicated (presented as $E_1, E_2, E_3, E_4 \ldots E_j \ldots E_N$).

The same costs are respectively presented in columns 4,5 and 6 for the equipment utilized in processing the raw material A (column 4), the raw material B (column 5) and the raw material C (column 6). In this way column 3 will represent the cost of all processing equipment units installed in the plant while columns 4,5 and 6 will represent the cost of all processing equipment units engaged in processing of raw materials A, B, and C respectively.

In column 7 of Appendix No. 17-A the cost E_{jm} of the processing equipment units utilized in the plant's multipurpose processing operations (processing of raw materials A and B, or A and C, or B and C or A, B and C) is indicated.

The total cost E of all installed processing equipment units in the plant will therefore be:

$$(3) \qquad E = \sum_{j=1}^{j=N} E_j$$

The total cost EA of all processing equipment units utilized for the processing raw material A, will be:

$$(12) \qquad EA = \sum_{j=1}^{j=N} EA_j$$

The total cost EB of all processing equipment units utilized for processing raw material B, will be:

$$(13) \qquad EB = \sum_{j=1}^{j=N} EB_j$$

The total cost EC of all processing equipment units utilized for processing raw material C, will be:

$$(14) \qquad EC = \sum_{j=1}^{j=N} EC_j$$

and the total cost of all multipurpose processing equipment units, implemented in the multipurpose processing operations will be:

$$(4) \qquad E_m = \sum_{j=1}^{j=N} E_{jm}$$

From this table the following multipurposeness characteristics can be calculated:

a. The multipurpose equipment cost ratio K

$$(5) \qquad K = \frac{E_m}{E} \quad ; \quad \text{and}$$

b. The cost ratio of the processing equipment of a multipurpose plant versus the total cost of the processing equipment of independent plants for the same production programme L

$$(15) \qquad L = \frac{E}{EA + EB + EC}$$

In column 1 and 2 of Appendix No. 17-B the same data of the respective columns 1 and 2 of Appendix No. 17-A are reported, being however limited only to the multipurpose processing equipment units.

In column 7 of Appendix No. 17-B the same processing equipment units j indicated in column 7 of Appendix No. 17-A are reported.

In columns 8 and 9 of Appendix No. 17-B the values of the yearly total production volume M_j and the yearly number of processing hours H_j for each of the multipurpose processing equipment units j indicated in column 7 are respectively indicated.

In column 10 of Appendix No. 17-B, the calculated production capacity rations C_j, following equation (1), are given for each of the multipurpose processing equipment units j_m.

In column 11 of Appendix No. 17-B, the nominal production capacity T_j is reported for each of the multipurpose processing equipment units.

In column 12 the respective values of the weighed costs, calculated following equation (6), for each of the multipurpose processing equipment units j, are reported.

From Appendix No. 17-B the following multipurposeness characteristics can be deducted.

a. The weighed cost of all multipurpose processing equipment units W:

$$(7) \qquad W = \sum_{j=1}^{J=N} W_j \quad ; \quad \text{and}$$

b. The Coefficient of Utilization of the cost of the multipurpose processing equipment I :

$$(8) \qquad I = \frac{W}{E_m}$$

4.9 Graphical Presentation of the Multipurposeness Concepts

In continuation to the example given in Appendixes 17-A and 17-B, a schematic graphical presentation concerning the characteristics of a multipurpose processing plant which processes there different raw materials A, B and C is given by Appendix No. 18, as follows:

In Appendix 18 the cost of the processing equipment related to an independent processing of each of the raw materials A, B and C is represented by the area of a different circle. These circles are crossing each other giving area common to different circles which schematically represent the cost of the multipurpose equipment. In this schematic figure:

The area EA = $E_1 + E_2 + E_3 + E_4$, will schematically represent the total cost of the processing equipment units employed in processing raw material A. (corresponds to column 4 of Appendix 17-A).

The area EB = $E_3 + E_4 + E_5 + E_6$, will schematically represent the total cost of the processing equipment units employed in processing raw material B (corresponds to column 5 of Appendix 17-A0.

The area EC = $E_2 + E_3 + E_5 + E_7$, will schematically represent the total cost of the processing eauipment units employed in processing raw material C. (corresponding to column 6 of Appendix 17-A).

The area E = $E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$, will schematically represent the total cost of all processing equipment units installed in the plant. (corresponding to column 3 of Appendix No. 17-A).

The area $E_m = E_2 + E_3 + E_4 + E_5$, will schematically represent the total cost of the processing equipment units utilized in the multipurpose processing operations of the plant (corresponding to column 7 of Appendix No. 17-A).

From Appendix No. 18 it can be also seen that:

The area E_1, will schematically represent the cost of the single purpose equipment utilized in processing only the raw material A.

The area $E_2 + E_3$, will schematically represent the cost of the multipurpose processing equipment utilized in processing the raw materials A and C.

The area $E_3 + E_4$, will schematically represent the cost of the multipurpose processing equipment utilized in processing the raw materials A and B.

The area $E_3 + E_5$, will schematically represent the cost of the multipurpose processing equipment utilized in processing the raw materials B and C.

The area E_3 is common to all three raw materials.

The area E_6 represents the cost of the single purpose equipment utilized for processing only raw material B and the area E_7 will represent the

cost of the single purpose equipment utilized for the processing only the raw material C.

From Appendix No. 18 it can be ssen that:

a. The multipurpose processing equipment cost ratio K, will be represented by the following ratio:

$$(5) \qquad K = \frac{E_m}{E} = \frac{E_2 + E_3 + E_4 + E_5}{E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7}$$

b. The cost ratio of the processing equipment of a multipurpose plant versus the total cost of the processing equipment of independent plants for the same production programme L, will be represented by the following ratio.

$$(15) \qquad L = \frac{E}{EA + EB + EC}$$

4.10 Application Aspects

The above indicated concepts and equations represent the interdependency of the principal factors related with the "multipurposeness" concept applied to fruit and vegetable processing plants. These concepts and their respective equations may be useful for the decision making process concerning the selection of the appropriate equipment and production programme for a multipurpose plant.

In the application of the multipurpose concept and the above equations attention should be paid to the practical meaning of the equations and the field of action to which they refer within the context of the project's feasibility study. As indicated above the application of the multipurposeness concept can take place on the level of a single equipment unit, or by sections of the plant. For a more accurate evaluation the pros and contras concerning the utilization of the multipurpose equipment should be examined along the whole life time of the project, by the calculation of the respective present values, as part of the financial analysis of the project's feasibility study.

V. PLANNING ISSUES

In this chapter a brief review concerning some of the planning factors and issues relative to the establishment of small/medium multipurpose fruit and vegetable processing plants is given in continuation.

5.1 Planning Methods and Procedures

The planning methods usually utilized in the establishment of small/medium multipurpose fruit and vegetable processing plants in developing countries are based on the same concepts and conducted by the same methods currently implemented for all other agroindustrial projects. Also in this case an examination of the existing alternatives for the accomplishment of the project target is done, generally by a comparative pre-feasibility or feasibility study, and on the basis of the obtained results the most appropriate alternative is evaluated and selected.

5.2 Identification of Tentative Alterntives for the Production Programme

In the schematic flow chart of Appendix No. 15 the principal planning steps and sequence of operations are indicated concerning the identification of tentative production programme alternatives to be considered in the establishment of a small/medium multipurpose fruit and vegetable processing plant. These steps will comprise:

Existing and Potential Raw Materials

The existing raw materials are those already available for processing. Potential raw materials are those that could be developed and employed for processing in the future. These may include the possible increase in production of the existing raw materials as well as new raw materials that could be incorporated in the processing programme of the multipurpose processing plant.

Considering the project's background a tentative list of the existing and potential raw materials could be prepared (Step 1 of Appendix No. 15).

All data of interest concerning the existing (available) raw materials will be summarized and classified (Step 2 of Appendix No. 15), such as:

production location, volume and season, yearly division of the production and peak production volume and season, quality characteristics and adaptability for processing, price, organization and cost of their supply as well as other issues of interest.

In parallel the possibilities to extend or diversify the production of the existing materials will be done (Step 3 of Appendix No. 15) indicating the respective prerequisites and execution time table. For all identified potential raw materials all data indicated for the existing raw materials (Step 2 of Appendix No. 15) will be summed up and presented.

As a result of Step 2 and Step 3 a global inventary of the available and potential raw materials will be summarized (Step 4 of Appendix No. 15) including their characteristics and all other relevant data relative to their present and future processing. These raw materials will be classified following their harvesting possibilities and peak harvesting time. For overlapping crops the keeping quality and storage possibilities will be indicated. Distinction will be also made between permanent cultures (trees, bushes etc.) that may give a more stable source of raw materials supply compared with vegetables (or fruit) cultivated on yearly basis. These issues will be also considered in relationship to the possibilities to increase the production volumes, diversification of the production and the yearly fluctuations in the production volume to be expected.

End Products, Intermediate Products and By-Products of Interest

For each of the identified raw materials, as per Step 4, all processed products of commercial interest, including end products, intermediated products and by-products will be indicated and classified (Step 5 of Appendix No. 15) following their characteristics (juice, pulp, solid pack, etc.) and processing technology (canning, freezing, dehydrating etc.).

A preliminary selection can be done at this stage in relation to the types of processed products common to more raw materials and for those of apparent better chances for marketing in the domestic markets and

inter-regional markets, and possibly also for export to extra regional markets.

Apparent Marketing Possibilities

For each of the processed products of commercial interest identified by Step 5, a preliminary marketing survey (study) should take place (Step 6 of Appendix No. 15) in order to evaluate their apparent marketing possibilities and the issues to be considered with reference to the domestic markets, inter-regional export markets, and the extra-regional export markets. This survey should cover the following subjects:

- Existing demand (volume, value and price in the principal markets of interest).
- Characteristics (quality, packaging etc.) of the marketed products to which the processing operations should be focused.
- Existing offers and principal suppliers (or competitors) for the above indicated demand in the different markets (volume, value, price etc.).

The apparently marketable products, including end products, intermediate products and by-products, identified by the above indicated marketing survey will be classified and grouped (Step 7 of Appendix No. 15) following their characteristics and processing technology in the same way as indicated in Step 5.

While considering the marketing possibilities attention should be paid to the fact that fruit and vegetable products processed by small/medium processing plants are generally directed to the domestic markets and the inter-regional export markets. The export of fruit and vegetable products to extra-regional markets is more frequent with medium/big plants.

With processed fruit and vegetable products destined to replace similar imported goods, quality standards should be competitive. If competitive by price these products may become potential export products.

Selection of Appropriate Alternatives for the Production Programme

On the basis of the global inventory of the existing and potential raw materials identified and classified following Step 4, and the identified list of processed products of commercial interest identified and classified following Step 5, and the identified marketing possibilities for the end products, intermediate products and by-products that could be processed and marketed following Steps 6 and 7, the most appropriate fruit and vegetables and their processed products to be considered for the multipurpose plant can be defined (Step 8 of Appendix No. 15).

Other pros and contras factors and issued related with the above selection should be also evaluated, weighed and indicated such as the importance to farmers and rural economy, employment creation, generation of foreign currency through exports, development of technological level etc.

In the above indicated selection a division into "principal" and "complementary" raw materials and processed products can be also done.

5.3 Selection of the Appropriate Processing Technology and Equipment

In the schematic flow chart of Appendix No. 16 the principal planning steps and sequence of operations are presented concerning the identification of alternatives for the selection of appropriate processing technology and equipment to be included in the terms of reference of the feasibility study concerning the establishment of a small/medium multipurpose fruit and vegetable processing plant. This chart follows the previous chart of Appendix No. 15 and will comprise the following steps.

Step No. 1 of this chart corresponds to Step 8 of Appendix No. 15, hence the identified alternatives for the most appropriate raw materials and processed end products to be included in the production programme for the planned small/medium multipurpose fruit and vegetable processing plant.

For each of the raw materials and processed products identified by Step 1, a flow chart for the respective processing operations will be prepared. (Step 2 of Appendix No. 16) including (1) materials balance and movement; (2) need in auxiliary products (packaging, chemicals, etc.); and (3) the need in utilities (electricity, steam, etc.); (4) need in direct labour.

The data of Step 2 could be registered and compared (Step 3 of Appendix No. 16) for all raw materials, processed products and unit operation and classified in relationship to the processing time and peak seasons.

The registered and compared data will be analysed (Step 4 of Appendix No. 16) for the definition of those unit operations common to different raw materials that could be processed by the same type of equipment (multipurpose equipment).

In a similar way the specific equipment of single purpose nature, will be also registered (Step 5 of Appendix No. 16), including its respective characteristics.

For the multipurpose equipment identified by Step 4, the characterisitcs and specification of each of the processing equipment units will be defined (Step 6 of Appendix No. 16), to suit all processed raw materials or products carried out by the same equipment unit. This specification will later serve for obtaining suppliers offers for this equipment.

For all single purpose equipment unit, identified by Step 5, the same procedure of defining the equipment specification will be repeated (Step 7 of Appendix No. 16).

For all identified multipurpose and single purpose equipment units, and considering their respective specifications, tenders for supply will be issued to the different potential suppliers (Step 8 of Appendix No. 16).

The offers for the different supply alternatives will be examined and compared (Step of Appendix No. 17).

On the basis of the above indicated comparison and evaluation the appropriate alternative(s) will be defined (Step 10 of Appendix No. 16) for the equipment and processing technology to be examined by the project's feasibility study.

As a result of the above indicated procedure the terms of reference and work plan for the preparation of the feasibility study for the respective small/medium multipurpose fruit and vegetable processing plant, will be prepared (Step 11 of Appendix No. 16).

5.4 Direct and Indirect Labour, Management and Administration Personnel

In small and medium multipurpose fruit and vegetable processing plants a higher flexibility in the employment of seasonal labour will be needed when shifting from one processing operarion to another one. On the other hand, extension of the plant operations during more months of the year will contribute to the stability in the employment of the seasonal personnel. The versatility in the processing duties will require a higher degree of training of the respective staff and will also oblige to maintain a nucleus of trained personnel that will be able to train the newly employed seasonal workers.

A better stability in the employment of seasonal labour may be also attained by processing seasonal surpluses into intermediate products that will be stored for later processing after the peak harvesting season.

Management and administration issues concerning the personnel employed on yearly basis, form part of the multipurposeness aspects on whole plant level, as indicated in chapters 2.6 and 3.3 of this report and in the division of raw materials and end products into "principal" and "complementary" groups.

5.5 Plant Location

The factors and issues involved with the selection of the location for a small/medium multipurpose fruit and vegetable processing plant, such as the location and volume of the available or potential raw materials, availability of labour force, availability of electricity, water supply and communication means, etc., may be considered on similar lines as done in planning other agroindustrial projects in developing countries.

5.6 Plant Design

With plants designed for batch operations the equipment will be installed in accordance with the material flow while keeping enough space for intermediate holding amd maneuvering between the different equipment units.

With plants designed for continuous operations the processing lines are generally composed of independent sections of continuous operations

linked by an intermediate free space left for intermediate holding and/or handling of processed products from one continuous section to the following one.

For equipment that should be totally or partially interchanged during the processing operations, when passing from one processed product to another one (change of screens or cutters, or replacement of a filter by a centrifuge, etc.) enough empty space and/or adequate handling facilities should be provided for a rapid and easy interchange of the respective equipment. In these cases the electric power main lines and main water and steam distribution lines may be placed below ceiling level with coming down connections for an easy linkage to the individual interchangeable machines.

For small/medium multipurpose fruit and vegetable processing plants that will be progressively developed and installed during more years, the plant design should be prepared for the full production targets. The effective purchase and installment of the multipurpose and other processing equipment could be progressively done in accordance with the increase of the production programme.

Other design issues concerning the characteristics of the site, internal roads, building and structures and the multipurpose installations and services on whole plant level (supply of electricity, water, fuels, steam, compressed air, draining and waste disposal, fire fighting equipment, ambient protection, repair and maintenance workshops, materials handling installations and services for the employed personnel, production and quality control etc.), will be carried out on the same lines as done in other plants for processing fruit and vegetable, and as indicated in the previous chapter 3.6.

5.7 Equipment Supply and Suppliers

Processing equipment for small/medium multipurpose fruit and vegetable processing plants are fabricated in many countries and can be obtained as single equipment units for specific duties or as "turn key" complete plants or processing lines.

In developing countries it is highly recommended to specify the solicitated equipment on the basis of the expected performance for each of the raw

materials, intermediate products and end products to be processed by the same plant. In addition to obtain a full description of the characteristics of the equipment that will be supplied comprising:

- Drawings and sections (prospect).
- Nominal and effective production capacities (with an indication of the respective operation conditions).
- Need for utilities: Electricity, water, steam, compressed air, etc.
- Manpower requirements to operate the machine(s).
- Price and delivery time.
- Performance adaptability to carry out the solicitated multipurpose processing operations.
- Weight and shipment volume.
- Materials of construction and corrosion resistency.
- Type and site of installed motors, electrical connections, controls and cut-out devices.
- Need for spare parts.
- Cleaning easiness when shifting from one product to another and at the end of the working shift or day.
- Suppliers guarantee.

Many of the equipment suppliers employ their own questionnaire delivered to the buyer for fulfilment, before presenting their offers.

Standardization in the types of the employed multipurpose equipment will reduce the cost of spare parts and also will simplify its maintenance.

The degree of mechanization and the production control system and devices will be defined by weighing the outcoming benefits by a higher mechanization and automation levels, versus the additional cost of the installed equipment and cost of operation.

The preparation and the evaluation of the solicited and offered equipment should be preferably prepared by a qualified specialist. The relevant procedures are similar to those utilized in general in the establishement of agroindustrial projects.

The cost of the plant may vary according to the type and origin of the selected equipment and the respective degree of mechanization and automation.

5.8 Project Document and Terms of Reference (see VIII References)

On the basis of the identified data, as indicated above the "Project Document" (1) and the "Terms of Reference" for the preparation of the needed feasibility study can be prepared.

The feasibility study itself could be done following UNIDO (2) or other available guides (3) for the prepration of similar feasibility studies.

In this report it has been assumed that all data relative and needed for the preparation of the feasibility study for the selection of the most appropriate multipurpose alternative have been investigated and defined.

5.9 Evaluation Aspects

The preparation and evaluation of feasibility studies and/or projects' profiles of small/medium multipurpose fruit and vegetable processing plants may be done along the same lines and by the same general methodologies carried out for other agroindustrial development projects. For this evaluation the project's objectives, evaluation criteria and the weight assigned to each of the outcoming results should be defined and indicated.

In the examination of existing alternatives and the justification for the selection of the most appropriate alternative, a full and quantified indication should be presented concerning the contribution of the multipurposeness concept to the project's outcoming results as well as the pros and contras related with it.

VI. MULTIPURPOSE PLANT FOR PROCESSING OF PAW-PAW AND MANGO PULPS - CASE STUDY (7)

A case study is hereby given, based on a prefeasibility study prepared by UNIDO, concerning the establishment of a small multipurpose processing plant for tropical fruit pulps (paw paw and mango), presented as an example for the calculation of the multipurposeness characteristics of the plant.

6.1 Background and Scope

Paw paw and mango are typical cultures of the project's area with fresh fruit sold for direct consumption and for processing by local fruit processing plants, principally for canning of fruit juices, nectars, marmelades and jellies.

In handling and marketing of the fresh fruit farmers have suffered big losses due to lack of coordination between harvesting and marketing, and because of the poor handling in post harvest and transporting to local markets. By this project farmers principal aim was to secure the outlet of their cultivated fruit, avoiding losses by dammaged fruit, hence to secure an increased income with less possible investments costs, due to their financial limitations.

6.2 Selection of Raw Materials, End Products and Processing Technology

Paw-paw and mango have been selected as principal initial raw materials to be processed by the plant. However, other fruits could be also processed by the same equipment in the future.

In the selection of the processing technology the following alternatives have been examined:

- Processing of canned (sterilized) pulp packed in No. 10 and No. 12 cans.
- Processing of aseptically canned pulp packed in 200 litres barrels.
- Processing of quick frozen pasteurized pulp in 200 litres barrels.
- Processing of pasteurized, cooled and/or frozen pulp packed in carton (fiber container) of 65 litres each.

The first processing alternative has been rejected because of the high cost of packing materials involved.

The second and third alternatives have been rejected because of the high cost of investments in machinery and equipment involved.

The last alternative appeared to be the most adequate due to the relative low cost of the needed investments and packing materials. Its disadvantage remain with the shorter keeping quality time of the end products, which will oblige to coordinate production and marketing within a predetermined time interval (keeping quality time).

6.3 Process Description

A schematic flow chart of the plant's processing operations is given by Appendix No.19. A summarized description of these operations is presented as follows:

Receiving:

The fresh fruit, paw-paw and mango, will be delivered in field boxes from the orchard to the plant. The delivered fresh fruit will be checked for weight and quality, unloaded and stored in the holding area, nearby the processing place.

Washing:

The fresh fruit destined for processing will be dumped in a washing basin in which the washing water will be continuously replaced. From there it will be lifted by an inclined scale elevator, rinsed and sorted for the removal of damaged fruit.

Cutting:

The washed, rinsed and sorted fruit will be passed over to the cutting conveyor belt. On both sides of this conveyor workers will be standing who will peel the fruit, trim the damaged and non adequate parts for processing, cut and remove seeds (paw-paw). The cleaned fruit will be placed on an upper conveyor belt that will lead the fruit to the blancher, while the peels, seeds and the remained parts will be collected and removed to the waste bin.

Blanching:

The blancher will consist of a stainless steel screw conveyor, about 3 m. long, steam heated, the outcoming product will reach a temperature of about 60°C.

Pulping:

The blanched fruit will be passed from the blancher to a stainless steel pulper which will consist of a perforated sieve cylinder with revolving wings which force the pulp through the cylinder wall sieve, while the coarse parts will be removed at the end of the cylinder.

Finisher:

The outcoming pulp from the pulper will be passed to a stainless steel finisher by which the pulp will be screened to the desired screen mesh. The refined pulp will be passed to a stainless steel intermediate holding rank, while the course parts will be removed.

Pasteurization:

From the intermediate holding tank the refined pulp will be pumped by a stainless steel sanitary pump to a stainless steel shell and tube pasteurizer by which it is heated to a temperature of 90°C.

Cooling:

From the pasteurizer the hot pasteurized pulp will continue to a stainless steel, shell and tube cooler, cooled with circulating water, by which it is cooled to a temperature of about 25 to 28°C.

Storage Tank and Filling Valve:

The cooled pulp will pass to a second intermediate storage tank equipped with a filling valve by which the pulp will be filled into fiber carton barrels (fiber containers) of 65 lbs each that will be placed on a balance for checking the filled weight.

Cooling, Freezing:

The filled carton containers are placed in air blast cooling-freezing rooms for precooling and subsequent freezing and storage. This room will be made out of an insulated trailer that will be equipped with a 30 HP refrigeration unit for the needed cooling freezing and storage duties.

From this trailer the product will be taken for delivery to the buyers.

Most of the plant's operations are of a continuous type. A time interval of about 30 minutes will be needed to process the fruit as from the receiving phase until the placing of the pulp into the cooling - freezing trailer.

6.4 Production Programme and Capacity

The monthly production programme, expressed in tons, for the raw materials, the end products, the number of shifts per day, and the number of working days per month is given in Appendix No. 20. This plan is based on the average processing of 2 metric tons of fresh fruit per shift of 8 hours work and 25 working days per month. This will mean an average production capacity of 250 kgs of fruit per hour or 50 tons per monthly shift.

The yield in paw-paw pulp has been estimated at 70% the fresh fruit, while the yield in mango pulp has been considered at 50% of the processed fruit.

The production capacity of the plant has been adjusted to the production plan considering a certain reserve in the production capacity for future increase in the present production programme.

6.5 Cost of the Project

The cost of the project and the nominal production capacity of the equipment are presented by Appendix No. 21. These costs refer to the year 1979 in which the study has been performed. Production capacities of the equipment have been estimated.

6.6 Calculation of the Multipurposeness Characteristics of the Plant

In this plant all processing equipment units will be employed for processing both raw materials, hence all equipment unit purpose nature.

From the data of Appendixes 20 and 21 the respective values of E_{jm}, P_{jm} W_{jm}, W, E_m, K and I have been calculated and presented by Appendix No. 22 as follows:

Column 1 of Appendix No. 22 lists the arbitrary equipment units j as given in Appendix No. 21.

Column 2 of Appendix No. 22 refers to the description of the processing equipment units j.

Column 3 of Appendix No. 22 represents the cost E_j of each of the above indicated processing equipment unit j as given in Appendix No. 21.

Column 4 of Appendix No. 22 represents the average coefficient of utilization of the nominal production capacity P_j of the multipurpose equipment units (Equation 2).

Column 5 of Appendix No. 22, represents the weighed cost $W_j = P_j E_{jm}$ of the multipurpose equipment, (Equation No. 6).

The sum of all values of E_j of column 3 of Appendix No. 22 will represent the total cost of the processing equipment E of the plant, (Equation No. 3), being equal to US $ 33,770.00.

The sum of all values of W_j of column 5 of Appendix No. 22 will represent the weighed cost W of all multipurpose processing equipment units of the plant, (Equation No. 7), being equal to US $ 15,016.00.

In this plant all the equipment is of a multipurpose application, therefore the value of E_m, representing the total cost of the multipurpose equipment (Equation No. 4) is equal to the value E given above. From this fact it will also result that the multipurpose equipment cost ratio $K = E_m : E$ (Equation No. 5) will become equal to 1.0.

The coefficient of utilization of the cost of the multipurpose equipment I (Equation No. 8) will therefore be

$$(8) \qquad I = \frac{W}{E_m} = \frac{15,016}{33,770} = 0.4446$$

Hence the average utilization of the nominal production capacity of the multipurpose equipment will amount to 44.46%.

Assuming that the effective production capacity will be 70% of the nominal production capacity. It will therefore result that the average utilization of the effective production capacity of the multipurpose equipment will be:

$$\frac{44.46}{70.0} = 0.6351 \qquad \text{hence,} \qquad 63.51\%$$

This figure could be of interest in the evaluation of the possibilities to increase the production volume of the plant with the same multipurpose equipment.

In this case study the multipurposeness characteristics have been calculated, for simplicity, only for the processing equipment itself. In a similar way it can be calculated also for other investment sections of the plant (other equipment, constructions, etc.), and/ or for the whole plant, based on the data of Appendix No. 21.

In this case study all the equipment under consideration is of multipurpose utilization therefore

$$K = 1.0 \quad ; \quad \text{and}$$

$$L = 0.5$$

6.7 Inputs Requirements

Some of the principal inputs needed for the yearly processing of 600 tons of paw-paw and 300 tons of mango into 420 tons of paw-paw pulp and 150 tons of mango pulp, indicated in the feasibility study, are presented in continuation as general information to the reader. However these data do not directly interfere with the above indicated calculations of the multipurposeness characteristics I, K and L indicated above. These

inputs comprise:

Raw materials

Paw-paw	600 tons
Mango	300 tons

End products

Paw-paw pulp	420 tons
Mango pulp	150 tons

Packing materials

Fiber carton barrels of 65 lbs each - about	19300 units

Electricity

Yearly need for electrical energy has been estimated to	165,000 KWH

Water

Water consumption has been estimated to be about 3000 m^3 per year, corresponding to and average of about 10 m^3 per day. This will comprise the steam boiler all processing operations and the plant's personnel.

Man power

Management and production control	8 persons
Direct production per shift	10 persons

VII. MULTIPURPOSE EQUIPMENT FOR PROCESSING CONCENTRATED PINEAPPLE AND PASSION FRUIT JUICES AND MANGO OR OTHER TROPICAL FRUIT PULPS

Case Study

This case study will refer to the definition of the multipurposeness characteristics of the processing equipment of a small/medium multipurpose tropical fruit processing line for concentrated juices, pineapple and passion fruit and for mango or other tropical fruit (guava, paw-paw) pulps. The study is based on information supplied by Bertuzzi (23), deliberately elaborated accordingly.

7.1 Process Description

A schematic flow chart of the multipurpose line operations is given by Appendix No. 23 as follows:

Receiving

The fresh fruit, pineapple, passion fruit, mango, or other tropical fruit, will be delivered to the plant in field boxes. The arriving fruit will be checked for weight and quality, unloaded and stawed in the holding area nearly the processing line.

Working

The fruit destined for processing will be dumped into a washing basin in which it will be washed by water that will be continuously replaced. From the washing basin the fruit will be elevated by an inclined scale elevator, rinsed and sorted for the removal of damaged fruit unfit for processing.

Distribution Conveyor

After elevation and sorting, the fruit destined for processing will be passed onto a distribution conveyor that will direct the fruit, according to type, to its proper preparation equipment.

Extraction and Defining of Pineapple Juice

The pineapple destined for processing will be passed by the distribution conveyor to the pineapple juice extractor (Bertuzzi-Pinetronic 15) that will extract the juice. The extracted juice will be passed through a helicoidal extractor for finishing and removal of the coarse parts. After finishing the juice will be passed to an intermediate storage tank and later pumped to a multipurpose mixing tank for blending, before deaerating.

Extraction and Refining of Passion Fruit Juice

The passion fruit destined for processing will be passed by the distribution conveyor to a passion fruit juice extractor (Bertuzzi - Passypress 250) that will extract the juice and after finishing will pass it to the same intermediate holding tank employed during the pineapple processing season to store the pineapple juice. From this tank the juice will be pumped to the multipurpose mixing tanks, the same employed for pineapple juice, for blending and holding before deaerating.

Processing of Mango Pulp

The mango destined for processing will be passed by the distribution conveyor to the mango destoner and pulper (Bertuzzi - Supercreamer) by which mango pulp will be obtained. This pulp will be passed through a continuous cooker (Bertuzzi - Model Thermobreak 1500). The hot pulp will then pass through a pulper refiner (Bertuzzi - Model Creamer) for final finishing. The finished pulp will pass to an intermediate holding tank from which it will be pumped to the multipurpose mixing tanks, the same employed for the pineapple and passion fruit juices, for blending and storage before deaerating.

Treatment Line

The pineapple, passion fruit and mango pulp will be treated by the same multipurpose equipment, each during its different processing season. These treatments will comprise:

Deaerating, that will be done under vacuum (Bertuzzi - Deaerator Model C 600); and

Pasteurizing, that will be done by a combined pasteurizing and cooling group (Bertuzzi - Pasteurizer Model PS 10).

After pasteurizing the pineapple and passion fruit juices will be passed for further concentration and later packing (canning or freezing), while the mango pulp will be directly passed to the filling and packing station (canning or other preserving process).

Concentration of Pineapple and Passion Fruit Juices

The hot pasteurized juices will be passed to an intermediary holding tank, before being pumped into the evaporator, by which concentration will take place to the desired concentration degree. After concentration the concentrated product will be passed to a holding tank from which it is passed to the filling station.

Final Filling and/or Processing

The multipurposeness considerations of this case study is terminated by the receiving of the concentrated juices of pineapple and passion fruit as well as the mango pulp. The study will not refer to the following processing operations such as filling containers, seaming, or aseptic canning or freezing, etc.

7.2 Production Programme and Capacity

Processing of pineapple, passion fruit and mango is assumed to take place during different seasons of the year as per the following production programme and average capacity.

Fruit	Yearly production (tons)	Working hours per year (hours)	Average production capacity (tons/hr)
Pineapple	1,200	800	1.5
Passion fruit	360	600	0.6
Mango	720	600	1.2
Total	2,280	2,000	

7.3 Cost of the Installed Equipment

The cost of the equipment is given in Appendix No. 24, as follows:

- In column (1) the description of the installed equipment is indicated.
- In column (2), the cost (E_j) of each unit (or line) of the respective equipment is given (in US $).
- In column (3), the cost $(EA)_j$ of each unit (or line) of the equipment utilized in processing concentrated pineapple juice, is given (in US $).
- In column (4), the cost $(EB)_j$ of each unit (or line) of the equipment utilized in processing concentrated passion fruit juice, is indicated (in US $).
- In column (5), the cost $(EC)_j$ of each unit (or line) of the equipment utilized in processing mango pulp, is indicated (in US $).

From Appendix No. 24, two economic ratios can be deducted.

a. The multipurpose equipment cost ratio (K), where

$$K = \frac{E_m}{E} = \frac{207,000}{280,000} = 0,7312$$

Which means that 73.92% of the cost of the equipment is utilized as multipurpose equipment, and

b. The cost ratio of the multipurpose plant versus the total cost of independent plant for the same production programme (L), where

$$L = \frac{E}{EA + EB + EC} = \frac{280,000}{237,000 + 292,000 + 165,000} =$$

$$= \frac{280,000}{634,000} = 0.4416$$

Which means the cost of the multipurpose line represents 44.16% of the cost of independent processing lines for the same production programme,

or alternatively the cost of establishing indepdendent processing lines will be 2.26 times higher compared with the multipurpose line.

7.4 The Production Capacities and the Calculation of the Coefficient of Utilization of the Cost of the Multipurpose Equipment (I)

The calculation of the coefficient of utilization of the cost of the multipurpose equipment (I) is summarized by Appendix No. 25, as follows:

- In column (1) of this Appendix the description of the installed equipment is indicated.
- In column (2) the nominal production capacity T_j of each equipment unit (or line) is given.
- In column (3) the yearly production volume of all raw materials processed by each equipment unit (or line) M_j, is given.
- In column (4), the total yearly number of working hours of each equipment unit (or line) H_j is indicated.
- In column (5), the average production capacity, $C_j = M_j/H_j$, of each equipment unit (or line), is calculated.
- In column (6), the yearly average coefficient of utilization of the production capacity, $P_j = C_j/T_j$, has been calculated
- In column (7) the cost E_{jm} of each unit (or line) of the multipurpose equipment of the plant, is given.
- In column (8) the weighed cost of each of the multipurpose equipment unit (or line), $W_j = P_j\ E_{jm}$, has been calculated.

From Appendix No. 25, the value of the coefficient of utilization of the cost of the multipurpose equipment I can be deducted as follows.

$$I = \frac{W}{E_m} = \frac{88,850}{207,000} = 0.4292$$

which means that the average coefficient of utilization of the multipurpose equipment is about 42.92% of its total cost.

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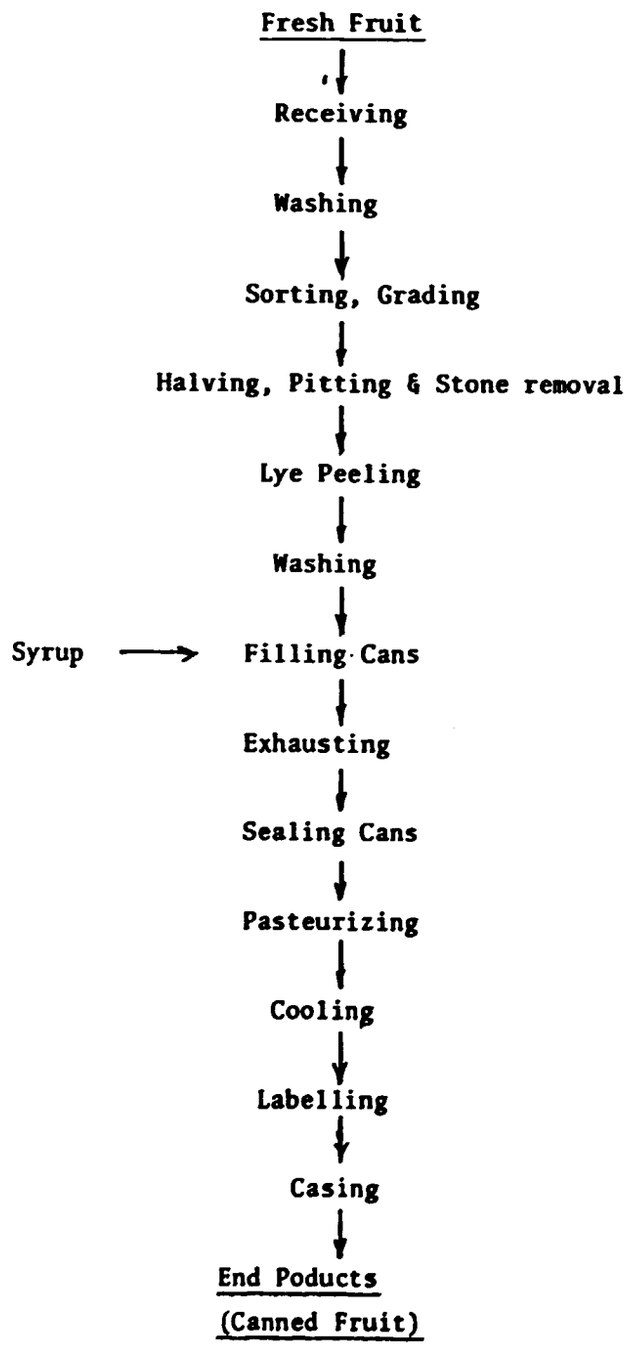
IX. APPENDIXES

Appendixes No. 1 to No. 25

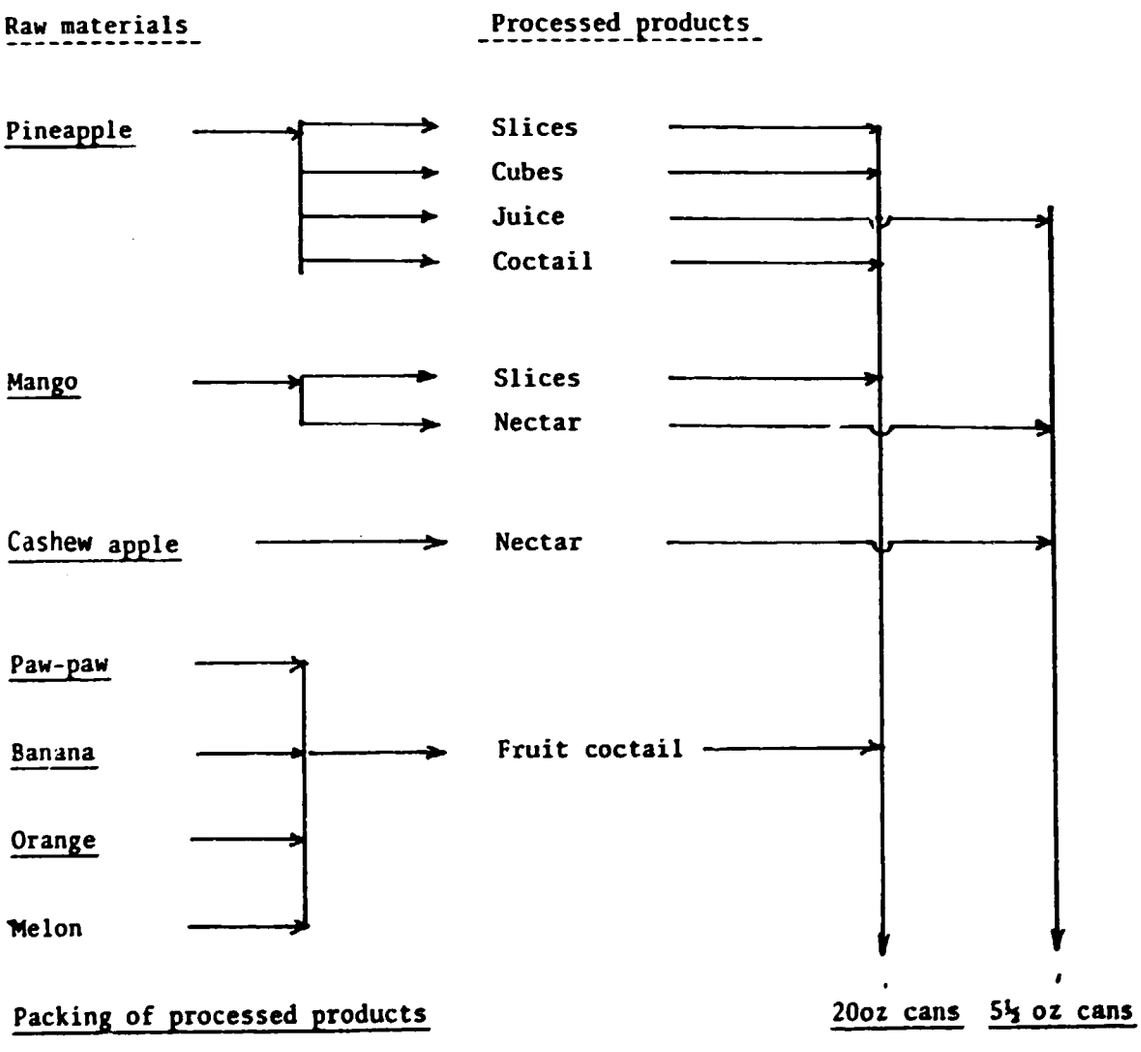
Appendix No. 1

Multipurpose Fruit Canning Plant-Schematic Flow Chart.



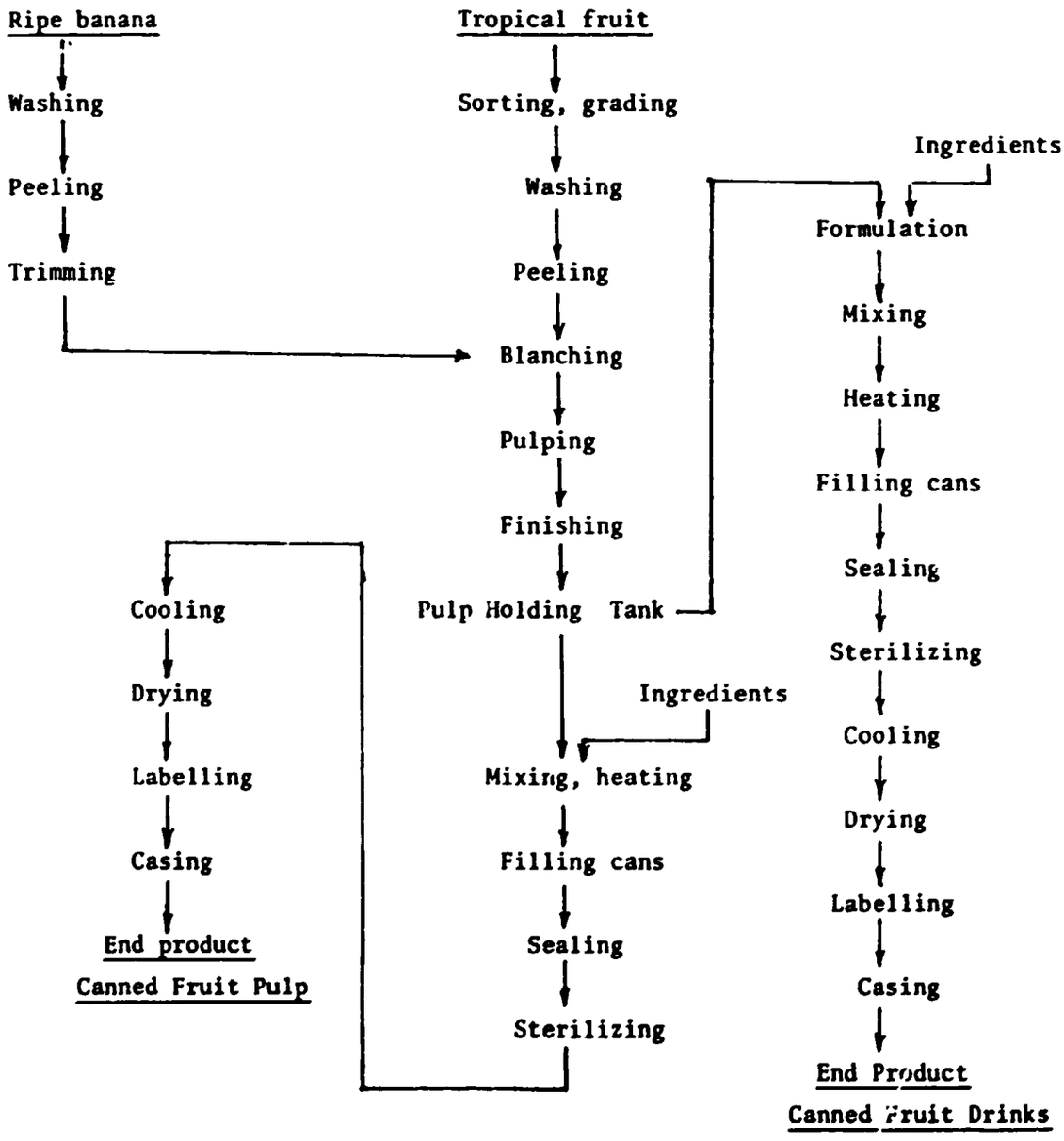
APPENDIX No. 2

Multipurpose Canning plant for sliced fruit, fruit juice, fruit nectars and coctails - Schematic Flow Chart



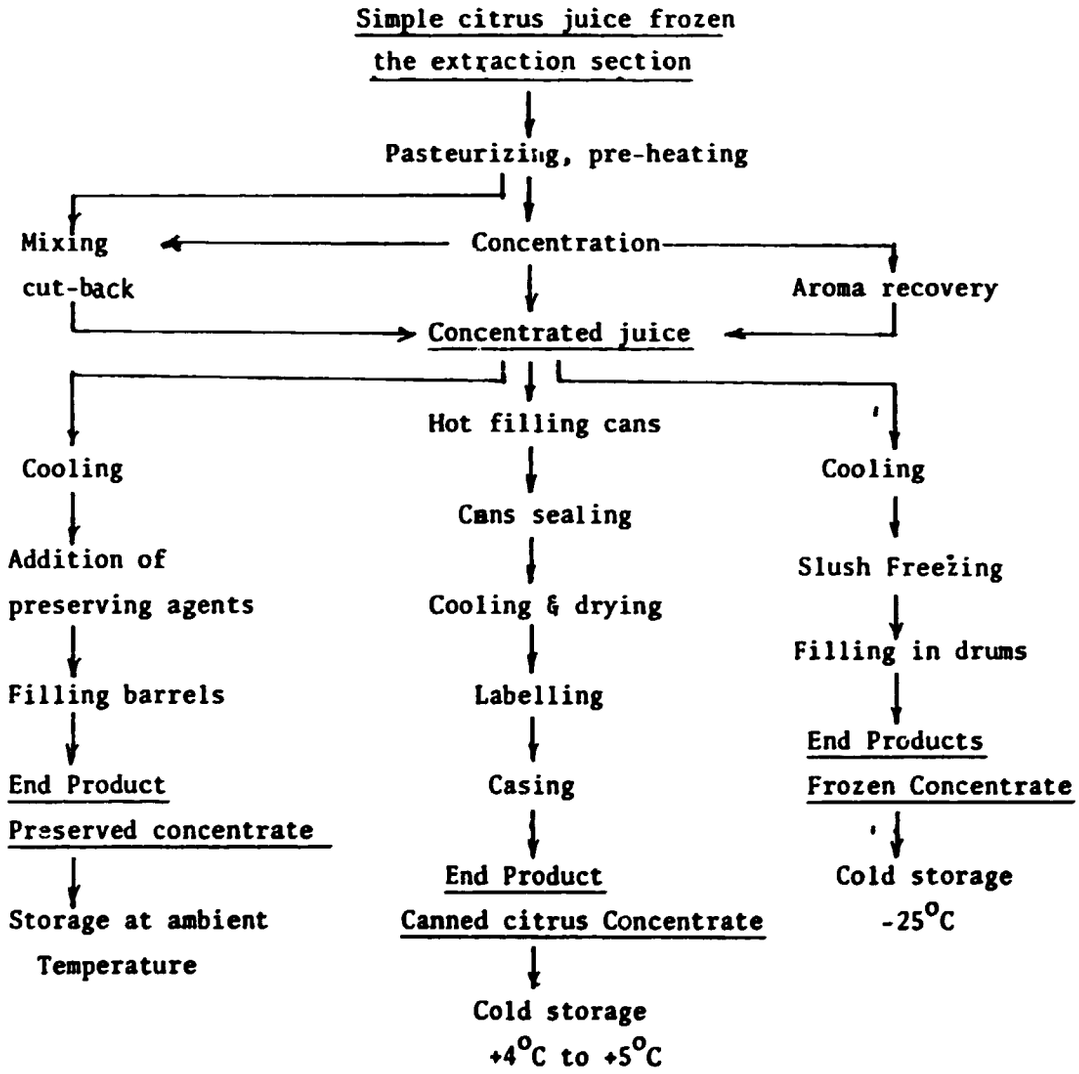
APPENDIX NO. 3

Multipurpose canning plant for fruit purees and drinks - Schematic Flow Chart



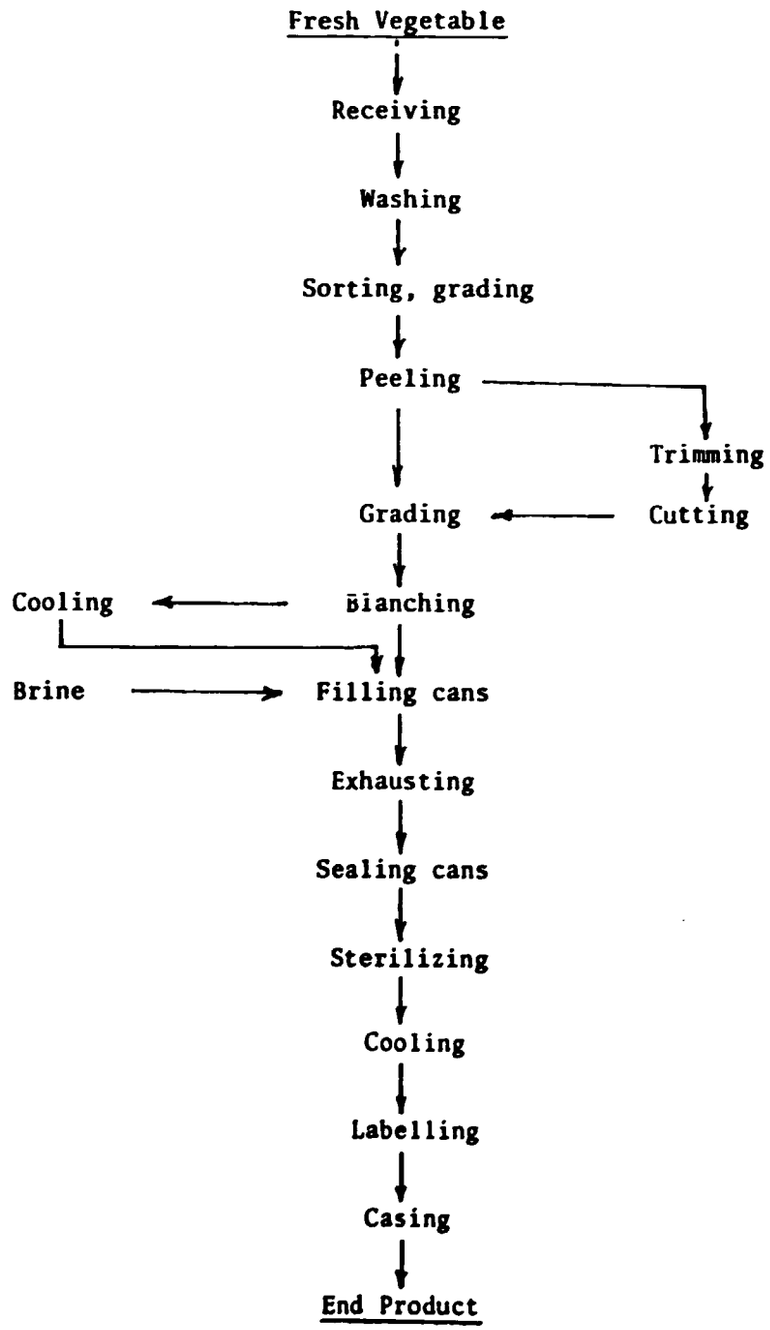
APPENDIX NO. 4

Multipurpose processing plant for canned, frozen and preserved citrus con concentrate - Schematic Flow Chart



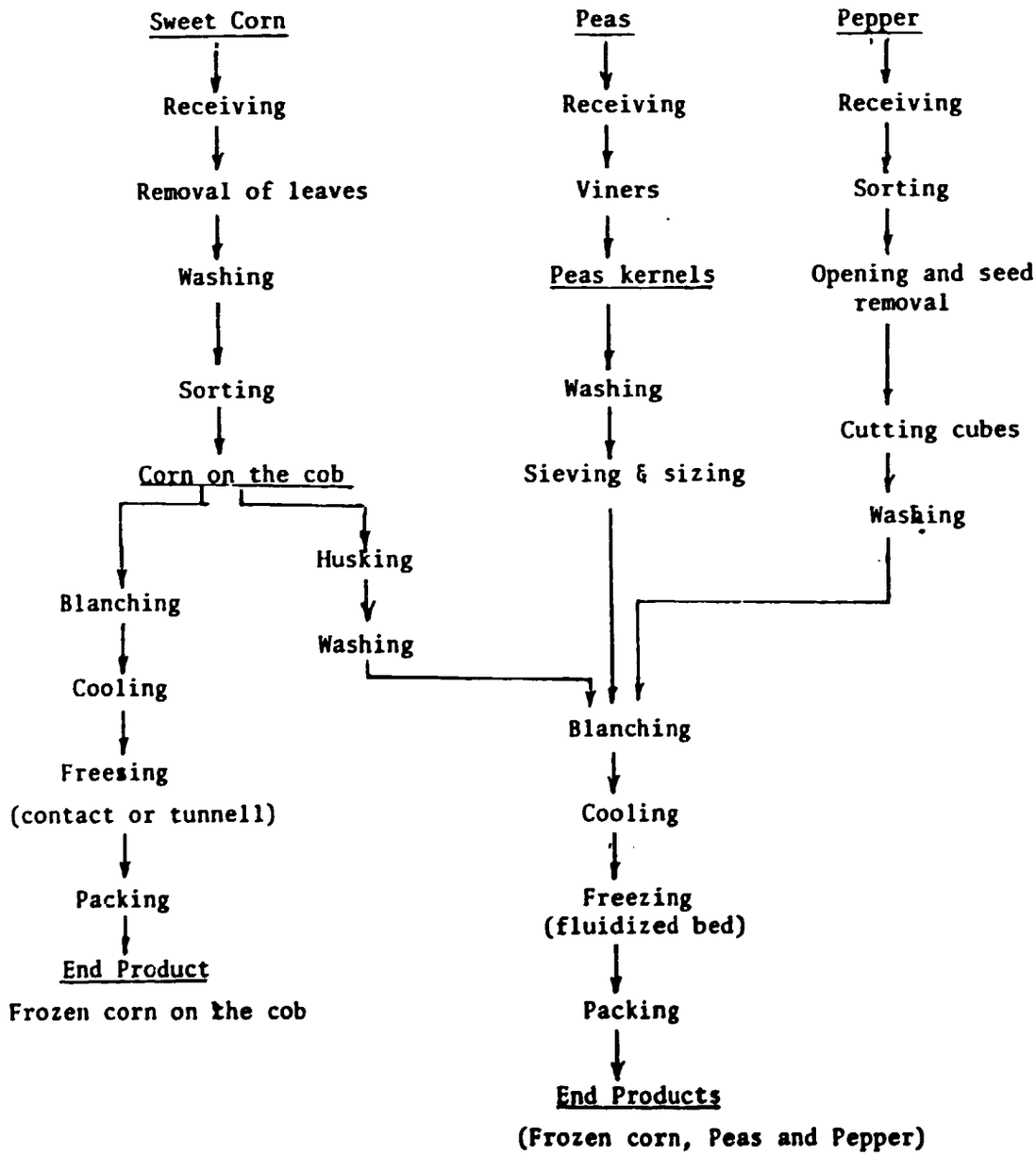
APPENDIX NO. 5

Multipurpose vegetable canning plant - Schematic Flow Chart



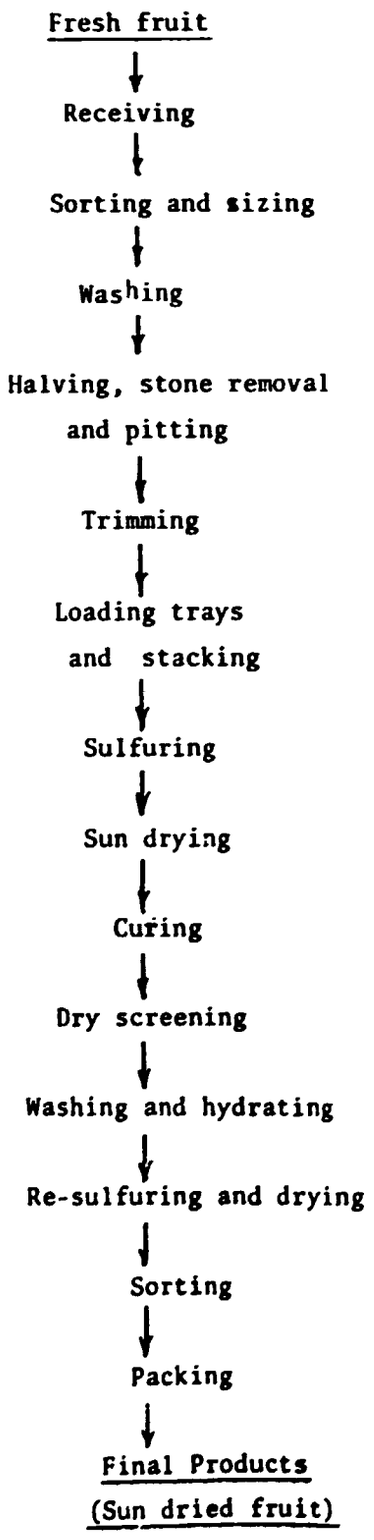
APPENDIX NO. 6

Multipurpose vegetable quick freezing plant - Schematic Flow Chart



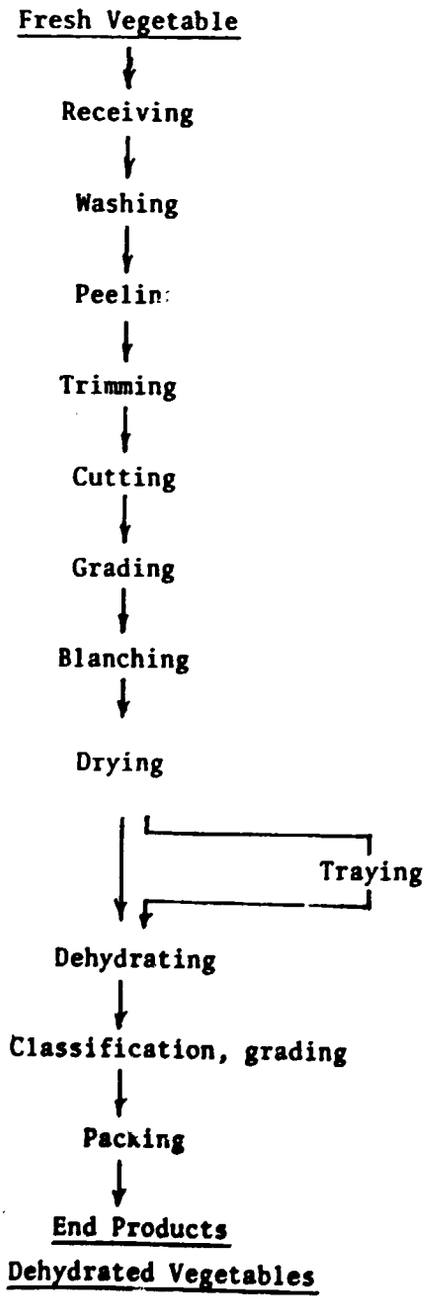
APPENDIX NO. 7

Multipurpose processing plant for sun dried fruit - Schematic Flow Flow



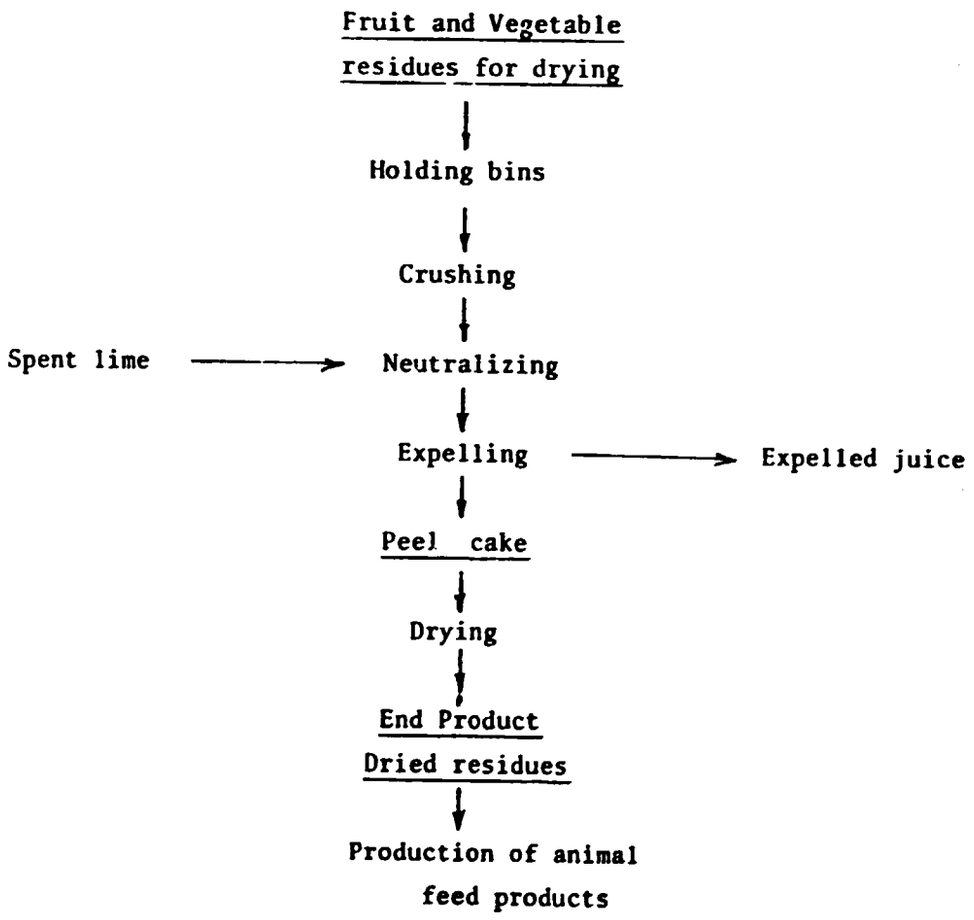
APPENDIX NO. 8

Multipurpose vegetable dehydration plant - Schematic Flow Chart



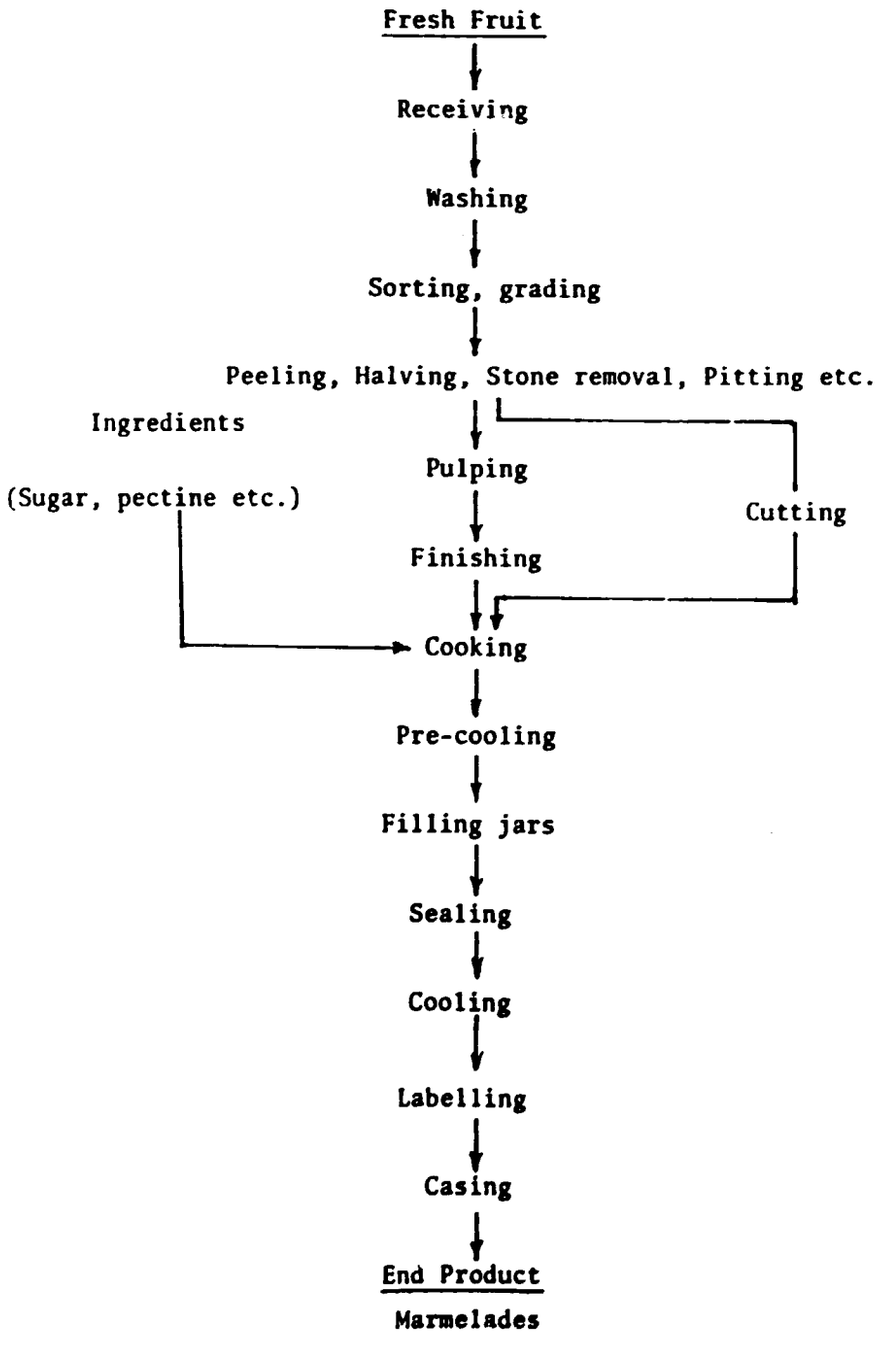
APPENDIX NO. 9

Multipurpose processing plant for drying citrus peels and other residues into animal feed - Schematic Flow Chart



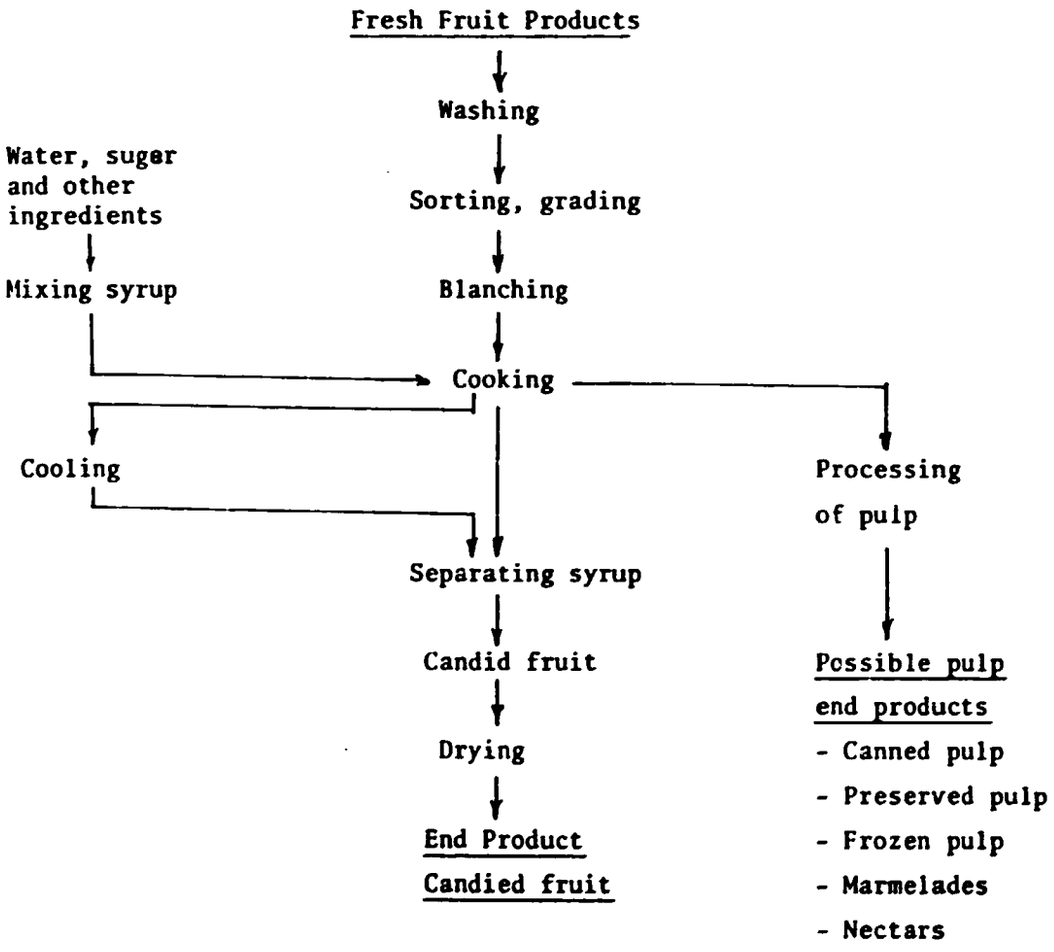
APPENDIX NO. 10

Multipurpose marmelades processing installation - Schematic Flow Chart



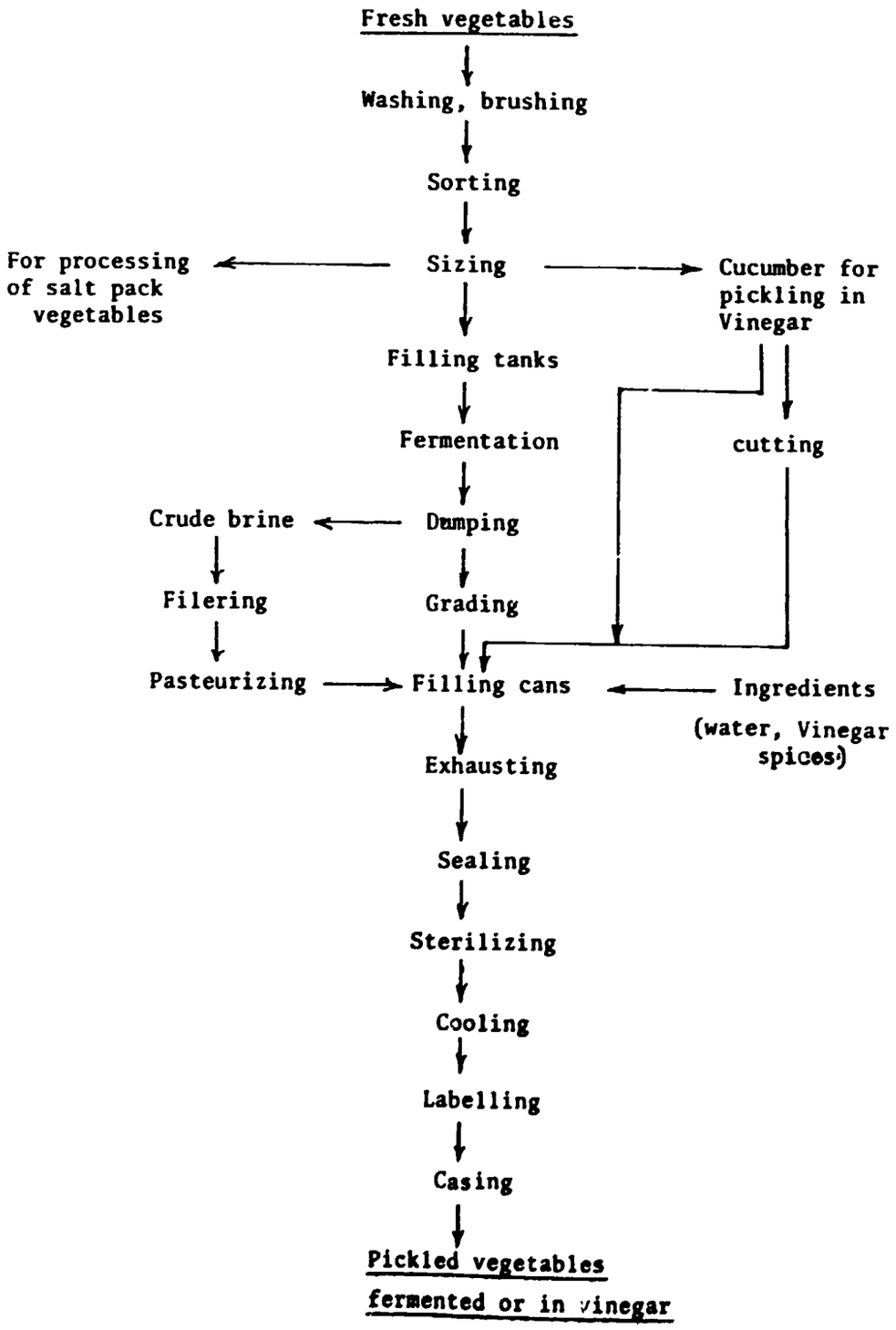
APPENDIX NO. 11

Multipurpose installation for processing candied fruit and fruit purees products - Schematic Flow Chart



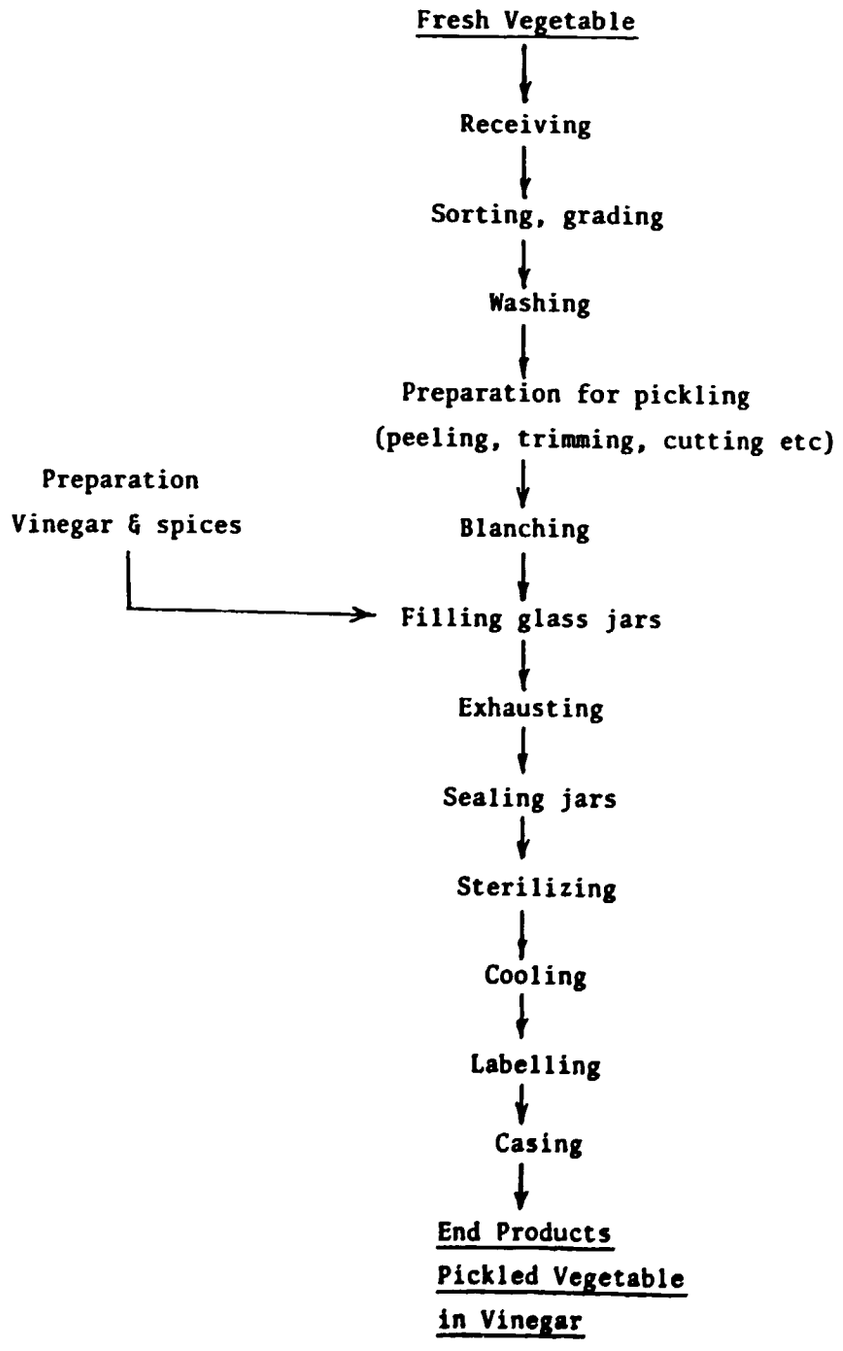
APPENDIX NO. 12

Multipurpose plant for processing fermented pickled cucumbers and other vegetables - Schematic Flow Chart



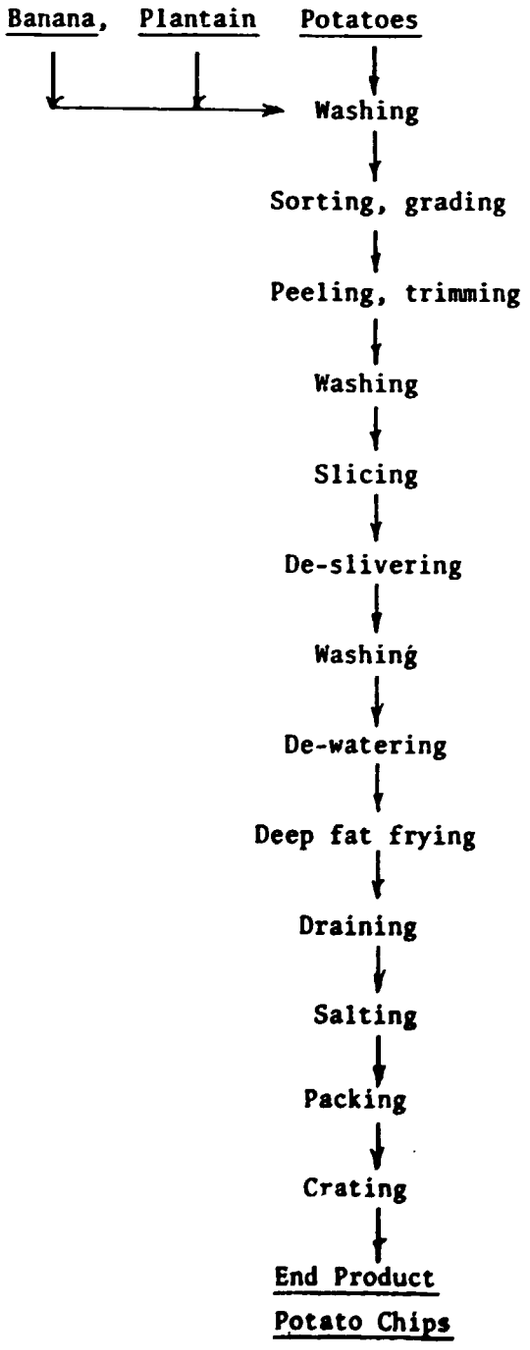
APPENDIX NO. 13

Multipurpose plant for processing pickled vegetable in vinegar - Schematic F.ow Chart



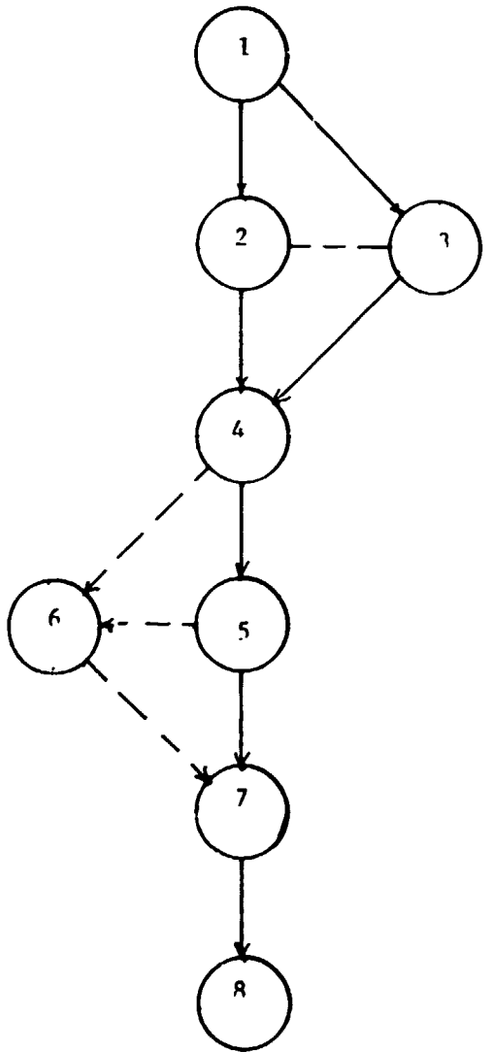
APPENDIX NO. 14

Multipurpose frying plant for potatoes chips and other fried products - Schematic Flow Chart



Appendix No. 15

Small/medium fruit and vegetable processing plants, identification of tentative alternatives for the production programme - Schematic Flow Chart.



APPENDIX NO. 15 - CONTINUATION

1. Preparation of a tentative list of the existing and potential raw materials.

2. Classification of raw materials following production, location, production volume and season, peak production, quality characteristics, etc.

3. Possibilities and prerequisites for the extension and/or diversification of the production of the existing raw materials in the coming years, and their respective classification as indicated in Step 2 above.

4. Preparation of an inventory of existing and potential raw materials to be considered for processing and their respective classification.

5. Definition of the intermediate and end products of commercial interest to be considered for processing from each of the raw materials and their classification following their characteristics.

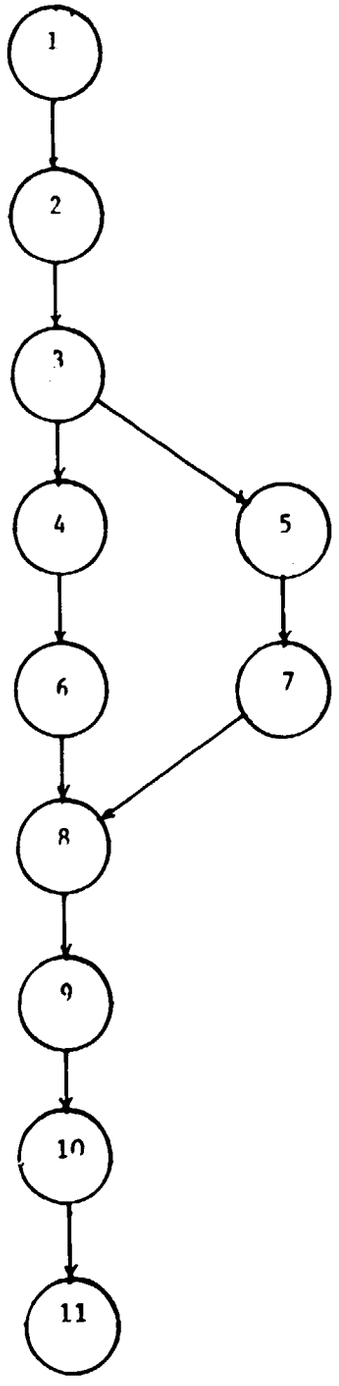
6. Examination of marketing opportunities (demand, offer, price,etc.) for each of the identified intermediate and end products of interest for processing.

7. Establishment of a tentative list of raw materials, intermediate products and end products of apparent production and marketing possibilities and their classification following their multipurposeness characteristics.

8. Identification of tentative alternatives for the production programme of the multipurpose plant.

Appendix No. 16

Small/medium multipurpose fruit and vegetable processing plants, selection of the appropriate alternatives for the processing technology and equipment - Schematic Flow Chart.



APPENDIX NO. 16 - CONTINUATION

1. Identified tentative alternatives for the production programme of the multipurpose plant (Step 8 of Appendix No. 15).

2. Preparation of process flow chart for each of the raw materials and its intermediate and end products including materials balance and movement, need in auxiliary and packing materials, utiiities, direct labour, etc.

3. Classification and comparison of the data indicated in Step 2 in relationship to processing time and peak season.

4. Analysing the data of Step 3 and their classification into unit operations and processing equipment units of multipurpose nature.

5. Classification and identification of the unit operations and processing equipment of single purpose nature.

6. Establishing the specifications of the equipment of multipurpose nature.

7. Establishing the specifications of the equipment of single purpose nature.

8. Preparation and issue of tenders for the supply of the needed multipurpose and single purpose equipment.

9. Receiving and examination of the tenders delivered by the different equipment suppliers.

10. Selection of the appropriate alternatives for the equipment (multipurpose and single purpose) and processing technology to be considered in the feasibility study.

11. Preparation of terms of reference for the needed feasibility study for the project and a work plan for its preparation, promotion and execution.

APPENDIX NO. 17-A

Small/medium multipurpose fruit and vegetable processing plant

Investment in equipment employed in the processing of the different raw materials

Equipment Ref. No.	Equipment Description	E_j	EA_j	EB_J	EC_J	E_{JM}
1	2	3	4	5	6	7
1		E_j	E_1	-	-	-
2		E_2	E_2	E_2	-	E_2
3		E_3	E_3	E_3	E_3	E_3
4		E_4	-	E_4	E_4	E_4
.						
.						
.						
j		E_j	E_j	E_j	E_j	E_j
.						
.						
.						
N		E_N	-	-	E_N	-
TOTAL		$E = \sum_{j=1}^{j+N} E_j$	$EA = \sum_{j=1}^{j=N} EA_j$	$EB = \sum_{j=1}^{j=N} EB_j$	$BC = \sum_{j=1}^{j=N} BC_j$	$E_m = \sum_{j=1}^{j=N} E_{jm}$

APPENDIX NO. !7-B

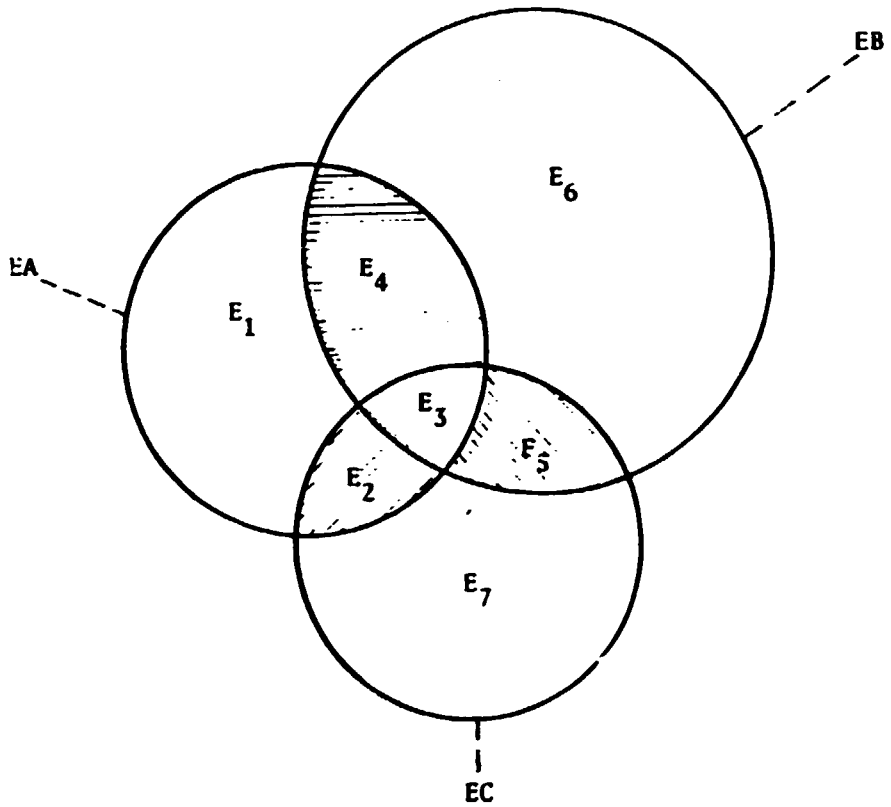
Small/medium multipurpose fruit and vegetable processing plant

Production capacities and weighed cost of the multipurpose equipment

Equipment Ref. No.	Equipment Description	E_{jm}	M_j	H_j	C_j	T_j	W_j
1	2	7	8	9	10	11	12
1		-	-	-	-	-	-
2		E_2	M_2	H_2	C_2	T_2	W_2
3		E_3	M_3	H_3	C_3	T_3	W_3
4		E_4	M_4	H_4	C_4	T_4	W_4
.							
.							
.							
j		E_j	M_j	H_j	C_j	T_j	W_j
.							
.							
.							
N		-	-	-	-	-	-
TOTAL		$E_m = \sum_{j=1}^{j=N} E_{jm}$					$W = \sum_{j=1}^{j=N} W_j$

APPENDIX NO. 18

Cost of the equipment of a small/medium multipurpose fruit and vegetable processing plant which processes three types of raw materials - Schematic Graphical Presentation.



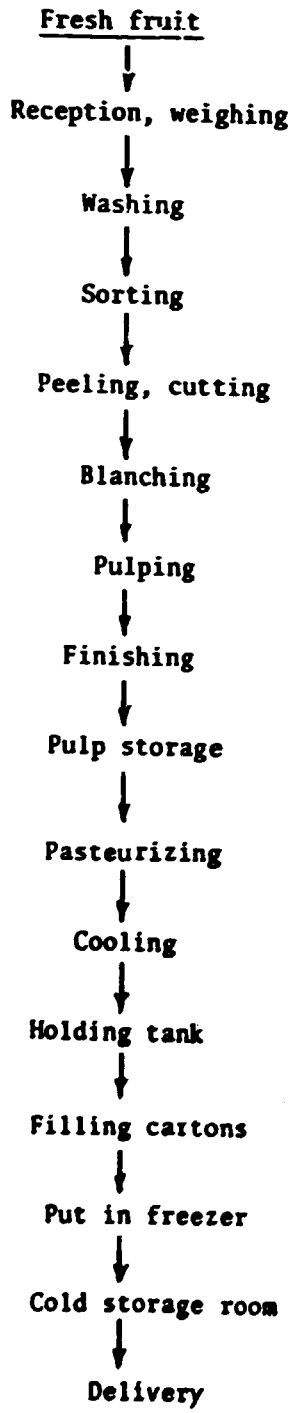
Raw material	Costs of the installed equipment for its independent processing
A	$EA = E_1+E_2+E_3+E_4$
B	$EB = E_3+E_4+E_5+E_6$
C	$EC = E_2+E_3+E_5+E_7$

$E_m = E_2+E_3+E_4+E_5$

$E = E_1+E_2+E_3+E_4+E_5+E_6+E_7$

APPENDIX NO. 19

Multipurpose preocessing plant for paw-paw and mango chilled/frozen pulps - Schematic Flow Chart



APPENDIX NO. 20

Multipurpose processing plant for paw-paw and mango pulps - yearly production programme

Month	Raw Materials (tons)		Fruit pulps (tons)		Working time	
	Paw-paw	Mango	paw-paw	Mango	Shifts per day	Days per month
January	100	-	70	-	2	25
February	100	-	70	-	2	25
March	-	100	-	50	2	25
April	-	100	-	50	2	25
May	-	100	-	50	2	25
June	50	-	35	-	1	25
July	50	-	35	-	1	25
August	50	-	35	-	1	25
September	50	-	35	-	1	25
October	50	-	35	-	1	25
November	50	-	35	-	1	25
December	100	-	70	-	2	25
Total	600	300	420	150	18	300

APPENDIX NO. 21

Multipurpose processing plant for paw-paw and mango pulps - Estimated cost of the project

	Processing equipment	Nominal Production capacity kg/hr	US $
1	Immersion fruit washer	1000	3,260.00
1	Elevating conveyor	1000	1,010.00
1	Transparting rubber conveyor (peeling, cutting, etc)	1000	1,410.00
1	Fruit blanches (about 3 m. long)	500	4,410.00
1	Pulper	500	5,180.00
1	Finisher	600	5,180.00
1	Crude pulp storage tank, capacity 100 gal.	400	1,740.00
1	Shell and tube pasteurizer	400	5,180.00
1	Shell and tube cooler	500	2,940.00
1	Storage tank for refined pulp capacity 1000 litres	1000	1,740.00
2	Sanitary pumps, 1 HP	1000	710.00
	Stainless steel pipes and accessories	1000	1,010.00
	Sub total		33,770.00

	Other Equipment	US $
1	Balance, capacity 50 kgs	300.00
1	Balance, capacity 500 kgs	940.00
1	Steam boiler, capacity 15 HP	3,830.00
1	Fuel tank, capacity 500 gal	420.00
2	Manual operated transporters	120.00
1	Electricity transformer	1,770.00
1	Refrigerated trailer as cold room	4,120.00
1	Refrigeration unit capacity 30 HP condenser, evaporator and all accessories	10,600.00
	Sub-total	22.100.00

	Constructions and Civil Equipment	
	Adjustment of the facilities of the existing plants	2,350.00
	Water tank, capacity 15 m^3	1,400.00
	Sub-total	3,750.00

	Unforeseen	
	Unforeseen, 5% of the above indicated costs	2,970.00
	Total	62,520.00

APPENDIX NO. 22

Multipurpose processing plant for paw-paw and mango pulps - Computation of the multipurposeness characteristics of the plant

	Equipment unit	E_j	P_j	$W_j = P_j E_j$
1	2	3	4	5
1	Immersion washer	3,260.00	0.25	851.00
2	Elevation conveyor	1,010.00	0.25	253.00
3	Transporting conveyor	1,410.00	0.25	352.00
4	Blancher	4,410.00	0.50	2,205.00
5	Pulper	5,180.00	0.50	2,590.00
6	Finisher	5,180.00	0.42	2,175.00
7	Storage tank	1,740.00	0.62	1,079.00
8	Pasteurizer	5,180.00	0.62	3,212.00
9	Cooler	2,940.00	0.50	1,470.00
10-12	Storage tank, sanitary pumps, piping & accessories	3,460.00	0.25	865.00
	T o t a l	E = 33,770.00		W = 15,016.00

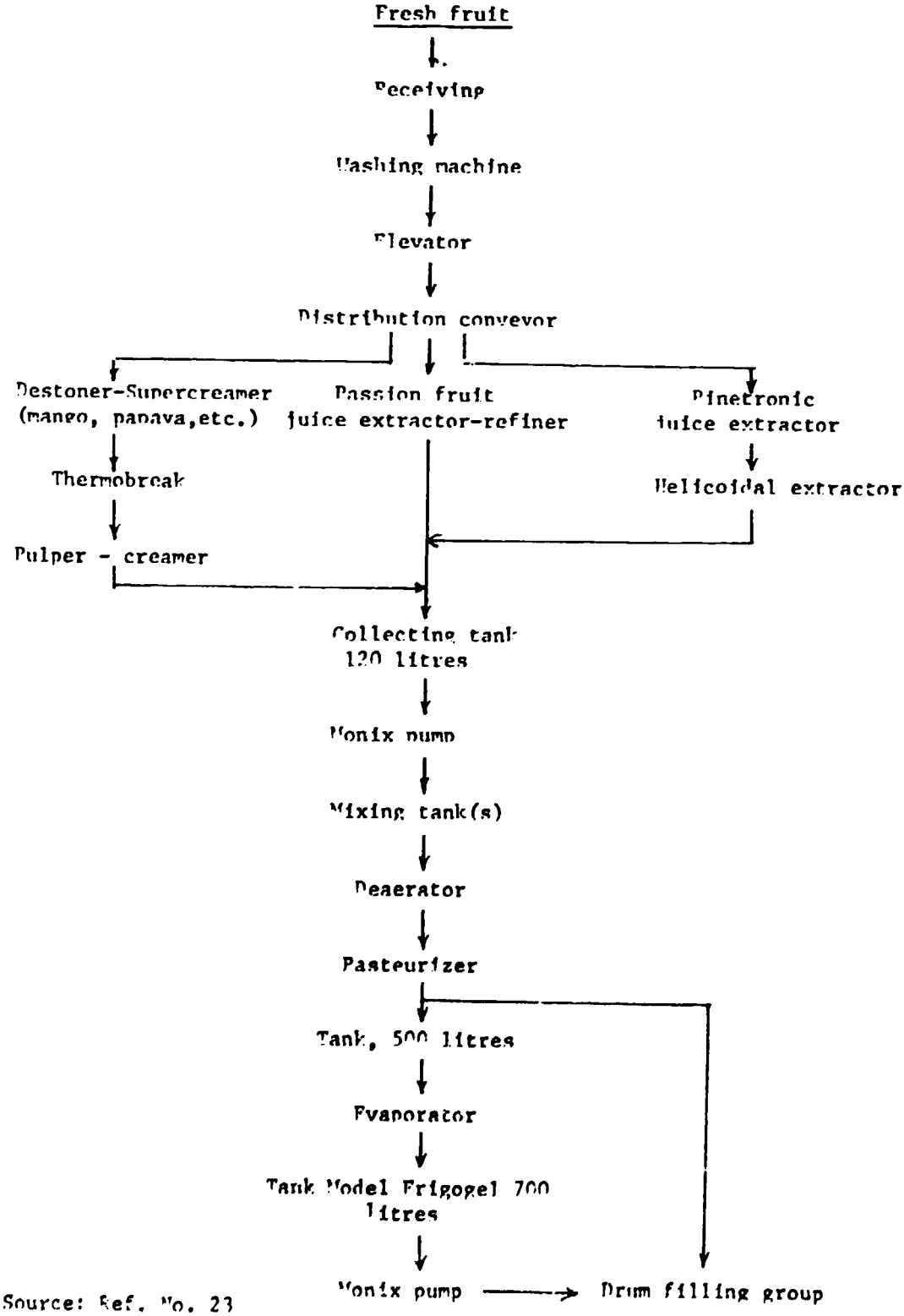
$$I = \frac{W}{E} = \frac{15,016}{33,770} = 0.4446$$

Hence, 44.46%

Appendix No. 23

Multipurpose line for processing concentrated pineapple and passion fruit juices and mango or other tropical fruit pulps

Process Schematic Flow Chart



Source: Ref. No. 23

Elaboration: J. Orshan

APPENDIX NO. 24

Multipurpose processing line for pineapple and passion fruit conc. juices and mango pulp - Cost of the installed equipment (in US $)

Description	E_j	Pineapple $(EA)_j$	Passion Fruit $(EB)_j$	Mango $(EC)_j$	E_{jm}
(1)	(2)	(3)	(4)	(5)	(6)
Washing & sorting line	50,000	50,000	50,000	50,000	50,000
Extracting & refining equipment					
Pineapple juice extractor	30,000	30,000	-	-	-
Passion fruit juice extractor	25,000	-	25,000	-	-
Mango supercreamer	18,000	-	-	18,000	-
Refining equipment	27,000	27,000	27,000	27,000	27,000
Treatment line	60,000	60,000	60,000	60,000	60,000
Concentration line	60,000	60,000	60,000	-	60,000
Control board	10,000	10,000	10,000	10,000	10,000
TOTAL	280,000	237,000	232,000	165,000	207,000

Source: Ref. No. 23; Elaboration: J. Orshan

APPENDIX NO. 25

Multipurpose processing line for pineapple and passion fruit conc. juices and Mango pulp - The production capacities and the weighed cost of the multipurpose equipment

Description (1)	T_j (2)	M_j (3)	H_j (4)	C_j (5)	P_j (6)	E_{jm} (7)	W_j (8)
Washing & sorting line	3.0	2,280	2,000	1.14	0.380	50,000	19,000
Refining equipment	2.5	2,280	2,000	1.14	0.456	27,000	12,370
Treatment line	2.0	2,280	2,000	1.14	0.57	60,000	34,200
Concentration equipment	3.0	1,560	1,400	1.11	0.37	60,000	22,200
Control panel	10.0	2,280	2,000	1,14	0.114	10,000	1,140
Pineapple juice extractor	2.0	1,200	800	1.5	0.15	-	-
Passion fruit juice extractor	0.8	360	600	0.6	0.75	-	-
Mango pulp extractor	2.0	720	600	1.2	0.60	-	-
						E_m =	W =
TOTAL						201,000	88,850

Reference No. 23; Elaboration : T. Orshan