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Distr.
LIMITED

ID/WG.172/9
22 May 1974

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

AFRIFOODS - Regional Consultation on
Promotional and Technical Aspects of
Processing and Packaging Foods for Export

Casablanca, Morocco, 23-28 June 1974

# PROCESSING FRUIT JUICE - THE QUALITY WAY 1/

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id.74-3707

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## Introduction

The interdependency of man has made mutual assistance and complementarity increasingly important in the interests of survival and progress. The ultimate goal of man is to find a means for securing reasonable living standards and social security for everybody on this small planet. Every nation, every community, each and every one of us must contribute, with all available resources, to the proper use and development of natural assets in the most effective manner.

## Market considerations.

In the last three decades, the fruit juice and soft drink industries have developed at a phenomenal rate. In less than 35 years, the commercial output of fruit juices and concentrates increased from almost nothing to about 7,000,000 tons, the breakdown being of the following order of magnitude.

| | Tons |
|---|---|
| Orange juice | 3,700,000 |
| Apple juice | 770,000 |
| Grapefruit juice and other citrus juices | 530,000 |
| Pineapple juice | 380,000 |
| Grape juice | 250,000 |
| Tomato juice | 660,000 |
| Tropical fruit juice | 260,000 |

A considerable expansion of the market has been predicted. Although three quarters of the world output of fruit juices is currently produced in the USA, there is every indication of an appreciable increase in some of the developing countries. The continuous search for new products offers tremendous openings to tropical fruit processors. The traditional markets for fresh fruit are getting so competitive that very often break-even prices cannot even be obtained. In the near future, when the new plantations in both established fruit processing areas and the newer ones come into production, the imbalance between supply and demand for fresh fruit will become even more pronounced. According to an FAO forecast, even at reduced prices the market will be unable to absorb all the additional fruit that will become available, yet given effective processing with proper equipment permitting the production of high-quality juice-concentrate products, there are still adequate opportunities for the utilization of any surplus produce.

On the other hand the demand for ready-to-consume "convenience beverages" is increasing owing to changes in living standards and drinking habits. Trends such as:

population growth;

higher average age;

increased communications;

social revolution (most notably the revolution of youth against parental traditions);

increased travel

increased consumption outside the home;

rising personal incomes.

are expected to cause an ever-increasing change in consumer habits as well as steadily increasing consumption. However, one fact remains undisputed: homo sapiens is the only creature that drinks when he is not thirsty. His basic organism remains unchanged and yet still requires a fluid intake of one and a half litres a day.

The steady increase in the consumption of beverages had led to a rapid development in the methods and ways of production, which in turn has called for the utilization of fruit juice concentrates because they are:

easy to handle and transport;

easy to store;

easy to dose;

This makes it possible to manufacture end products of consistently high quality.

As a result, the industrialized countries today are importing increasing amounts of different varieties of fruit juice concentrates from countries with a high production. The modern and quality-conscious fruit juice industry can benefit from this trend.

In the Mediterranean countries, for instance, where natural conditions favour good fruit cultivation (citrus, apricots, peaches, grapes, etc.) a large number of processing factories have been established during recent years.

The concentrates produced by most of these factories are mainly intended as premium quality products for the export markets. It is also very common for these plants to be equipped with processing equipment for "ready-to-sell" juice products intended for the expanding home market.

Modern technology

A modern multi-purpose plant for processing . ' fruit entails considerable investment. When a new plant is designed, every point in the process should be approached from various directions to ensure an optimum engineering and economic solution. Quick return on invested capital depends, inter alia, on the utilization of the equipment over the longest possible period. The best means of achieving a high degree of utilization is to maintain production almost throughout the year. In the northern hemisphere this can be done in the following way:

| | | |
|---|---|---|
| May - July | - | Nectar fruits (peaches, apricots, strawberries, etc.) |
| August | - | Tomatoes |
| Sept.-Nov. | - | Apples, grapes |
| Dec. - April | - | Citrus |

Thus much of the processing machinery will be utilized for several products over a longer period, i.e. pasteurizers, separators, deaerators, pumps, tanks, etc. In this connexion, it is worth pointing out that the optimization of a specific plant requires long experience, and that local conditions and all other variables must be taken into consideration. The growing, yet variable supply of fresh fruit, the overlapping ripening seasons of the different varieties and the increasing demand for first-class products present problems which require a modern technological approach.

Modern technology is synonymous with:

1. Efficient processing
   a) continuous flow
   b) preserving the natural properties of the raw material (taste, flavour, colour, aroma, vitamins)
   c) easy change-over from one product to another without large losses in raw material and end product, i.e. no waste of time.
2. Easy-to-handle compact machines with flexible performance.
3. Highest sanitary standards through use of cleaning-in-place (CIP).
4. Remote control and automation, thus minimizing the human error factor.

Investment in a modern multi-purpose plant is high from the initial cost point of view, but the returns can be decisive to the future of the whole operation. There is only one best possible solution for every case. In modern technology there is no place for weak points, and compromises are not acceptable insofar as **product quality** is concerned.

## Concentration

Concentration of fruit juice is fundamental to modern fruit juice handling. Without concentration, distribution to beverage manufacturers would not be feasible.

The following principal advantages are achieved:

Preservation during storage with minor physical and chemical changes;

Considerably reduced storage and transport costs;

The weight of the concentrate is only 1/6 to 1/7 of the original weight of the juice, the volume being only about 1/10;

Constant product quality;

Wider geographic distribution;
Distribution problems, if aseptic juice was to be transported, would be almost insoluble from both the technical and cost points of view.

Concentration is the heart of the process. The key to the high quality end product is based on the concentration step. In other words prime quality raw material, processed in the best possible way, will be irreparably damaged by an inferior evaporator. Nothing can restore lost quality.

In a good evaporator, final concentration should be reached with as little thermal degradation as possible. The degree of thermal decomposition is a function of time and temperature. The reaction speed is proportional to time and dependent on the temperature in such a way that a 10°C increase leads to 2-3 times as fast a reaction.

An evaporator has been developed that makes a vital contribution to the quality of the product (see illustration 1). It embodies a combination of the two engineering principles: indirect heat exchange with thin-film liquid flow, and centrifugal separation. The heating surface consists of a nesting stack of hollow conical discs rotating on a common spindle.

The juice is fed in and sprayed on to the undersides of the rotating cones, where centrifugal force immediately spreads it over the whole of the surface in a film only about one-tenth of a millimetre thick.

The juice crosses the cone surface in about one second. The entire evaporation process takes place in this short time, and the finished concentrate leaves the apparatus.

The steam heats the cone surfaces, and the condensate is thrown off by rotation as soon as it forms. The vapour boiled off from the product is drawn off to the box condenser.

Extremely fast evaporation and low temperature add up to a very gentle form of treatment that guarantees the high quality of the end product.

This evaporator is the only evaporator incorporating centrifugal force with indirect heat transfer. This system has the following advantages:

- Concentration from single strength juice to 70° Brix takes place within less than a second and in one pass, thereby ensuring retention of product characteristics (colour, taste, vitamin content, etc.);
- Products with high viscositites can be concentrated owing to the "spreading effect" of the centrifugal force;
- No recirculation is needed: all in one pass;
- Extremely compact installation: owing to very high heat transfer co-efficient (k-value), only a very small heating area is needed;
- Almost no loss of product: operating parameters are reached rapidly after start-up, shut-down being equally fast;
- Minimum supervision;
- Cleaning-in-place.

Aroma recovery

Although the above mentioned evaporator has a very low stripping effect, there is no doubt that the most volatile fractions are lost with the condensate, and to obtain a high quality end-product aroma recovery is necessary.

In the fruit juice processing sector, it is a well-known fact that the first 10-30 per cent stripped off contains about 90 per cent of the aroma components. This first aroma fraction, which contains 1/3 - 1/10 of the original juice volume, has to be concentrated to 1/100 of its original volume.

Earlier it was a commonly accepted opinion that the volatile components were not heat-sensitive. Today it is common knowledge that aroma is influenced by heat and that there is a time-temperature-relation about the same as that mentioned earlier for concentration. Some aromas, such as passion fruit juice, are highly sensitive.

If degradation of the aroma components is to be avoided, their holding time should be short. A few years ago, a technique was developed, called PAR, which utilizes the principle of repeated distillation. The advantage of this system is that the heat-sensitive aroma vapours are condensed and cooled immediately upon formation in the distillation unit.

The PAR unit consists of two plate heat-exchangers (see diagram 2). The lower plate (2) pack acts as an evaporator. The vapour and juice leave the plate pack through the openings at the upper edge of the plate passages and hit the baffle plate (5) which directs the flow downwards. The stripped juice is drawn off at the connection (5). The upper plate pack (1) acts as a condenser, the vapour being condensed by cooling water.

You can build a two-stage aroma recovery unit or more by using standard models of the PAR system (see illustration 2). Extension of capacity is obtained simply by adding more plates to the unit. The holding time of the aroma components is rated in seconds, and the results are excellent: fully in keeping with the aims of modern fruit juice processing.

The combination of a PAR aroma recovery unit and a centrifugal evaporator gives a concentrate which, when reconstituted, cannot even be distinguished from the original juice, the crucial test of a high-quality product.

In accordance with the market's steady emphasis on high-quality end products, the machinery manufacturers have introduced a series of new processing equipment. It is not only the demands made of the existing equipment that have increased, but in certain cases, completely new techniques have been required, and in research and development, an intense search is being made for new ways, methods and techniques.

The basic unit operations in fruit juice processing can be broken down as follows:

1. Fruit treatment and extraction of juice.
2. Recovery of essential oils (in the case of citrus).
3. Deaeration.
4. Pasteurization.
5. Aroma recovery.
6. Clarification.
7. Concentration.
8. Preservation of the end product.
9. Packing.

Having already dealt with aroma recovery and concentration, there are other processing operations to be discussed.

Fruit treatment and extraction.

The incoming fruit should be stored in well aerated bins made of wood or concrete for a maximum of 10-15 hours. In the event of longer storage periods, metal constructions with metal screen walls should be used to permit adequate ventilation. The depth of the fruit container should prevent excessive pressure and crushing of the fruit at the bottom of the container. The fruit must be thoroughly brushed and washed before inspection, and damaged and mouldy fruits rejected, on the principle that "there is no product better than the raw material."

The juice is extracted from the clean fruit in special presses. (In the case of citrus the essential oils are liberated from the peel at this stage as well). Juice extraction is a complex process *per se* .

Essential oil recovery.

Especially when limes, lemons and grapefruit are processed, it is important to get the highest possible yield of oil with an extremely good purity on account of their high value.

This can be solved by applying two-stage separation (see illustration 3). In the first stage a self-cleaning concentrator removes the pulp particles and most of the water. Further the oil is polished by a special separator called a polisher, resulting in a brilliantly clear oil free from impurities. The whole process is fully automatic and incorporates CIP.

Deaeration

Deaeration is an important operation in fruit juice processing, especially where citrus is concerned, since immediately after the whole fruit is crushed, its natural anti-oxidation mechanism is destroyed. Deaeration reduces the risk of oxidation and consequent undesirable changes in taste and vitamin content. The more pulp contained in the juice, the more difficult efficient deaeration becomes. This is due to the microscopic air bubbles clinging to the pulp particles. A question connected with deaeration has also been that of deaerating without losing the very valuable flavour. On the market today very efficient deaerators are available with integral aroma retention (see illustration 4). Without advanced knowledge, one can never guess that such a simple and small vessel can do so much in helping to solve such an important problem.

A point to be remembered here is the importance of preventing air from re-entering the deaerated product. The correct design of pipework, pumps and agitators helps to avoid air being mixed in.

Pasteurization

Pasteurization is a method of killing micro-organisms which would otherwise cause undesirable fermentation, yeasts and moulds. In the case of citrus and some other cloudy juices, it also inactivates the natural enzymes which would otherwise cause a breakdown of the desired cloudiness of the juice. A very gentle and short treatment has always been the goal of fruit juice processors.

High heat-transfer co-efficients, minimum pressure drop, small temperature difference between product and heating media, turbulent flows at low velocities, no burning-on, efficient cleaning-in-place, ease of maintenance, etc. are some of the built-in features of modern pasteurizers (see illustration 5). A recent refinement is the development of a plate heat-exchanger using the "mixed theta" technique, in which the corrugation patterns of individual plates are varied for optimum thermal efficiency, according to the difference in temperature between the fruit juice and the heating or cooling media. Every plate heat exchanger is computer-optimized for the specific duty for which it is sold.

In most cases, pasteurizers are equipped with automated heating and cooling systems. In some cases, they are equipped with a safety circuit with a valve that automatically diverts the juice back to the pasteurizer inlet into an automatically activated cooling section, should the temperature drop below a set limit - or if, for example, there is a temporary stoppage in the line.

Clarification

The type of separator most widely used in the fruit juice industry - and indeed in all industries that demand high-speed sanitary separation equipment - is the self-cleaning clarifier (see illustration 6). This machine is designed to remove pulp residues and other solids from a continuous product flow. The discharge mechanism is actuated either by an automatic timer set to operate at intervals matched to the rate of solid build-up or by a pressure-sensitive trigger that reacts when the solid holding space is filled to a certain point. In both cases, the solids are ejected before they can accumulate to the point of interfering with further separation, so there is no fall-off in efficiency during the production run. Self-cleaning separators are designed to work as an integral part of a continuous processing system. They can be cleaned-in-place by circulation without having to be opened, and all functions can be remote-controlled or automated.

A most important factor for efficient clarification is the gentle handling of the product prior to clarification. Correct pumping technique has a great deal to do with it.

## Cleaning-in-place (CIP)

CIP by circulation of detergents through the product line is the surest way of maintaining a high standard of plant hygiene. CIP systems can be supplied both in the form of permanent custom-built installations for complete plants (see illustration 7), and as small prefabricated CIP units for cleaning individual groups of equipment (see illustration 8). Economical features, such as regenerative heat recovery and recovery of cleaning fluids for re-use (impurities picked up during circulation are removed when the fluid goes through a self-cleaning separator), are important factors when designing for CIP. Almost all types of equipment can be CIP treated by using hot water, detergents or cold sterilizing agents. The system can be made completely safe: no cleaning agents can be fed into the production process by mistake.

A CIP system can be fully automated and programmed to perform a series of different functions at pre-set times and temperatures.

Owing to the effectiveness of a properly designed CIP system, the duration of the cleaning is relatively short.

Further to its labour-saving features, CIP guarantees that every part of the plant is properly cleaned and it is therefore essential for a quality-conscious modern processor.

## Automation

The results of properly executed automation should be better and more consistent product quality at less cost. Accompanying benefits are a high standard of hygiene, less risk of inadvertent product mixing, fewer manual operations (with consequent savings in labour and reduced equipment wear), more efficient equipment utilization, less complex buildings requirements and a more compact machine installation.

There can be no question that all these are objectives well worth striving for. The degree of automatic process control desirable depends very much on such local factors as availability of skilled personnel. The chief criterion is what will be most economical from the processor's point of view. The pros and cons must be weighed up in each individual case. A full and frank collaboration between the user and the supplier of the equipment will generally help to achieve maximum economy in plant design - both in conditions existing at the time of commissioning and for the future.

Automation is successfully entering the juice processing lines. The self-cleaning separators with automatic timers mentioned earlier are an example of spot automation, as is the programmable controller of the CIP system which checks the cleaning cycle through pneumatically operated valves. An example of a completely automated juice processing plant is that in Italy where the complete juice treatment (deaeration, pasteurization, clarification, concentration, etc.) is controlled and regulated from the master control panel (see illustration 9).

The processes that can be automated are numecurs. For example, a sugar-flow plant has been developed (see illustration 10) for the continuous production of liquid sugar for addition to still drinks or nectar juice. The concentration as well as the pasteurization temperatures are automatically kept constant within close tolerances and continuously recorded with a minimum of supervision.

Another example of complete automation is a continuous flow installation (see illustration 11) in Spain. This is a new system for the continuous production of soft drinks. The new and advanced developments in mechanical engineering and electronics are here utilized to a great extent. The whole production - from the input of sugar and juice concentrate, right up to the filling operations - proceeds in a full continuous flow.

In the paper hitherto, emphasis has been laid upon the hardware aspects of a fruit juice plant: the actual processing equipment in place and ready to start producing.

The software aspects should not be forgotten: the informative part. In order to secure the proper functioning of a process line, there are two further important factors: the operative and supervisory personnel. Sufficient instruction on the operation and maintenance of the equipment is indispensible to the efficient running of a factory and production of good quality products. Not only should experts be on the spot during the running-in period of a new factory, but training should also take place long beforehand at well established factories and training centres. Those who have the know-how must share it with anybody who wants to accept new ideas.

It should also be kept in mind that, in addition to processing techniques and equipment design, the quality of juices is naturally greatly influenced by the variety, cultivation, ripeness, freshness and quality of the raw material.

Correctly processed good fruit yields the best possible products. Newcomers to the industry have to establish a market and a good reputation. High quality-products are surely the best way of accomplishing both, those objectives. Quality products are in short supply and therefore readily accepted at higher prices.

Illustration 1

Evaporator in-situ

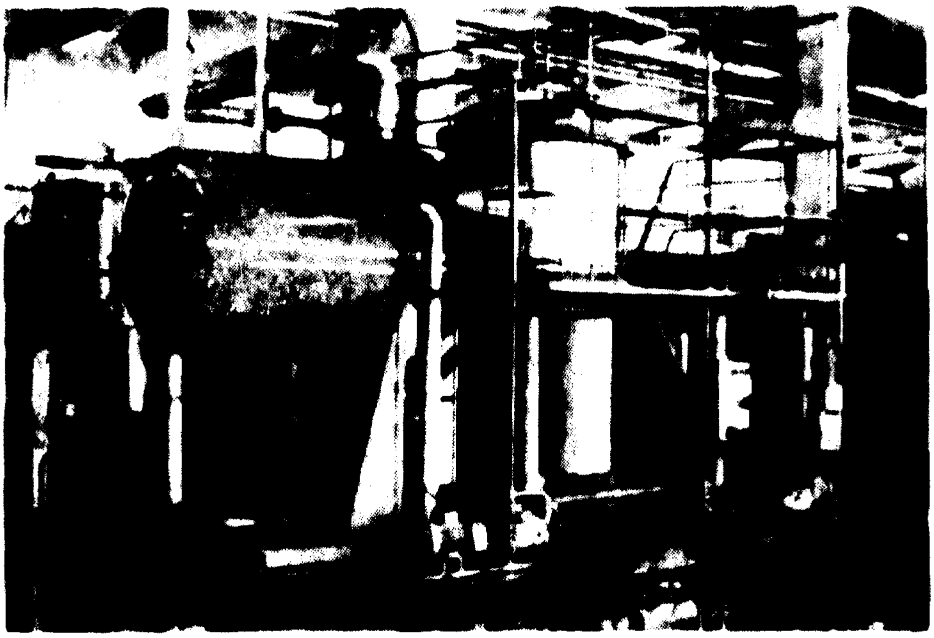


Diagram 1

Evaporator cross-section

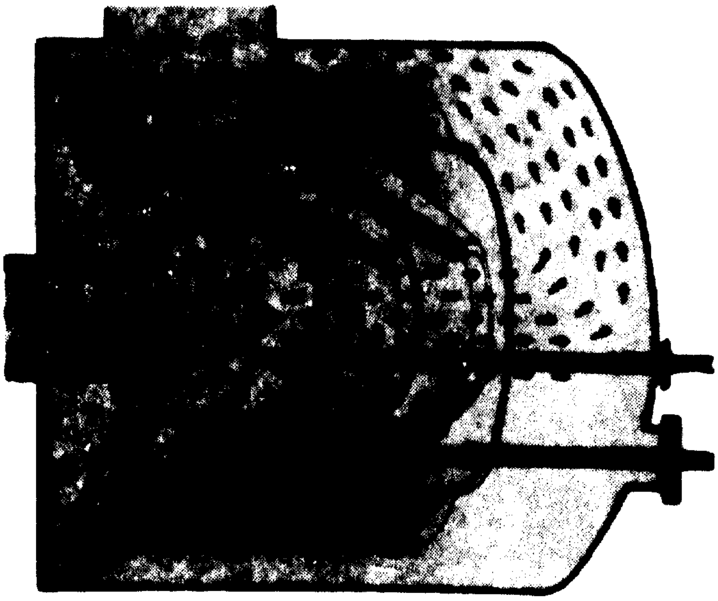


**Diagramm 2**

**PAR Unit**

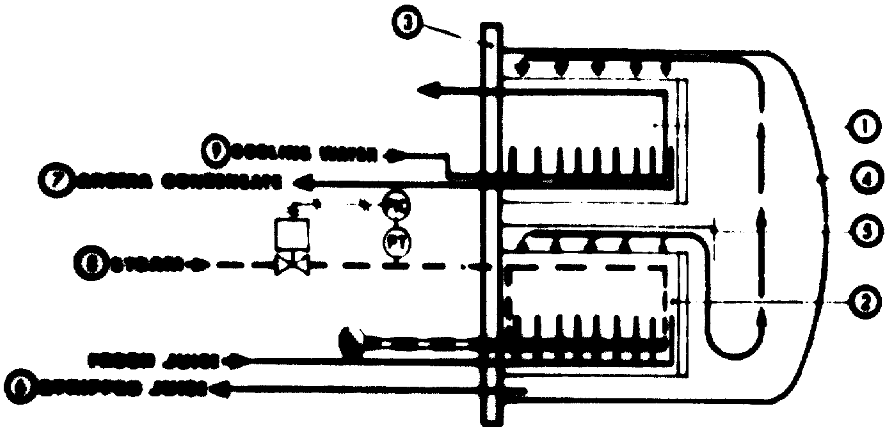



**Illustration 2**

**Two-stage aroma recovery unit**

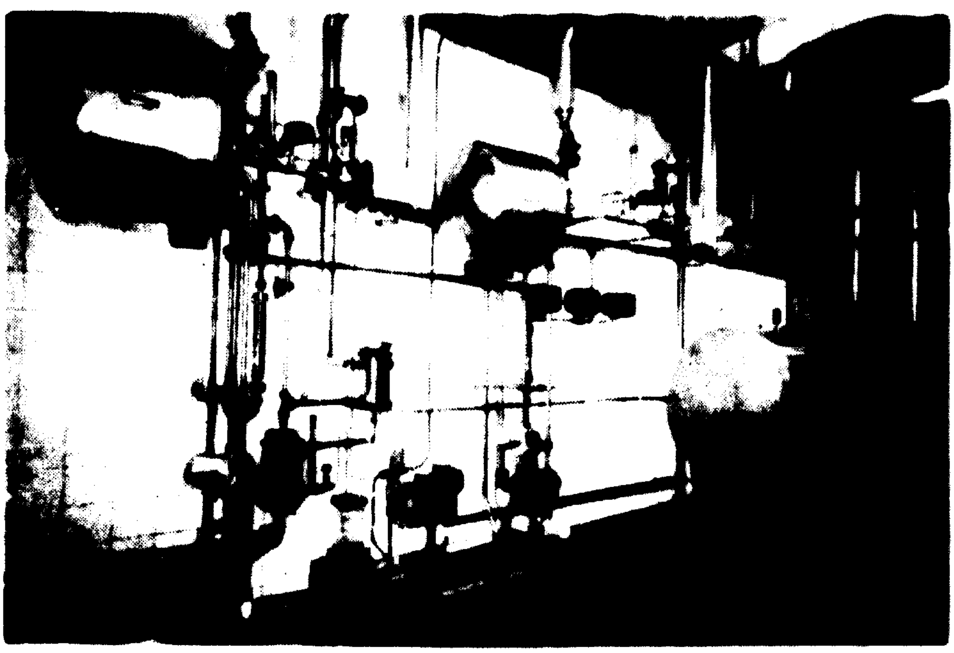


**Illustration 3**

**Two-stage separation**

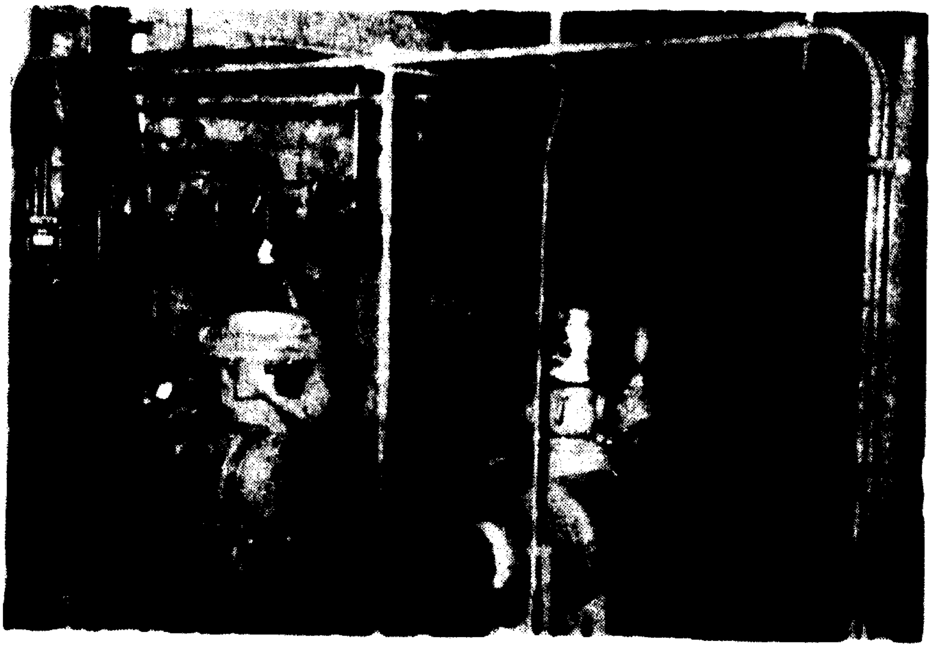


**Illustration 4**

**Deaerator in-situ**

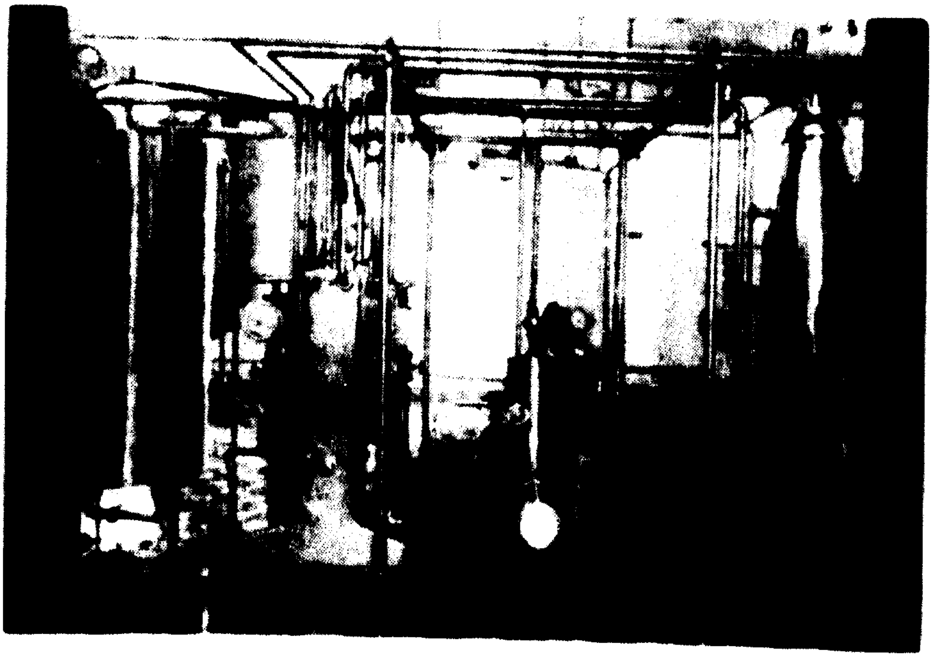


Illustration 5

Pasteuriser *in-situ*

Illustration 6

Self-cleaning clarifier *in situ*

Illustration 7

Custom-built CIP unit

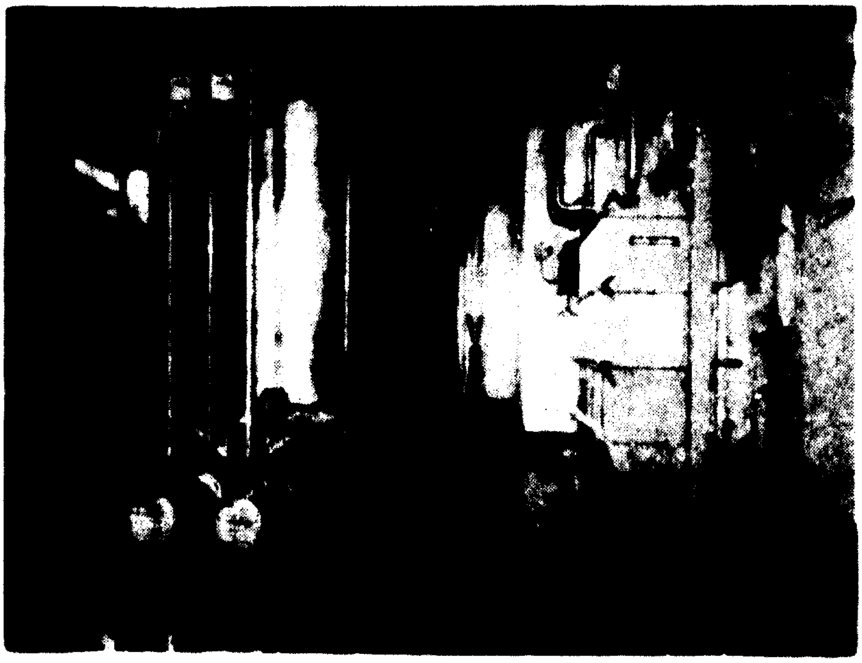


Illustration 8

Standard pre-fabricated CIP unit

Illustration 9

Completely automated juice-processing plant

Illustration 10

Sugar-flow plant for continuous production of liquid sugar.

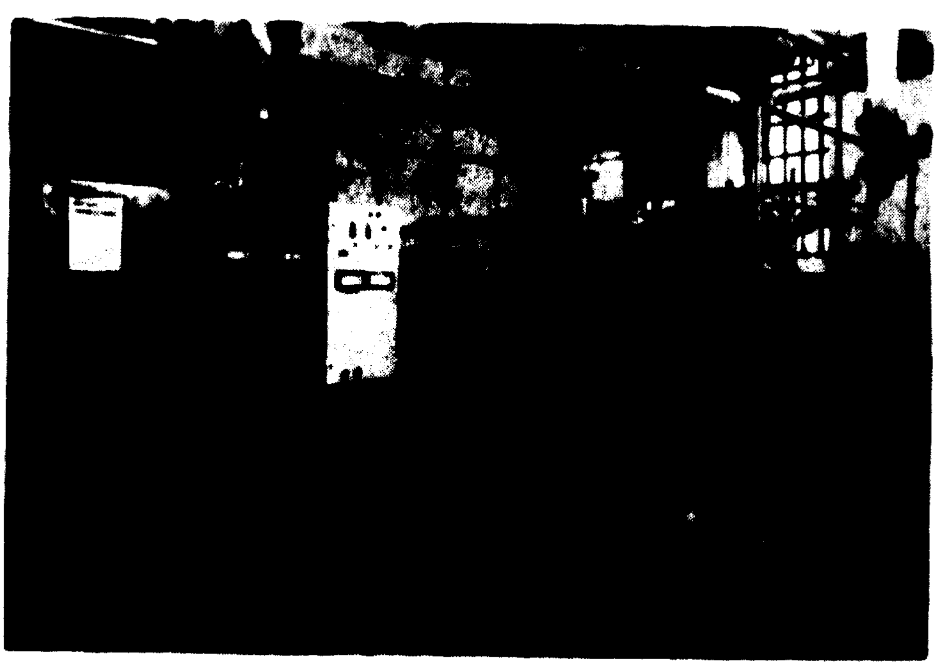
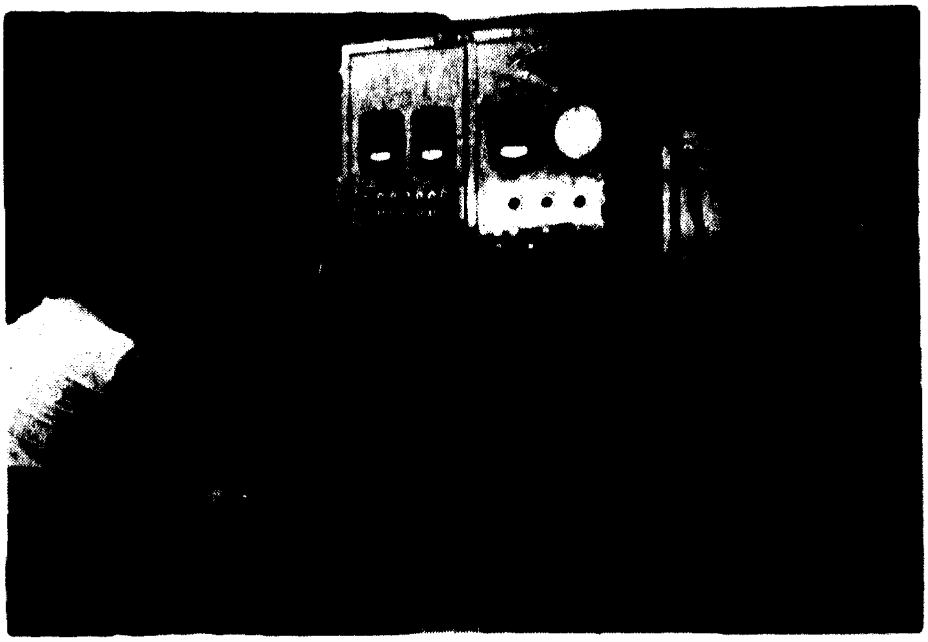


Illustration 11

**Continuous-flow installation**



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