FRUIT JUICE CONCENTRATION

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Introduction

Fruit juice concentrates are today considered as semi-finished products suitable for the production of respective fruit juices, fruit juice beverages, jams and jellies and also in the preparation of fruit juice powders (1)**.**Concentration of liquid foods is a very important unit operation in food engineering. Consequently removal of water from fruit juices offers the advantages of reduction in weight, volume and cost of packaging, storage and transportation besides ensuring microbial stability. The composition of fruit juices reveals that they contain water as the major component (75–95%). (2).Obviously, removing this water partially (concentration) or almost completely (dehydration) will have several advantages.

This episode deals with the

Advantages and disadvantages of concentration process,

Evaporative concentration,

Freeze concentrati*on*

Membrane separation process

Comparative evaluation, Packaging and storage

A) Advantages

i) Economy in packaging, storage & Transportation.

It is obvious that by reducing the volume of fruit juices by concentration, these requirements will be almost proportionately reduced.

ii) Convenience

FJC are today very important semi-finished products which can be conveniently used for producing a number of products like beverages, fruit juice powders, jams, jellies etc. The convenience comes from the reduce volume.

iii) Economic utilization

Economic utilization of fruits during glut season ensures price stability and better microbial stability. By concentrating fruit juices, excess fruits during glut season can be preserved and stored conveniently in a small volume. This will prevent spoilage losses in fruits and price fall leading to distress sale. All these means better returns to the farmers.

iv) Better microbial stability

Highly concentrated fruit juices have better microbial stability. This is largely depended on the low pH (2-4) and low water activity. Microbial cell membrane behaves like semi- permeable membrane. Water from microbial cells permeates to the concentrated solution thereby shrinking of cells (plasmolysis of cells) occurs.

B) Problems / disadvantages in concentration of fruit juices:

i) Cost of concentration

Energy and other utilities, capital cost, maintenance and labor constitute cost of concentration. Cost of concentration is largely dependent on the method of concentration. The methods available for concentration can be grouped under three major heads.

1. Evaporative Concentration
2. Freeze concentration.
3. Reverse osmosis (membrane process).

Whichever method is followed, some energy input is required for water removal. In practice about 1.2 kg steam is required for 9evaporating 1 Kg water from the juice. We will see that this requirement can be reduced by multi effect evaporation.

ii) Nutrients loss

Among the nutrients in fruit juices, ascorbic acid is the most important which is subjected to losses depending again upon the method of concentration.β-Carotene, which is the precursor of vitamin A, though is reasonably stable under the modern concentration procedures, can also be destroyed to some extent. Essential amino acids (free) are also destroyed to varying extent.

iii) Aroma loss

Fruit aroma is the major contributing factor for fruit quality. Aroma loss is one of the most important disadvantages in concentration of fruit juices. This again is dependent on the method of concentration, evaporative concentration resulting in maximum loss.

iv) Browning and off flavour

Browning of fruit juice concentrates can take place during concentration, particularly in evaporative concentration and also during storage of the concentrates. Browning reactions or non-enzymatic browning reactions are of different types. They can be due to reactions between reducing sugars and free amino acids generally termed as Maillard reactions. Browning can also be due to degradation and polymerization of ascorbic acid or polymerization of polyphenols.

As in most chemical reactions, rate of browning reactions are proportional to the concentration of reactants. Therefore, rate of browning is faster in fruit juice concentrates than in single strength juices.

Browning reactions, in addition to imparting undesirable colour to the product can also cause off flavor development because some of the products of browning reaction are volatile compounds. Since nutrients like ascorbic acid and amino acids are also involved in browning reactions, it may be said that browning can also impair nutritional quality of the product.

v) Cloud loss and gel formation

Cloud or turbidity in citrus juice is a desirable characteristic. Cloud is responsible for most of the colour and flavour associated with citrus juices. The cloud is a heterogeneous mixture of cellular materials and emulsoids held in suspension by pectin eg (25% lipids, 34% protein, 32% pectin). Retention of the cloud in citrus juices and concentrates is very important. The pressure applied in juice extraction largely determines the content and dimensions of the cloud particles. Large particles (>1mm) settle down on standing the juice. The particles that remain in suspension after centrifugation for 10 min at 360 × g is defined as ‘cloud’. The cloud or turbidity can be quantified by measuring the transmittance of light radiation at 660 nm in a colorimeter or spectrophotometer.

Cloud loss is usually attributed to be due to the activity of pectic enzymes. Pectin methyl esterase converts pectin to low methoxyl pectin which gets precipitated as insoluble pectate by combining with Ca or Mg ions. On precipitation, it carries the cloud particles along with it. Cause for cloud loss in lemon juice prepared from concentrate is reported to be due to reduction in water activity below the critical level necessary for

maintaining pectin in solution. High acidity in concentrates can also cause pectin degradation and cloud loss.

Pasteurization is the most convenient way to stabilize cloud. Any delay in pasteurization before concentration, therefore, can be a cause for cloud loss.

The aim of technological development in fruit juice concentration is to offset the disadvantages infavour of advantages. We have already seen that there are three methods available for fruit juice concentration. Among them, evaporative concentration is far the most common method followed. Obviously there are some advantages in this method of concentration over the other two methods.

Evaporative concentration

Evaporation is considered to be the best developed and most widely used method **(3)**.In this method of concentration, water from fruit juices is removed by boiling. For this purpose, different types of evaporators, with different shapes, design and way of operation are in use today. Fruit juice concentration is commonly carried out in table evaporators, plate evaporators , centrifugal evaporators , agitated film and wiped film evaporators .It is needless to say that today, all evaporators used for concentration of fruit juices operate at low pressures (i.e. at low temperatures). The evaporators used in the food industry are plenty (4-6).

In principle, every evaporator plant consists of three main parts, namely

1. Heat exchanger

2. Vapour liquid separator

3. Condenser

In addition, evaporation plants include vacuum and feed pumps as well as metering and control devices.

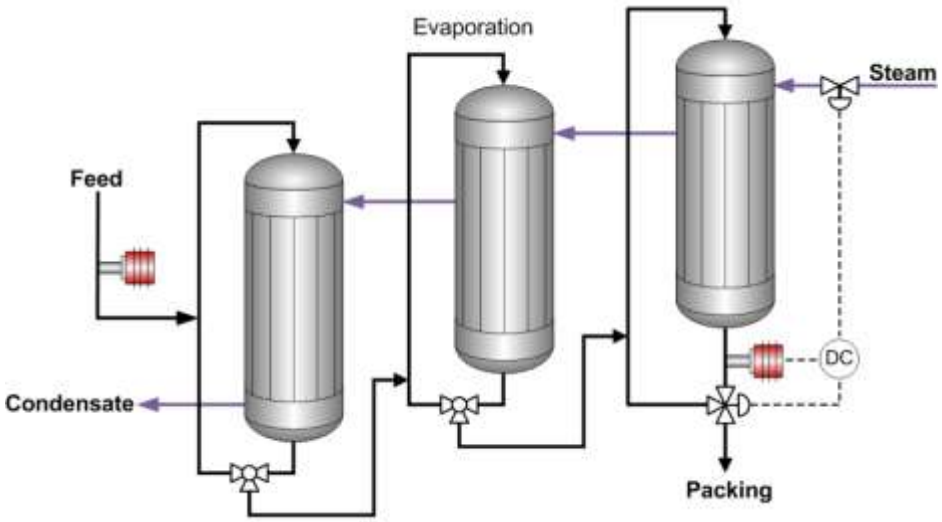


Fig1. Evaporation system

The major difference in the design of various types of evaporators is in the heat exchanger. Accordingly, there are:

Calendria type (evaporator)

a) Plate type (evaporator)

b) Mechanically agitated type (evaporator)

c) Centrifugal type (evaporator)

These evaporators can be classified under:

a) Low temperature evaporators

b) Mean temperature evaporators

c) High temperature evaporators

i) Low temperature evaporators: They operate at 10 –35^{0}C. They make use of a refrigerant as heating and cooling agent. Though this type of evaporators cause very less heat damage to the product, there are many technical problems that make them not economical.

ii) Mean temperature evaporators:

Most of the multi effect evaporators belong to this category in which the maximum temperature is 70^0 –80^0C in the first stage and 40^0-45^0C in the last stage. Steam is used usually at 2.5 atm. and cooling water at 15^0C.examples are:

i) Double effect forced circulation evaporator design of CFTRI.
ii) Rising and falling film evaporator of ∝- Laval; (Sweden) WIEGAND (WG), Unipektin (Switzerland), STORK (Denmark), VEB (GDR), KOVACS (Hungary).

iii) High temperature short time evaporators (HTST):

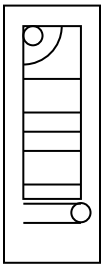
This type of evaporators are based on the high temperature short time principle, according to which though water can be brought to boiling in a very short time at a high temperature, heat damage to the product is less. This type of evaporators usually operates at a maximum temperature of 98^0C (first effect) and 40-45^0C in the last effect. Examples are:

UNIPEKTIN's horizontal evaporator (2-3 effect) and the TASTE (Thermally accelerated short time evaporator) of Gulf co; USA (3-4effect).

iv)Plate type evaporators:

This type of evaporators are made almost exclusively by APV co. Ltd, although W. Schmidt of W. G.(FRG) are also producing in a small scale.

The heat exchanger is made up of a set of corrugated rectangular SS plates, each separated by special rubber gaskets.



Advantages of plate evaporators are mainly their low head room, possibility of increasing or decreasing the heating surface by increasing or decreasing the number of plates and hence evaporation capacity and easy cleaning. They have high heat transfer coefficients. They can be falling film or rising and falling film type. Prime costs (capital) are low.

v) Mechanically agitated evaporator:

It consists of a large tube, which is heated by steam. Inside the tube there is a rotor whose baffle plate's move along the surface of the tube.

Depending on whether the baffles touch the tube surface or have a very small clearance, they are classified as scraped surface or thin film evaporator. For scraped surface heat exchangers, the edges of the baffles are fitted with materials like Teflon.

By rotation of the rotor along with baffles at high speeds, the juice is distributed evenly on the whole heating surface by turbulence with scraping, new surfaces are continuously created which means less heat damage and higher heat transfer coefficients. This type of evaporators is suitable for concentrates of high viscosity up to 20,000 cps.

vi) Centrifugal evaporators:

They make use of the centrifugal force to set the liquid to be concentrated into motion where by the liquid is evenly distributed as a thin film over the heating surface. The heating surfaces are steam-heated double walled conical dishes rotating on a shaft.

All these evaporators using steam as heating medium and water at about 15^0C for cooling require about 1.2 Kg and 18-22 Kg respectively for evaporation and condensation of 1 kg water from fruit juices respectively. This is not a very economical proposition. Technological developments have made considerable progress to reduce these requirements.

vii) Multistage evaporation:

Evaporation with multi effects are characterized by the fact that they have 2 or more evaporator bodies which are connected in a way that the vapor's escaping from one vapors-liquid separator is fed into the heating section of the next stage to supply heat energy.Fig 2.

It can be seen from the data in table (1) ,that steam requirement is proportionally reduced with the number of effects. Similarly, cooling water requirement is also reduced because, vapors from only the last effect is to be condensed.In practice the reduction of steam and cooling water are:

Table 1 : Steam and cooling water requirement

No. of effect	Steam (Kg)	Cooling Water (kg)
1	1.10	18
2	0.65	10
3	0.45	07
4	0.35	05

Even though steam and cooling water requirement in multi effect evaporators reduce proportional to the number of effects, prime costs and operating costs increase proportional to the number of effects. Based on these contradicting factors, it has been found that about 4 effects evaporator is the most cost effective.

2.1Selection of evaporators

With so many types of evaporators at the disposal, proper selection of evaporators for a specific purpose (duty) is very important. To accomplish this, one has to take into consideration various aspects.

Among the factors to be considered, the physical and chemical properties of the feed (juice) and the concentrate are very important. Cost of evaporators is equally important because that will reflect on the final product cost.

i) Viscosity:

The rheological properties of the feed & concentrate play very important role in the concentration process. The resistance to flow offered by a liquid against the direction of flow is termed as viscosity.

ii) Rheological properties and evaporation rate

Rheological properties of fruit juices have a significant effect on evaporation rate (9).The rheological parameters have been used for the design of the evaporation equipment. One of the criteria for the proper choice of the most suitable evaporator for the concentration of given fruit juice is the maximum value of fruit juice viscosity that can be handled in the different types of evaporator. Different types of evaporators have limits for maximum product viscosity (Table **2)**

Table 2: Viscosity and concentration limits for concentration process

Concentration process	Viscosity (Cps)	Maximum brix
Scraped film evaporator	40,000	
Centrifugal film evaporator	20,000	
Plate evaporator	400	75
Falling film evaporator	200	
Rising film evaporator	100	
Freeze concentration	200	50
Reverse osmosis	50	25-30

Source: Ref: 9

iii) Fouling: Evaporator surface foulingresults from the destruction of some heat sensitive compounds (10).It is the major problem in fruit juice concentration because it reduces heat conduction into fluid through heating surfaces which in turn affects the rate of heat transfer and finally impairs product quality. Many operating variables notably the temperature of heating surface and to a different degree, factors like flow direction, flow rate, amount of vapor in the fluid and boiling or warming of fruit juice on the heat transfer surface are known to affect fouling rate (11).

iii) Heat sensitivity: Heat sensitivity is important in selecting an evaporator since it affects the quality of the concentrates. Changes in quality due to thermal degradation are dependent on process temperature, residence time in the evaporator and the nature of the product(12).Even though low temperature evaporators cause less damage , High Temperature Short Time (HTST) concept has been successfully used in evaporating heat sensitive juices. (9).Residence times for different types of evaporators vary considerably (determined by Methylene blue technique).

Table 3: Residence time of different evaporators

Evaporator	time (min)
Recirculation type	
Forced, falling	~ 40
Natural, rising	~ 23
Single pass	
Mechanically agitated	1.80
Tubular, rising/falling	0.90
Plate, rising/falling	0.33
Centrifugal	0.11

Fruit juices like orange juice and passion fruit juice are highly heat sensitive and hence have to be concentrated in evaporators having low residence time and temperature (or HTST, combining effect

iii) **Energy and cooling water consumption**

Steam and cooling water consumption are the two major factors determine operating cost. Their cost can be reduced in multiple effect evaporators (13). Steam consumption can be further reduced by vapor compression (14). Even though multistage evaporation almost proportionately reduces steam consumption, the optimum stages are limited by higher construction and operating costs. (15)(Table1).

3.0 Freeze concentration

Freeze concentration involves partial freezing of the product and removal of the pure ice crystals, thus leaving behind all the non-aqueous constituents in the concentrated phase (16). The process is particularly suited for concentration of liquid foods like fruit juices containing volatile aromas.

Present status of freeze concentration: Freeze concentration of fruit juices has claimed many advantages. Thermal damage to the product and aroma loss are minimum in this process. Energy needed to freeze a unit of water is only about that of vaporization. Energy can also be saved because the concentrate obtained in freeze concentration can be directly frozen before storage. It is further claimed that multistage freeze concentration processes reduce energy consumption (37-47%) and operating cost (50-70%) (17).

A major problem which still remains to be solved is that the final degree of concentration that could be achieved by freezing is much lower, only up to 50-55% w/w than that by evaporative process.

4.0 Membrane separation process

Concentration by evaporation and freeze concentration involves phase change which makes them energy intensive. Membrane concentration processes do not involve phase change. The application of membrane separation processes for concentration of liquid foods is of recent origin (18).Many advantages such as low operating temperature, selective dewatering and low energy consumption are claimed in favour of membrane concentration processes.

Osmosis and reverse osmosis: Concentration of fruit juices by direct osmosis has found very limited commercial application. Reverse osmosis (RO) is finding increasing application to concentration of fruit juices. Concentration of apple and orange juice s by RO has been carried out(19).Pre-concentration of tomato juice by RO from 5 to 8-8.5 prior to tomato paste manufacture was found to improveflavor and reduction in processing cost (20).

Membranes used for Ultrafiltration (UF) and RO: Cellulose nitrate and acetate membranes were the earliest to be used for UF and RO (21).Since 1975, many types of membranes having different chemical composition and functional properties have been developed. They include polyamides,(nylon), poly-Benz imidazole, sul-phonated dimethyl poly-phenalene.(22).

5.0 Comparative evaluation

Three types of concentration Viz. evaporative concentration, freeze concentration and membrane concentration have been applied to the concentration of fruit juices. The most challenging task before the processor is to choose the best process for a particular product. The economics of important concentration process such as evaporation with aroma recovery, freeze concentration and reverse osmosis has been carried out. (23).

Aroma volatiles are almost lost completely in evaporative concentration and partly in RO depending on the molecular size of the aroma constituents. These aromas could be recovered at least partly, by either separating them from vapour produced in the evaporator or the permeate during RO which can be subsequently concentrated in distillation column.In freeze concentration, aroma loss is minimum but loss of solids is possible due to flocculation, crystallization and insufficient separation.

The final concentration that can be achieved in the process affects the microbial stability of the product. The packaging, storage and transport cost. The maximum

concentration that can be obtained is primarily dependent on the viscosity at the maximum admissible process temperature.

Concentration cost: They include, labor, capital, maintenance, utilities, non-selective product loss and other cost aspects. Laborcost vary depending on the degree of automation and the capacity of the process unit. Capital cost is directly proportional to the installed cost of the concentration equipment including cost of spares and auxiliary equipment.

Costs of utilities: The main utilities are energy and water. Energy consumption is usually expressed in steam equivalents.

Cost of non-selective product loss: Substantial quantities of the product may be lost during concentration. In evaporation, about 0.1 % of the feed may be lost with the condensate due to entrainment. In membrane processes, product loss occurs because of the pin holes in the membrane and in freeze concentration solids can be lost along with separated ice, though in the new freeze concentration process, the loss is below 100 ppm.

6.0 Packaging and Storage

i) Drum filling

Most common used method of packaging FJC is into large metal drums lined with heavy industrial plastic bags, usually double.The cooled or chilled product is filled, weighed, the bags sealed and the drum lid fastened. The filled drum is then held in cold stored.

ii) Container filling- Aseptic

The method similar to the above can be employed for filling concentrate into containers aseptically. The treated product from the pasteurizing plant passes through aseptic filling machine where the pre-sterilized bag is filled and sealed under aseptic conditions.

iii) Canning

Cans of large capacity are used.The process employs a volumetric can filler to receive the heated product, sterilization and cooling process.

Fruit juice concentrates are semi-finished products and concentration of fruit juices using conventional concentration technique can sometimes give rise to the product with poor quality. Under such circumstance’s application of membrane technology will make the product more acceptable in the International market.