CONCENTRATION OF LIQUID FOODS

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Contents

Summary

This paper is a review of the current methods used to concentrate liquid foods. It includes a section on the physical properties of liquid foods and the effect of suspended solids on the flow properties of the raw and concentrated materials. It focuses on evaporation and membrane treatment as the main methods to concentrate liquid foods. A list of the principal types of evaporators is included, as well as tables describing the characteristics and applications of each type of evaporator. A section is included showing the basic equations needed to design and evaluate evaporation systems. This paper also reviews the main types of membranes used in the food industry, including ultrafiltration for the removal of suspended solids and reverse osmosis for the removal of water. A list of the different types of membranes and applications includes the different types of configurations and modules used to concentrate liquid foods. Emphasis is placed on the growing use of a combination of membrane pre-treatment and evaporation to concentrate liquid foods. The removal of suspended solids prior to

evaporation has several advantages, which are outlined. Examples of specific applications to liquid foods are also mentioned.

1. Introduction

The concentration of liquid foods basically consists of the removal of water to reduce the weight and volume of liquid food products. The main objective of concentration is to reduce packaging, transportation, and storage, and to improve the stability and handling of the product. Other purposes are to condition the product for subsequent processing operations such as drying (see *Drying*), crystallization (see *Crystallization*), and mixing (see *Food Mixing*); and to reduce water activity (a_w) to prevent spoilage and lengthen shelf life (see *Colligative Properties*).
There are several methods to concentrate liquid foods, but generally evaporation and membrane processes (like reverse osmosis) are considered the most important. Evaporation is the most widely used method. It involves the removal of water from a non-volatile component by turning the water into vapor though the application of heat and/or vacuum. Examples of foods typically concentrated by evaporation include fruit juices, dairy products, sugar, syrups, jams, and some canned foods.

Separation operations are based on principles that depend on the physical properties of the components of the liquid product and their differences (see *Separation*). For example, a separation process such as ion exchange depends on the difference in charges to separate different species from one another.

A separation process such as centrifugation relies on differences in solubility and specific gravity to separate blends of immiscible materials. In the case of evaporation, a volatile phase is separated based on the principle of vapor pressure difference between two or more components. In the case of membranes, separation takes place with the use of the difference in size or osmotic pressure of the components of a liquid food.

Food products concentrated by reverse osmosis are generally more heat labile; they include high-priced fruit juices, dairy products, and some pharmaceuticals. Desalination of seawater in countries with a low supply of fresh water represents the majority of concentration by reverse osmosis. In most reverse osmosis applications, the liquid products are pre-filtered using membranes with larger pore openings, such as ultrafiltration or macrofiltration membranes.

The industry has made major improvements, has diversified into different membrane systems, to help overcome the major limitations of concentration polarization and membrane fouling, due to the high pressures needed to obtain high product concentrations. Other membrane systems used in the industry include direct osmosis and osmotic distillation. Osmotic distillation has advantages, such as cheaper membranes and a longer life cycle.

In general, the methods used to concentrate liquid foods depend on the composition of the product, the sensitivity of the components to decompose with heat, and the economics of the process.

2. Physical Properties of Liquid Foods

Factors to consider when concentrating foods include recovery and preservation of flavor compounds, viscosity of the product, and the tendency of the product to scale or foul the concentration system. Table 1 shows some heat transfer properties of some common liquid foods.

Thermal and rheological properties of most liquid foods change with both temperature and solids content (see *Thermal Properties*, *Food Rheology and Texture*). The density and viscosity increase with the amount of dissolved solids. The viscosity always increases at lower temperatures. High viscosity affects the rate of heat transfer, and foods may become too viscous for adequate flow. The boiling point of the solution may also rise considerably as the solid content increases (see *Colligative Properties*).

Product	**Concentration (%)**	**Product temperature (°C)**	**ΔT (°C)**	**Evaporator type**	**U ($W/m^2.°C$)**	**Tube length (m)**
Dextrose	27-35	93	28	FF SP	1136	6.1-8.5
	49-78	57	22	FF SP	795	6.1-8.5
Corn syrup	35-43	57	22	FF SP	568	6.1-8.5
	57-82	93	28	FF SP	1022	6.1-8.5
Skim milk	88-212	68	14	RF SP	2158	3.0
	21.2-44	46	22	RF SP	988	3.0
Corn steep liquor	7.7	104	17	FF REC	1420	6.1-8.5
	50	57	19	FC	1022	-
Sugar	67	57	11	CAL	1476	0.6
	33	57	11	CAL	3407	0.6
	19	100	21	RF REC	2726	6.1
	50	43	19	RF REC	636	6.1
	39.5-67	93	22	FF SP PAN	943-477	2.4
	39.5-67	93	22	FF REC PAN	1124-676	2.4
Tomato paste	5-8.7	93	28	RF REC	1408	-
	8.7-20	77	17	FC	1022	-
	20.7-28	54	22	FC	721	-
	8	108	34	FC	3009	-
	12.5	87	18	FC	2413	-
	30	53	33	RF REC	823	-
Gelatin	2.75-4	92-104	7.38-9.7	RF SP	1959-2129	6.4
	4-6.4	78-95	8.9-13.3	RF SP	852-1334	6.4
	6.4-19.5	44-52	30.6-43.3	RF SP	159-244	6.4
Stick water	2-35	43-96	25-27.8	FF SP	909	6.1

Note: FF = Falling film, RF = Rising film or thermosyphon; FC = Forced-circulation; SP = Single pass; REC = Recirculating; PAN = Panel-type heat exchange surface; CAL = Calandria.

Table 1. Typical heat transfer coefficients for evaporative concentration of liquid foods. [From: Schwartzberg H.G. (1977). Energy Requirements for the Concentration of Liquid Foods. *Food Tech*. 31(13), 67-76.]

The flavor, texture, colors, and nutrients are also affected; therefore, both temperature and residence time are important criteria in selecting an evaporator. Some materials, especially liquid foods containing proteins, may foam during agitation and vaporization, and may cause entrainment of liquid into the vapor phase. Scale formation on the heating surfaces can present a problem when evaporating food that is high in solids. The overall heat transfer coefficient then steadily diminishes, until the evaporator must be shut down and the tubes cleaned. Scale may also be a result of local burn-on due to improper operation; hence the importance of designing efficient clean-in-place systems, as well as periodic cleaning and maintenance of the evaporator.

3. Concentration by Evaporation

An evaporator system generally consists of three principal elements: heat transfer, vapor-liquid separation, and vapor condensation. The units in which heat transfer takes place are called heating units or calandrias. In order to save energy, many food evaporation systems use what is known as multiple-effect evaporation. A multiple-effect evaporator is an evaporator system in which the vapor from one effect is used as the heating medium to boil a subsequent effect at a lower temperature. This type of system is usually used under vacuum in order to sustain evaporation at the lower temperatures.

Evaporation remains the most widely used method to concentrate liquid foods. The design of heat transfer surfaces and evaporation systems is continuously being modernized. For example, new applications now exist in the multiple effect evaporation system in orange juice to regulate more closely the final Brix of the concentrated juice. This minimizes variability of Brix in the concentration. These computerized systems are more adaptive. Model-predictive control software can adapt dynamically to process changes, dealing with the many interrelationships in the evaporation process. Examples of control variables are feed rate, discharge concentration, and variation in feed rate to control the final concentrate. Feedstock concentration changes are tightly monitored, and changes in steam pressure are used to predict the effect of pressure change in the brix of the final product.

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Biographical Sketch

Dr. Ernesto Hernandez is a Food Science Associate Professor and the Head of the Fats and Oils Program at Texas A&M University, where he leads research and training on processing of oilseeds and vegetable products. Dr. Hernandez has conducted extensive research on the processing of liquid foods; he is currently involved in developing new processing techniques for the recovery and application of nutraceutical components from oilseeds and vegetable by-products through enzymatic and adsorptive processes. He is also actively involved in contract research to implement new refining technologies on the use of buffered caustic solutions for the refining of vegetable oils.