

434c Model and Analysis of Vacuum Membrane Distillation for the Recovery of Volatile Aroma Compounds from Black Currant Juice

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Fruit juice technology involves a purification operation where the solid content of the juice is increased from 10–12% up to 65–75% by weight. The fruit juices are concentrated to reduce liquid volume, which not only lowers the costs in terms of storage, packaging and transportation, but also assists in preventing microbial spoilage of the juice concentrate. In industrial juice processing plants, juice concentration step is usually accomplished by aroma-stripping and the stripped aroma concentrate is later added back to the concentrated juice.

The most commonly used method for fruit juice concentration and aroma-stripping is one or several multistage falling film vacuum evaporators connected to a separate aroma recovery plant. In one of the consequent steps the aroma compounds are subjected to high temperature rectification (counter current distillation), condensation and washing. During high temperature distillation the aroma profile of black currant juice has been demonstrated to undergo an irreversible change that results in heat induced transformations of sensory attributes (color, taste and aroma) and loss of nutrients (vitamin C).

Lately, membrane distillation, reverse osmosis and pervaporation have been considered as alternatives to the conventional techniques for the purification step in fruit juice industries. Lower operating temperatures and reduced vapor spaces (as compared to conventional distillation), lower operating pressures (as compared to other pressure driven membrane separations), reduced chemical interactions between membrane and process solutions and less demanding membrane mechanical property requirements are some of the benefits of membrane distillation over other more popular separation processes.

Based on the method to create the pressure difference between the feed and the permeate side, the membrane distillation can be classified into different modules, such as direct contact membrane distillation (DCMD), sweeping gas membrane distillation (SGM), vacuum membrane distillation (VMD) etc. In VMD the feed solution is brought into contact with one side of the microporous membrane, and a vacuum is pulled on the other side to create a driving force for trans-membrane flux. This microporous membrane acts only as a support for a vapor-liquid interface. Depending on the membrane pore size and the system operating conditions the VMD membrane may impart some selectivity based on individual Knudsen diffusing species, but the largest degree of the separation is realized as a result of the vapor-liquid equilibrium conditions at the membrane solution interface. One of the benefits of VMD relative to the other MD configurations is that conductive heat loss through the membrane is negligible.

The unique aroma profile of black currant juice comprises more than 60 constituents but we have used the twelve most characteristic aroma compounds to validate our VMD model. This functional model of VMD predicts the permeate concentration of the aroma compounds given the feed composition, operating temperature and vacuum pressure. The feed concentration of the aroma compounds have been fixed at 1 ppm for the simulations (which is in accordance with the available experimental data). The concentration of aroma compounds in feed is so low that it was assumed that the presence of one aroma compound does not affect the transport of another. This assumption ultimately leads to the simplification of the model resulting from taking the system as twelve binary systems of each aroma compound with water rather than a multicomponent system. This functional model is integrated with the property models for both the aroma compounds and the polymer(s) used for the membrane. The model has been already validated using experimental results.

The calculations described above assumed a specified polymer with the corresponding properties as a membrane but a design problem we are currently investigating is to find an optimal polymer that would satisfy the separation needs with respect to higher fluxes and purity. This could be done by using the developed VMD model in the reverse mode to determine the desired properties that would achieve a required separation and then designing a polymer that could have these properties. This has not been done previously. One reason for this has been the unavailability of experimental data of end-use properties as a function of microscopic structural parameters (branch structure) measured through a systematic design of experiments. As these experiments are complex, time consuming and expensive, an alternative is to generate data through molecular modeling, and, based on these, design experiments to obtain also experimentally measured data. Through our collaboration with the ICE-FORTH institute in Patras (Greece) we have obtained an initial set of data based on molecular modeling to develop the necessary end-use models for structured polymer design.