Adding Value: The treatment of juices and liquid foods with ion exchange resin and adsorbent polymers

1) Introduction

Bucher Unipektin AG in Switzerland, and its subsidiary Bucher Alimentech Ltd in New Zealand have been working for decades on researching, developing, and deploying fruit juice and liquid food technologies using ion exchange and adsorptive polymers. There are now close to 100 machines operating in 24 countries on six continents. Our international team of chemists, food scientists and engineers of various disciplines collaborate closely to provide complete skid-mounted solutions applying these technologies.

Adsorption vs Ion Exchange

Both of these processes rely on pressure vessels containing small porous polymeric resin beads, typically less than 1 mm in diameter. Juice flows through the vessel, making contact with the beads, which then removes undesirable target components. When exhausted, the resin bed can be automatically regenerated, and reused.

Adsorption: The chemical nature and physical structure of the polymer beads provides an environment which adsorbs mostly macromolecules using physical chemical attraction forces (primarily van der Vaal and London forces).

Ion exchange: The resin is manufactured to have “functionality”, which means a chemical group is added onto the beads’ polymer matrix which can then attract ionic components in the juice.

The economic benefit of these technologies generally falls into two categories:

(i) Upgrading of juices to higher value, or being able to use cheaper fruit, using processes such as debittering, deacidifying, decolourising etc.
(ii) Use of by-products or wastes, such as deionisation of waste juices, or treatment of aqueous extracts from solid wastes, to recover valuable components to re-integrate into prime juice, or be used elsewhere.

This paper will discuss a number of applications relevant to juice producers.

2) Citrus debittering

This is an example of an “Adsorption” process. The bitter principles are reduced by up to 95 % with minimal affect on other characteristics of the citrus juice. The process is particularly useful for prime juice from early season navel orange and grapefruit varieties, and even HLB-affected fruit (citrus greening). Of additional interest is the ability to lower the very high bitterness content of peel extract and pulp wash. This can enable inclusion of these at a much higher percentage in drink formulations than would otherwise be possible.

Incoming juice is centrifuged to less than 1.0 % spin-down pulp. This pulp-reduced juice then flows through a bed of Alimentech P-495 adsorbent resin. On completion of the cycle, juice flow then switches to a second vessel, thus ensuring continuous operation. The exhausted resin can then be washed and regenerated with caustic and acid.
and can be used again and again for many years. Meanwhile, the separated pulp can be reintegrated into the juice exiting the plant.

Combining debittering with deacidification and having the ability to independently control the degree of both gives the citrus processor opportunities for maximising usage of fruit from a variety of sources and of varying qualities.

3) Acid reduction

This is an example of an Ion Exchange process. Whilst mechanically the process is very similar to debittering, it is chemically quite different. An ion exchange resin (Alimentech A-100) is used to remove acid. Also, the juice flow is carefully controlled so ensure the acid content in the juice does not drop too low.

A benefit to the processor of deacidification can be reduced reliance on imported high-ratio concentrate with a consequent reduction in inventory and cost. Furthermore, low ratio fruit can often be bought at a lower cost.

4) Apple and pear haze stabilisation

Haze formation can occur on reconstitution of stored apple juice and concentrates, even after ultrafiltration, due to the formation of protein phenolic complex. This can be treated using an adsorber system which uses the hydrophobic nature of the problem phenolics and peptides to be selectively captured by adsorbent resins. Colour is simultaneously reduced with the process to provide a low coloured, haze-stable concentrate with superior storage stability.
5) Decolourisation

Using a macroporous adsorbent polymer, the colour of apple, pear, and grape juice can be rendered almost colourless for use in light coloured beverages. Dark or old concentrates can be lightened for inclusion in standard juice products, or used in other applications. The opportunity is to use low cost or even unusable stocks.

6) Deionisation and fruit syrup production

Using a pre-determined combination of both ion-exchange resins and adsorptive polymers, commercial deionisation has been deployed at a number of producers in South-East Asia, Europe and Australia.

A common application is to produce a clear natural sweetener, used as canning syrup, or to manufacture high value fruit sugar concentrates. For example, the use of pineapple skin waste extract known as PMJ (Pineapple Mill Juice), by producers in Thailand, Indonesia and the Philippines.

7) Safety and compliance

All processing plants are designed and built to comply with either the CE or UL standards applicable to this type of machine, and the pressure vessels are ASME rated. For the taller Citrus Debittering Plant, the structure is designed in accordance with the appropriate Building Code for seismic strength, and OSH regulations.

8) Sustainability

This is a technology that can take materials that would otherwise be disposed of and turn them into valuable products. This is an obvious benefit both economically and environmentally, as food wastes can impact air, land and water quality. Furthermore, an increase in overall yield of products from the same quantity of fruits means we are able to supply more consumers per unit volume of raw materials.

Electrical demands from these processes are also minimal. A case study of the comparative citrus debittering system plus upstream centrifuge identified it used around 80% less power than alternative systems. Other systems use expensive and unreliable filtration membranes that often need replacing. Avoiding this waste, reducing power, and the use of simpler chemicals; this alone has helped justify replacement with our systems, with additional quality benefits.
Whilst the processes require water, caustic and simple acids to regenerate the resins, steps can be taken to reduce their volume and impact. Water and chemical reuse system are employed, and in some cases effluent creation can be carefully planned so they balance the pH of other waste streams in the factory, to create more neutral effluents.

9) Production economics

It has to be said that each process, and indeed, each client will have very different production economics.

However, by way of example, the calculation below is a model of an Australian customer who was able to procure Navel orange at 100 AUD / Metric Ton (68 USD). Whilst freshly extracted early season Navel Orange juice may not be bitter, after expression, the non-bitter compound limon-A-ring-lactone converts over time to bitter limonin.

Other than the cost of fruit, other marginal costs of debittering (excluding amortisation of capital cost of the plant), can be very minor and include regenerant chemicals (caustic and acids), water (which can be clean condensate), and a 37 kW centrifuge upstream. Also, it is estimated that 0.1 FTE (full-time employee) per shift is generally used to oversee the plant alongside their other duties, due to the high degree of automation.

The example diagrammed in fig. 4 is a framework only and each processor should consider local conditions, and of course, to consider all other additional costs such as evaporation, and packaging etc.

10) Conclusion

Consumer demands change, challenges occur in the supply side of the business, and environmental and regulatory pressures are increasing. As the Greek philosopher, Heraclitus said “the only thing that is constant is change”. To adapt to these pressures, producers might look at all opportunities to extract more value in their operation. Our machinery is robust and the designs have been refined and optimised over the years to provide excellent cost of ownership, ensuring opportunities for our customers to add significant value to their business.

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