5. Separation

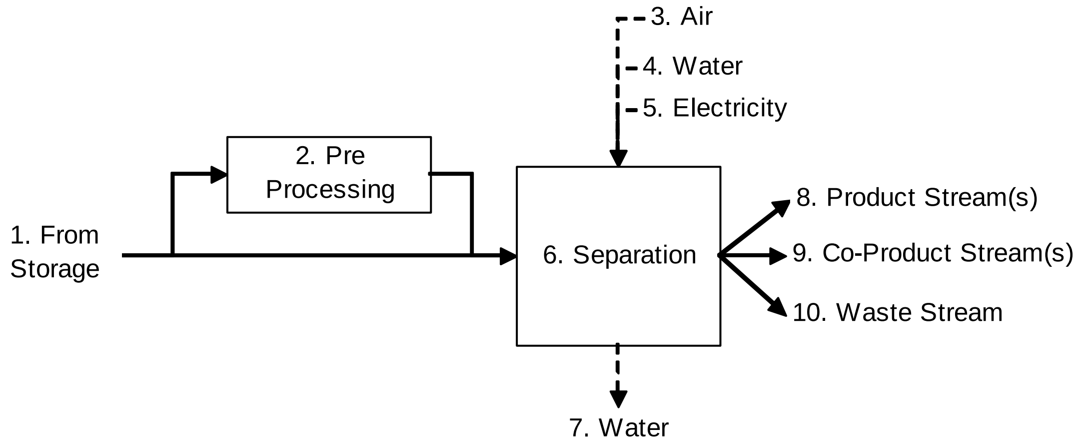

Figure 5.1 – Separation system diagram

SEPARATION SYSTEM OVERVIEW (REFER TO FIGURE 5.1 ABOVE)

Separation is simply the process of dividing material into its component parts. This may involve separating a solid from a solid, such as removing nuts from their shells; separating a solid from a liquid, such as removing pulp from juice; removing a liquid from a solid, such as squeezing oil from a kernel of corn; removing a liquid from a liquid, such as separating fat from milk; or removing gas from a solid or liquid, such as vacuum canning.

Separation is a process that is arguably more important to the bottom line of food processors today than any other. This claim is based on three factors:

- multiple value streams from one raw material
- improved yields
- energy savings in downstream processes

Separation adds value to the extracted product, its residue, or both. As the United States seeks to reduce its reliance on fossil fuels, the economic importance of effective separation has never been greater. Petroleum is used to produce a large number of industrial products from fabrics to paints to chemicals to medicines. Nearly all of these goods can be produced with biobased materials. A cluster of biobased manufacturers, referred to as a biorefinery, can produce food, enzymes, medicines, and fuel in one complex. What was previously considered waste now can be separated and processed, and used to make a variety of products. This can significant increase profitability.

As shown in Figure 1.1, material may come directly from storage (1), or it may undergo some pre-processing (2), such as size reduction, before entering the separation process (3). It is possible to separate foods based on many physical properties including size, shape, density, viscosity, solubility, and thermal, diffusional, and optical properties. For this reason, the food processing industry uses many different methods to separate materials. Several are described below.

Sedimentation relies on gravity to separate solids from fluids. Large pieces of equipment are needed to handle economic volumes and still allow sufficient time for proper settling. In continuous flow operations, flow rates are usually low to avoid agitating the sediment; the process must include a way to remove sediment without re-contaminating the fluid.

In many cases, gravitational sedimentation is too slow. For example, if whole milk is left to stand, the cream will rise to the top and eventually there will be a clean separation from the skim milk. However, this process takes many hours to complete, which makes it too costly.

Centrifugal sedimentation accelerates the separation rate. Many different designs are available for applications from milk separation to removing solids from beverages and dewatering sugar crystals. The most common application of centrifugal sedimentation in the food industry is probably the use of cyclones.

Flotation is used in applications where the particles to be removed adhere to the surface of a bubble. The bubble rises to the surface and the froth, which contains the target particles, is easily skimmed. This is commonly used to remove fat from wastewater.

Filtration uses a porous medium to prevent the passage of particles above a certain size. The objective is either to remove a relatively small amount of small solids from a valuable fluid or to separate slurry into a solid cake and a liquid. In the latter case, the cake, the liquid, or both could be the desired product. Examples include filtrations of juices to remove high levels of insoluble solids and yeast recovery after fermentation in the brewing industry.

Membrane separations are used when the size of the target particles is too small for conventional filters. Terms such as hyperfiltration (reverse osmosis), ultrafiltration, microfiltration, and nanofiltration are used to describe methods of membrane separation. These are used in water treatment and milk processing as well as to create high concentrations of fruit juices. Instant coffee concentration also makes use of membrane technology because it has been proven to give better retention of aromatics.

Screening is used to separate material into various particle sizes. A single screen or sieve may be used to separate material into two streams, or a series of screens may classify the material into multiple sizes. The time required to separate by screening is affected by size of the particles, size distribution, density, intensity of the vibration, and humidity of the air. Screening is used, for example, to separate the various fractions of flour.

Air classification may be the original separation process. The separation of chaff from wheat by winnowing is a simple method of air classification. When performed in an enclosed chamber, lengthening the chamber, including collision surfaces, or adding centrifugal force can increase separation effectiveness. “Cut size” indicates the desired point of separation. Ideally, all particles smaller than the cut size end up in the fine stream, and all particles larger than the cut size end up in the coarse stream. The extent to which each stream is "pure" determines the efficiency of the process. Air classification is used in the cereal and legume industries to separate components (particularly proteins).

Electrostatic sorting is used to clean some raw materials. The solids are fed into a rotating drum that is electrically charged, or grounded, and particles in the air that have the opposite charge are attracted to the drum and scraped away. Humidity must be controlled for this process to be effective. Electrostatic sorting is used in the tea and cereal sectors to remove dirt or unwanted residues.

Reflectance refers to the ability to reflect light off the product. This enables optical sensors to detect color differences on the surface of products. Applications include sorting ripe produce from green fruit and vegetables and then rejecting discolored or spoiled product.

Expression uses mechanical forces to separate liquids, such as oil or juice, from within the cellular structure of plant material. Belts, rollers, or rotating screws provide the force to express fruit juices, cane sugar, and oil from seeds.

Extraction is used for similar purposes as expression, but it relies on the different solubility of the components to be separated. A liquid is thoroughly mixed with the components and then the streams are separated. Coffee and sugar are commonly extracted from the bean or cane/beet, respectively. "Many oil extraction processes employ expression, followed by solvent extraction, to obtain a high recovery of oil."[12]

Crystallization separates a solid component from a liquid solution. "Soluble components are removed from solution by adjusting the conditions so that the solution becomes supersaturated and excess solute crystallizes out in a pure form. This is generally accomplished by lowering the temperature or by concentration of the solution, in each case to form a supersaturated solution from which crystallization can occur."[13]

Dehulling and *peeling* are separation processes that remove the outer covering from the raw material. Dehulling is usually accomplished by milling, and efficiencies can range from 85 to 95%.[14] Peeling is done by abrasive, chemical, or thermal mechanisms. All present some risk of damaging the product.

Separation will create a product stream (8) or product streams, and possibly a co-product stream (9) or co-product streams, and possibly a waste stream (10). The co-products may or may not be used in the food industry and may or may not be further processed in-house. The co-products may be packaged and shipped or, in the case of a biorefinery, simply piped to an adjacent processing facility.

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[12] *Separation Processes In the Food and Biotechnology Industries*, Edited by Grandison and Lewis, Woodhead Publishing Limited, Cambridge England, 1996.

[13] *Unit Operations in Food Processing*, R.L. Earle, The New Zealand Institute of Food Science and Technology, http://www.nzifst.org.nz/unitoperations/index.htm.

[14] *Separation Processes In the Food and Biotechnology Industries*, Edited by Grandison and Lewis, Woodhead Publishing Limited, Cambridge England, 1996.

ENERGY EFFICIENCY

In most cases, the separation process itself is not energy intensive. *Electric motors* are widely used to power conveyor belts, rotating drums, fans, screw presses, vibrators, scrapers, etc. Information on them and their energy efficiency is contained in the Appendix. *Pumps* are also used in separation processes and are discussed in the same Appendix.

Process heat is used in many separation processes. In general, heat increases the efficiency of the separation. "However, there are limitations with biological materials: higher temperatures increase degradation reactions, causing color and flavor changes, enzyme inactivation, protein denaturation, loss of functionality, and a reduction in nutritional value. Safety issues with respect to microbial growth may also need to be considered."[15] Factors effecting energy efficiency in the generation of process heat are covered in the process heat chapter.

PRODUCTIVITY

The purity that is achieved during the separation process affects both yield and energy productivity. Yield, the amount of usable product after separation compared to the total amount in the raw material, has obvious impact on the productivity of the operation. As yield increases, so does productivity and profitability.

In addition, the yield and purity of the extracted product have a significant impact on the energy required for downstream processing such as drying. This, in turn, increases the energy efficiency as the total amount of product made per unit of energy increases. Thus the true cost of production decreases.

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[15] *Separation Processes In the Food and Biotechnology Industries*, Edited by Grandison and Lewis, Woodhead Publishing Limited, Cambridge England, 1996.

RESOURCES

Printed Material

Grandison, A.S. and Lewis, M.J. eds., Separation Processes In the Food and Biotechnology Industries, Woodhead Publishing Limited, Cambridge England, 1996.

Perry, R.H., Green, D.W., and Maloney, J.O. eds., Perry's Chemical Engineers' Handbook, Seventh Edition, McGraw Hill, 1997.

On-Line Tools

Earle, R.L., Unit Operations in Food Processing: http://www.nzifst.org.nz/unitoperations/index.htm

Organizations

Association of Energy Engineers: www.aeecenter.org

International Energy Agency: www.iea.org

Iowa Energy Center: www.energy.iastate.edu

Iowa State University Industrial Assessment Center (IAC): (515) 294-3080 or www.me.iastate.edu/iac