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Introduction
How often do you need to reduce the size of a food in the kitchen? Almost every time you prepare a dish. In the kitchen, manipulation of size is mostly needed to accelerate heat and mass transfer, to separate different parts of a material, to mix ingredients, and to obtain uniform cooking (as in the wok). Size reduction continues on your plate as you portion your bite and then in the oral cavity during mastication (Chen, 2009).

In engineering, size reduction is one of many “unit operations” or actions that must be taken on a material as part of a process. Size reduction is divided into two major categories depending on whether the material is a solid (grinding and cutting) or a liquid (emulsification or atomization) (Earle, 1983). Technically, forces acting on a body produce the fracture or shearing of the material. While engineers are mostly concerned with the energy involved in grinding, cooks appreciate the effects of size reduction in cooking (i.e., colour, flavour and texture).

Cutting
Cutting is the controlled separation of a material into two or more parts using a blade or a sharp tool (Atkins, 2009). Cutting takes many names in the kitchen: slicing, flaking, dicing, shredding, mincing, etc., leading to several types of cuts. For example, julienne are basically thin strips; batonnet refers to rectangular sticks; brunoise are small dices; and chiffonade is a cut for vegetable leaves and fresh herbs whereby they are stacked, rolled and then sliced as thin strips. Cutting is quite relevant in cooking, since the time for doneness is proportional to the square of the thickness of the piece (e.g., in a steak or roast).

Grinding
Some structures produced by nature must be destroyed, or at least significantly modified in their size and shape, in preparation for processing, cooking or consumption. If food structures were not destroyed, there would be no fruit juices or wine to drink and no flour, sugar or oil to make baked products. There are several methods to effect drastic physical changes in the structure of foods, some of which are shown in Figure 76.1.

Size reduction (grinding, milling, crushing, etc.) is a frequent intermediate stage to prepare materials for further uses. Grinding reduces ingredients to a finer size, resulting in a powder or a collection of particles that can be as small as a few micrometres. Reduction in size facilitates an intimate mixing, improves the appearance of the product, increases the surface/volume ratio (e.g., for more even cooking), and accelerates the transfer of heat and mass (as in frying, extraction, impregnation or moisture conditioning). For example, roasted coffee grains are ground in a mill to speed up and improve extraction in hot water.

Food engineers know that not all grinding machines produce the same type of particles. Wheat is ground first between serrated cylindrical rolls separated by a narrow gap to break open the grain. Successive passes through smooth cylindrical rolls “scrape” off particles of a frail white endosperm, leaving the plastic and deformable bran (fibrous outer layers) intact. This process can go on until approximately 78% of the weight of the whole grain becomes white flour.

Roasted coffee grains are pulverized at home with high-speed rotating blades, but commercially, they are ground between two rotating hard plates that rub together. The particle size of powders is often controlled by periodic sieving and removal of “fines”

FIGURE 76.1  Mechanisms of size reduction for solids and liquids.
from the already disintegrated fraction, while the coarse particles continue the grinding process (see the chapter on coffee in this book). Parmesan cheese should be shredded and garlic cloves crushed with a press. Size reduction of cellular tissue causes the fracture of cells, exposing the internal contents. Breakage of the cells of plants releases enzymes that can participate in biochemical reactions altering the colour and flavour (e.g., browning of potatoes or the pungent flavour of garlic). Therefore, it is often recommended to apply a mild heat treatment beforehand to inactivate enzymes (blanching) and later protect the tissues from air once they are cut (e.g., by putting them under water).

**Emulsions and Suspensions**

A food emulsion is a dispersion of a liquid into another one, produced by the application of energy in the form of shearing forces (Figure 76.1, far right). As a result, one of the liquids becomes the dispersed phase (droplets), while the other is the surrounding medium, or continuous phase. The droplets in a liquid emulsion generally vary in size from 1 to 100 micrometres and have some sort of emulsifier on their interfaces. Creams and many sauces are oil-in-water emulsions with soft, creamy, palatable consistencies. A food suspension is a two-phase system in which rigid or soft particles are dispersed within a liquid, as in fruit juices and some salad dressings. The sedimentation rate in which rigid or soft particles are dispersed within a liquid, as in fruit juices and some salad dressings. The sedimentation rate of particles depends on their density and is proportional to the square of their size.

**Processes and Equipment**

Equipment used in food engineering for size reduction of solids and emulsion formation is thoroughly described in Brennan (2006). Moisture content, food composition and temperature are key factors in the fracture properties of solid foods. Usually, dry material is easier to grind than wet material, and lower temperatures increase brittleness and favour the breakage of otherwise sticky, oily or fatty foodstuffs. Since, during size reduction, energy is introduced to the system, a large proportion of it is converted into heat, and chefs have to be aware that this influences odour retention and colour.

The Pacojet™ is a kitchen appliance that was patented in 1992 and that allows grinding of pre-frozen materials as well as the preparation of frozen desserts and ice cream. Cryogenic grinding of frozen brittle material produces finer particles and lower volatilization of aroma compounds than conventional milling. It has been used advantageously to grind spices (Balasubraman et al., 2012). Although, in industrial practice, many different types of mills are used, the kind of appliance used in the kitchen depends on the type of material (wet tissue, dry solids, liquids, frozen foods, etc.) and the final expected result (coarse or fine paste, powder, emulsion, etc.). Specific apparatus and applications are dealt with in extenso in Myhrvold et al. (2011). The mini-pimer or hand-held blender with a high-speed set of rotating blades is one of the most used appliances in home kitchens to disintegrate all kind of foodstuffs; its name comes from the acronym of its Spanish designer, Pequeñas Industrias Mecanico-Electricas Reunidas (PIMER).

**Measuring Particle Size**

Often, materials containing pieces, particles or droplets need to be characterized for the size (and sometimes the shape) of the dispersed phase. There are several means of measuring particle size:

- Sieve analysis is the oldest, cheapest and easiest way, and utilizes standard sieves with calibrated grids to classify the dry or wet material into size fractions as they pass or are retained in progressively smaller mesh sizes. The weight of material retained over a sieve is expressed as a fraction of the total mass.
- Image analysis utilizes a digital image acquired with a camera, either directly or using a light microscope if particles are relatively small (e.g., less than 0.1 mm). Particles should be dispersed so that they do not touch or overlap each other. Then, software identifies, counts and determines different sizing parameters (Saragoni et al., 2007). This method is simple and can be used for small dry or wet particles, as well as for droplets in emulsions. In the latter case, phase contrast may be enhanced using chemical stains. It also provides information on the shape of particles (e.g., roundness, aspect ratio, etc.).
- Laboratory methods. There are several laboratory instruments that measure and count particles down to the nanometre size (Robins, 2006).

**Particle Size Distributions**

One must be aware that any size reduction method will yield a distribution of particle sizes, which can span several decades in size. A typical size distribution graph obtained by sieve analysis (histogram) is a plot of the relative percentage fraction versus the respective size interval (Figure 76.2).

![FIGURE 76.2 A particle size distribution curve (histogram and curve).](image-url)
A curve may be adjusted using curve-fitting techniques (Barbosa-Cánovas et al., 2005).

Most particulate systems are characterized by a single parameter: the average size (or the mode). Cooks should be aware that finer and coarser material than the mean size are also present in the product. Stored food powders may change their size distribution curves, particularly those containing amorphous components such as sugars and protein hydrolysates. Unfavourable storage conditions of high temperature and high moisture content favour the formation of lumps and agglomerates, a phenomenon called caking (Aguilera et al., 1995).

REFERENCES