- Microwave drying – this is often used in combination with hot air drying. It may cause browning of the material, but it is useful in reduction of microbial contamination (Oztekin and Martinov, 2007).

Size reduction

The main aim of size reduction of the dried material is to create particles of similar size which permits uniform and maximum extraction of the required plant material. The rate of extraction is dependent upon the rate of diffusion of solvent into the plant material and of solutes from the material into the surrounding solvent. Hence reasonably fine powders are preferred, with diameters approaching 0.5 mm.

Care must be taken during size reduction of fresh (undried) material as in some cases it can lead to degradation of constituents via a number of chemical reactions and also endogenous enzymatic action. Low temperature can be used to reduce these possibilities and deep freezing may be required during storage of fresh materials prior to comminution (Bombardelli, 1991).

Size reduction can be carried out using a variety of crushers and mills, usually fitted to a magnetic separator to collect extraneous metal particles. Dust collection devices are imperative for this process. Typical types of size reduction apparatus (see Chapter 10) used for plant material include:

- cutting and shredding mills for leaves and herbs
- hammer and pin mills for herbs with high fat content
- shredding and hammer mills for roots and barks
- further specialized mills for difficult samples.

Size reduction of plant material is a very inefficient operation, with only about 1% of the energy input directly responsible for the size reduction (Chaudhri, 1996).

Extraction of active constituents

Types of extracts

The next step in the process is to remove the active constituents from the dried and powdered plant. This is achieved mainly by the process of *extraction*. In its most common form, extraction consists of soaking the powdered material in a liquid (usually aqueous or ethanolic) solvent. The solvent diffuses into the powdered material, dissolves the ingredients which then diffuse out into the liquid. Decreasing particle size of the plant matrix, within limits, will therefore decrease extraction time.

The major types of liquid product obtained by this process and then used in the manufacture of medicines include (Bonati 1980, Vlietinck et al, 2009):

- decoctions and infusions
- liquid extracts and tinctures
- soft and dry extracts
- purified (refined), standardized and quantified extracts
- single chemical entities.

Each of these products has particular advantages and disadvantages.

Liquid extracts are preferred over decoctions (plant boiled with water) and infusions (plant stood in hot or cold water) because of the higher concentration of active constituents in the extract. Liquid extracts are produced by extracting 1 part of plant material with 1–2 parts of solvent, whilst tinctures require 1 part of plant material with 5–10 parts of solvent. These liquid extracts can be incorporated directly into semi-solid formulations such as ointments or into liquid formulations such as drops or solutions (Vlietinck et al, 2009).

The choice of extract type depends on the intended application; dry extracts (liquid extracts that have been subsequently dried) are suitable for tablet/capsule formulations, while solvent extracts are more widely used in liquid formulations.

Purified (refined) and standardized extracts are intermediate between crude extracts and single chemical entities and as such have widespread application. They avoid the need to separate complex mixtures, but provide knowledge of the levels of constituents.

It is important to appreciate that with many plant materials a single chemical entity usually has the greatest activity, although synergistic interactions may increase the activity of complex mixtures.

All types of extracts need to be made with knowledge of the polarity of targeted constituents, which may impact on cost of the most appropriate solvent for the process, waste solvent disposal, extract stability, etc. The composition of most end materials is highly dependent on the procedures used for extraction, and often the most valuable constituents are produced using the most sophisticated processes.