in a continuous process unless significant vacuum is used and the crumb is left static during the last stages of drying. This has the disadvantage that it makes the mixture less likely to crystallise.

6.6.5 Overall particle size distribution

The final structural element of crumb that is vitally important is the particle size distribution. The earliest batch oven crumb was composed largely of 1.0–2.5 cm (0.5–1.0 in) lumps with a minimal amount of dust. This is very important to the crumb's handling characteristics. Very dusty crumb cannot be stored in large bulk without severe compaction problems which lead to bridging in hoppers, build up in conveyors and so on. One of the great difficulties with newer continuous processes has been their tendency to create too much dust.

The most successful crumb processes create lumpy product just prior to the final drying stage and preserve it through drying as well. Vigorous tumbling action during drying creates very dusty crumb, which is hard to handle.

One option to eliminate dust problems is to form the finished crumb into uniform sized "briquettes" in a high pressure forming device. Processes to do this are described in the patent literature (Nestec S.A., 1978; Mars Inc., 2000).

6.7 Typical crumb processes and equipment

The different stages of a typical milk crumb process listed in Table 6.3.

The first stage of the crumb process involving pasteurising and evaporating the milk is exactly the same as in other dairy processes. Pasteurisation is ensured

Table 6.3 Crumb processing stages

Material	Process	Solids (%)	Water (%)
Full cream milk		12.5	87.5
	Pasteurising/evaporating		
Concentrated milk		50.0	50.0
	Sugar dissolving		
Sweetened condensed milk (SCM)		72.0	28.0
	Air/vacuum cooking		
Cooked SCM		88.0	12.0
	Cocoa liquor addition		
Crumb paste		90.0	10.0
	Kneading/mixing		
Kneader paste		90.0	10.0
	Air/vacuum drying		
Dried crumb		99.0	1.0

by keeping the milk at 72 °C (162 °F) for at least 15 s. Evaporation is carried out in multiple effect evaporators to the solid content required. Granulated sugar is then dissolved in the condensed milk according to the recipe. Treatment of the SCM from this point onwards varies substantially, the more modern continuous processes having, to differing degrees, all tried to mimic the original batch oven process which will be described first.

6.7.1 Batch oven process

- *Cooking* of the sweetened condensed milk was done in large pans under partial vacuum at around 75 °C (167 °F) with rapid boiling. When the solids reached about 88%, signs of crystallisation could be recognised by a skilled operator through an inspection window. At this point cocoa liquor was put into a heavy duty melangeur pan (Chapter 1) again according to recipe and the crystallising SCM gradually discharged from the vacuum pans.
- *Kneading* of the stiff paste at this point was carried out for about 30 min. Samples of kneader paste were examined under the optical microscope to ensure that crystallisation was extensive and that the sugar crystal size was less than 35 μm. It was believed that coarser particles than this could cause difficulties in later chocolate refining. When the operator was satisfied, the kneader paste was charged onto trays and placed on shelves in a vacuum oven.
- *Vacuum oven drying* reduced the crumb moisture content to around 1%. The drying temperature was varied from 75–105 °C (167–221 °F) depending on whether the shelves were heated with hot water or steam. The drying time was in the range 4–8 h. Virtually all the typical crumb flavours were developed during this last stage.
- *Crushing and storage.* The contents of the oven trays were put through a rotary crusher to reduce the crumb to pieces of 1.0–2.5 cm (0.5–1.0 in) size with as little dust as possible. This material was then stored either in protectively lined bulk storage bags or in cylindrical silos of up to 500 t capacity.

Because of the very large labour input into filling and emptying trays, much effort over the last 50 years has gone into developing continuous processes that can replicate the key steps of cooking, kneading and drying, while producing a similar flavour and texture. Some of the variants will now be described.

6.7.2 Continuous processes

A number of options have been used for continuous cooking of the sweetened condensed milk up to a solids content of around 88%. These include:

- Scraped surface evaporators;
- Falling film evaporators.

These and other processes are critical to the whole crumb process. Many of them are proprietary, however, and so cannot be discussed in detail.

There is much more information on various whole, continuous processes and last stage drying steps from the 88% solids stage onwards. These will now be described.