3 The post treatment of the tempered chocolate masse in pumps, moulding devices, coating devices/enrobers;
4 The cooling and solidification process;
5 Post tempering and storage temperature conditions;
6 The factory environmental conditions.

Tempering-related *structural aspects* are:

1 The fat crystal fraction;
2 The fat crystal size distribution;
3 The fat crystal polymorph distribution (the relative amount of each type of crystal present);
4 The fat crystal network density (total amount of crystal) and its homogeneity;
5 The crystallisation kinetics (how fast the fat will set);
6 The polymorph transformation kinetics (how fast one type of crystal changes into another);
7 The migration kinetics of liquid components through the fat crystal/particle network (how fast the liquid fat components move through the solid network formed by the fat crystals and the other solid components).

13.2 Physics of cocoa butter crystallisation

Chemically fats are triglycerides with three fatty acids connected to a glycerine molecule. Most fat systems form crystals with several different polymorph (same chemical composition different molecular arrangement) structures. For fats containing only a small number of triglycerides like cocoa butter (with SOS, POP, SOP triglycerides; S denoting stearic acid, P palmitic acid and O oleic acid) up to six different polymorphs have been identified (γ, α, β_{III}, β_{IV}, β_V, β_{VI}, see also Chapter 7). Different crystal types are formed depending upon the steric (ability to fit together because of shape) or energetic compatibility of the molecules, the temperature/temperature gradients they are submitted to and for how long this takes place. The higher the temperature and the longer the crystal formation time, the denser and more perfect molecular ordering occurs (i.e. the individual molecules can pack more closely together, giving a higher crystal density). This is demonstrated in Figure 13.1 and Table 13.1.

Different forms of nomenclature for the polymorphs are shown in Table 13.1. Within the chocolate industry and the scientific community it is accepted that the β_V cocoa butter crystal polymorph is the most preferable in chocolate with respect to giving the best overall surface gloss, colour, hardness/snap, smooth melting and shelf life (heat shock) characteristics.

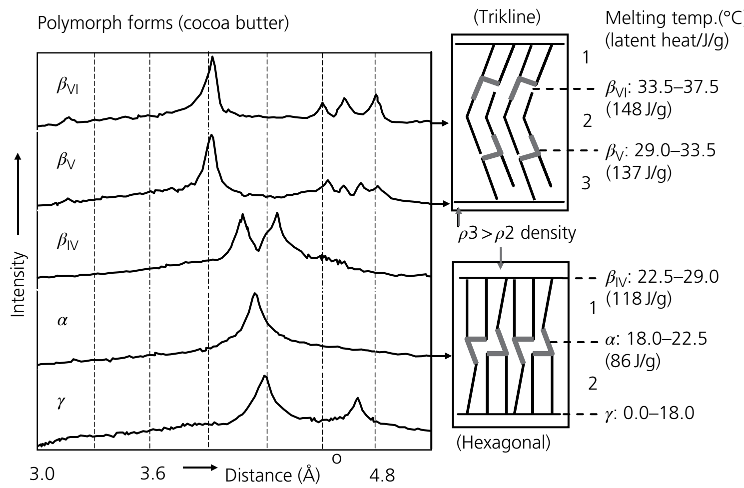

Figure 13.1 Cocoa butter polymorph characteristics.

Table 13.1 Melting temperatures/melting temperature ranges of cocoa butter polymorphs (°C, with °F in brackets).

Vaek (1951)	**Duck (1963)**	**Wille and Lutton (1966)**	**Lovegren *et al.* (1976)**	**Dimick *et al.* (1987)**	**Windhab and Zeng (1998)**
				From onset to peak maximum	Melting range
γ 18.0 (64)	γ 18.0 (64)	I 17.3 (63)	VI 13 (55)	13.1 (55) to 17.6 (63.5)	γ 13.0–18.0 (55–64)
α 23.5 (74)	α 23.5 (74)	II 23.3 (74)	V 20 (68)	17.6 (63.5) to 19.9 (68)	α 18.0–22.5 (64–72)
		III 25.5 (78)	IV 23 (73)	22.4 (72) to 24.5 (76)	III 22.5–27.0 (72–81)
β″ 28.0 (82)	β″ 28.0 (82)	IV 27.5 (81.5)	III 25 (77)	26.4 (79) to 27.9 (82)	β_{IV} 27.0–29.0 (81–84)
β 34.4 (94)	β′ 33.0 (91)	V 33.8 (92)	II 30 (86)	30.7 (87) to 34.4 (94)	β_{V} 29.0–33.5 (84–92)
	β 34.4 (94)	VI 36.3 (97)	I 33.5 (92)	33.8 (93) to 34.1 (93.5)	β_{VI} 33.5–37.5 (92–99.5)

13.3 Chocolate tempering technology

Chocolate and similar coatings are produced according to many different recipe formulations (see Chapter 20), but all contain a mixture of finely milled solids (cocoa, sugar, milk crumb or powder) suspended and well dispersed in cocoa butter with or without milk and substitute fats, which at normal processing temperatures is the liquid carrying medium.