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Review of cocoa butter and alternative fats for use in chocolate—Part A. Compositional data

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This work reviews the literature on the compositional data of vegetable fats used or proposed as alternatives to cocoa butter in chocolate and confectionery products. Cocoa butter is the only continuous phase in chocolate, thus responsible for the dispersion of all other constituents and for the physical behaviour of chocolate. Unique to cocoa butter is its brittleness at room temperature and its quick and complete melting at body temperature. There were, and are, strong efforts to replace cocoa butter in part for chocolate production for technological and economic reasons. Such cocoa butter alternatives are the so-called cocoa butter equivalents (CBEs), cocoa butter substitutes (CBSs) and cocoa butter replacers (CBRs). These are mostly mixtures of various vegetable fats (often modified) and can consist of palm and palm kernel oil, illipé fat, shea butter, sal fat and kokum butter. In addition, a large variety of other vegetable oils can be used. Their composition according to triglycerides, fatty acids, sterols and other unsaponifiable components is discussed in this report. © 1998 Elsevier Science Ltd. All rights reserved.

INTRODUCTION

Nomenclature

Triglycerides (triacylglycerols) are the main components of cocoa butter and other oils and fats. Triglycerides are esters of glycerol and fatty acids. The carbon atoms of the glycerol part are numbered 1–3. While fatty acids in the 1- and the 3-positions are most often interchangeable and very difficult to differentiate, the 2-position is of special interest. The fatty acid in this position is important for nutritional and functional aspects. The following conventions for labelling triglycerides are used in this report: (i) according to the carbon number (CN), e.g. a triglyceride-labelled as C_{52} contains 52 carbon atoms in its fatty acid part and could consist of two molecules of stearic acid (18 carbon atoms) and one molecule of palmitic acid (16 carbon atoms); and (ii) according to the fatty acid composition, e.g. a triglyceride labelled PSS contains one molecule of palmitic acid and two molecules of stearic acid. Fatty acids are abbreviated according to Table 1.

Labelling and legislation

This report presents a summary of the literature describing the composition of vegetable fats potentially added to cocoa butter in chocolate. Until now, an addition of 5–10% of fats other than cocoa butter in chocolate is allowed in several Member States of the European Union (Denmark, UK, Ireland, Sweden, Portugal, Finland, Austria). Recently the European Commission prepared a new draft directive on chocolate in which the amount of other vegetable fat besides cocoa butter is allowed up to 5% (EEC).

Due to functional differences the vegetable fats added to chocolate are to be distinguished and are labelled as follows (Brinkmann, 1992; Bouscholte, 1994):

Cocoa butter alternatives (CBAs): generic name for fats fulfilling the function of cocoa butter completely or in parts;

(a) Cocoa butter equivalent (CBE): non-lauric (not containing lauric acid) plant fats, which are similar in their physical and chemical properties to

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cocoa butter and mixable with it in every amount without altering the properties of cocoa butter;

   (a) Cocoa butter extender (CBEX): subgroup of CBEs not mixable in every ratio with cocoa butter;
   (b) Cocoa butter improvers (CBIs): similar to CBEs, but with higher content in solid triglycerides; used for improving soft cocoa butters.

(b) Cocoa butter replacer (CBR): non-lauric fats with a distribution of fatty acid similar to cocoa butter, but a completely different structure of the triglycerides; only in small ratios compatible to cocoa butter.

(c) Cocoa butter substitutes (CBSs): lauric plant fats (containing lauric acid), chemically totally different to cocoa butter, with some physical similarities; suitable only to substitute cocoa butter to 100%.

The classification according to function, the principal composition of the fats and some examples are summarized in Table 2. No attempt was made to include components such as esterified propoxylated glycerin compositions used for the manufacturing of calorie-reduced chocolate (Cooper, 1993).

In this report no differentiation will be made between the subgroups of CBEs; i.e. no differentation between CBIs and CBEXs. They are all referred to as cocoa butter equivalents. Due to the technological and economic advantages of partly replacing the cocoa butter by other vegetable fats, a tremendous variety of sources has been investigated for their usefulness in the past. This also includes processing of fats by enzymatic interesterification.

The typical ranges of edible oils and fats without botanical curiosities, thus resembling the majority of the harvest, are described in the *Codex Alimentarius* (Codex Alimentarius, 1987) or in *Ullmann's Encyclopedia of Technical Chemistry* (Thomas, 1976) as well as in publications of national regulation agencies. In this report those figures will not be given again.

Figures shown here are supposed to serve as an example. Moreover, it is not expected that the distribution of fatty acids or triglycerides will vary randomly within the given limits. There will always be a sort of correlation, i.e. if one constituent is low another will also be low or the inverse. To indicate this shift of patterns, emphasis was put on the representation of individual data rather than of a representative range. Whenever appropriate a citation is made where the typical range is estimated.

Cocoa butter for chocolate production

The special position of chocolate among other food products is not only based on its taste and nutritional value. Moreover, physical parameters are important, such as brittleness (the 'snap' when the chocolate breaks) and the fast and complete melting in the mouth (Soeters, 1970).

The distribution of the ingredients of chocolate, i.e. the fine dispersion, is crucial for the taste of the product. The fat phase is the only continuous phase in chocolate, thus responsible for melting behaviour and the dispersion of all other constituents. Cocoa butter itself exists in different crystal modifications. A careful tempering of the chocolate is necessary in order to obtain the fine crystals in the correct form (β-modification). Without this tempering, cocoa butter tends to

Table 1. Nomenclature of fatty acids

Symbol	Name	CN:DB	Symbol	Name	CN:DB
	Caprylic acid	8:0		Capric acid	10:0
L	Lauric acid	12:0	M	Myristic acid	14:0
P	Palmitic acid	16:0		Palmitoleic acid	16:1
S	Stearic acid	18:0	O	Oleic acid	18:1
L	Linoleic acid	18:2	E	Elaedinic acid	18:1 (tr9)
A	Arachidic acid	20:0	Ln	Linolenic	18:3
	Behenic acid	22:0		Arachidenic acid	20:1

CN, carbon number; DB, double bonds.

Table 2. Cocoa butter alternatives: examples, properties and composition — an overview (Brinkmann, 1992)

	Plant fat type (examples)	Function	Main fatty acids	Main triglycerides
Cocoa butter equivalent (CBE)	Palm oil, illipé butter, shea butter, kokum butter, sal fat	Non-lauric fat, does not alter the properties of cocoa butter in mixtures	Palmitic, stearic oleic, linoleic arachidic acid	POP, POS, SOS
Cocoa butter replacer (CBR)	Soya oil, rape seed oil, cotton oil, ground nut oil, palm olein	Partially compatible different triglycerides	Elaidic acid, stearic acid, palmitic, linoleic	PEE, SEE
Cocoa butter substitute (CBS)	Coconut oil, palm kernel oil, MCT	Lauric fats, suitable for 100% substitution only	Lauric, myristic	LLL, LLM, LMM

crystallise in rather coarse crystals, with the tendency to blooming. Blooming describes the unfavourable occurrence of big white fat crystals on the surface of the chocolate.

One of the typical properties of cocoa butter is the occurrence of substantial quantities of 2-oleyl glycerides of palmitic and stearic acid (POP, POS, SOS). These triglycerides are mainly responsible for providing the valuable crystallisation and melting characteristics so essential in providing sharp melting at body temperature in chocolate confectionery. This particular melting behaviour provides a cooling effect in the mouth, the typical 'mouth feeling' while eating a high-quality chocolate. Thus the substitution of cocoa butter is crucial in several respects: the melting behaviour has to be very similar to cocoa butter in order to achieve the same 'mouth feeling' and, if cocoa butter is only to be substituted in parts, the addition of the fat must not alter severely the crystallisation and the melting behaviour of cocoa butter.

COCOA BUTTER

A comprehensive overview of the composition of cocoa butter and climatic influences on the composition is given in Chalseri and Dimick (1987). For characterisation of the cocoa butters no attempt was made to include volatile compounds such as aromas. They cannot be considered useful for the characterisation of vegetable fats in mixtures with cocoa butters for two reasons: (i) the foreign vegetable fats normally show no flavour at all; and (ii) the flavour typical for cocoa butters alters significantly with climate, seasonal variations, country of origin, etc. Moreover, flavour constituents are easy to remove from cocoa butter in a process called desodoration, widely applied in the industry. More detail about the components responsible for the typical cocoa flavour can be found in Pino (1992), Pino and Roncal (1992) and Pino *et al.* (1993).

Sterols and other unsaponifiables

A very detailed analysis of sterols (methylsterols, desmethylsterols, triterpenes) in cocoa butter is given in Staphylakis and Gegiou (1985). The results are summarised in Table 3.

An overview of geographic influence on sterol composition is given in Kanematsu *et al.*, 1978*b*. Two African, one Asian and three South American cocoa butters were examined. One of the South American cocoa butters, produced from wild grown plants, had a higher content of sterols. For the others, no correlation between geographical origin and overall sterol concentration or the ratio of stigma-, sito-, and campesterols could be detected.

The tocopherol (vitamin E) composition of cocoa butter (Erickson *et al.*, 1983) was found to be dominated by the β-tocopherol, followed by γ-tocopherol, while the amount of α-tocopherol was found to be insignificant.

Fatty acids

The geographical influence on fatty acid composition is given in Kanematsu *et al.* (1978*b*) and Klagge and Sen Gupta (1990). Examples are summarised in Table 4. The cocoa butters from Africa (Ghana, Ivory Coast) contain a significantly lower amount of oleic acid than the cocoa butters from South America (Ecuador, Brazil). South East Asia (Malaysia, Java) cocoa butters range in-between.

Triglycerides

The triglyceride composition of typical cocoa butters is given in Table 5 as an example (Podlaha *et al.*, 1984). Twenty-eight cocoa butters were characterised according to their triglyceride composition (Podlaha *et al.*, 1984). All cocoa butters gave a relative homogeneous pattern, except the cocoa butter from Bahia (Brazil). This cocoa butter contains a significantly lower amount of monounsaturated triacylglycerols (e.g. POP, POS) and a higher amount in di-unsaturated triacylglycerols (e.g. SOO, POO), which might explain its unsatisfactory crystallisation behaviour. A more detailed analysis of triglycerides in cocoa butter is published in Rezanka and Mares (1991). The normalised percentages for C_{50}, C_{52} and C_{54} for a large variation of cocoa butter samples was published by Kanematsu *et al.* (1978*b*) and Padley and Timms (1978). However, the large naturally occurring variations allow only limited use for the detection of the addition of other vegetable fats to cocoa butter.

The stereospecific analysis of the triglyceride data was published in Itabashi *et al.* (1990, 1991) Takagi and Ando (1991, 1995). Such an analysis is performed by the conversion of triacylglycerols to diacylglycerols and their subsequent separation on a chiral phase. While being very time consuming, it offers far more detail about the triglyceride composition. The *sn*-1,2-(18:1,18:1)-diacylglycerol is about 3.5 times higher, the *sn*-1,2-(18:1,18:2)-diacylglycerol about twice as high, and the *sn*-1,2-(20:1,18:1)-diacylglycerol only about 0.2 as high as their corresponding *sn*-2,3-diacylglycerols. However, few data are available despite the promising potential of the method.

COCOA BUTTER EQUIVALENTS

In separate sections the compositions of the most common cocoa butter equivalents (CBEs) are characterised. These are palm oil, palm mid-fractions and related products, illipé (*Shorea stenoptera*) fat, shea (*Butyrospermum parkii*) butter, sal (*Shorea robusta*) fat, kokum

(*Garcinia indica*) butter as well as some commercially available mixtures blended from various, sometimes processed, vegetable fats.

Palm oil, fractions and related products (*Elaeis guineensis*)

The composition of palm oil as well as factors influencing the quality of it are published in extensive reviews (Jacobsberg, 1975, 1983). A summary of the survey performed in the Malaysian Agricultural Research and Development Institute and in the Palm Oil Research Institute of Malaysia with respect to characteristics of palm oil and products derived by fractionation hereof is given in Maclellan (1983). Palm oil can be divided by fractionated crystallisation into a fraction of palm olein and palm stearin using different processes. These fractions may then be used for further processing such as interesterification (Cotton, 1980; Chong *et al.*, 1992).

Sterols and other unsaponifiables

The composition of sterols and other fractions of the unsaponifiables of palm oils and related products are summarised in Table 6.

The analysis of free sterols (Grob *et al.*, 1994*b*) and sterol ester (Gordon and Griffith, 1992) was proposed for the identification of oils in blends. While the greater variety of these components offers a very characteristic

Table 3. Sterol (4-desmethylsterol, 4,4′-desmethylsterol and triterpene) composition of cocoa butter (Staphylakis and Gegiou, 1985)

4-Methylsterols		4,4′-Dimethylsterols or triterpenes	
Compound	Free sterol (mg/100 g fat)	Compound	Free sterol (mg/100 g fat)
31-Norlanostenyl	0.54	β-Amyrin	0.6
24(28)-Dihydroobtusifoliyl	0.004	Cyclobranyl	0.4
31-Norcycloartanyl	0.18	Lanostenyl	0.7
Lophenyl	1.39	24-Methyllanostenyl	trace
Methyllophenyl	0.42	Lanosteryl	0.5
Ethyllophenyl	1.07	Cycloartenyl	18.9
31-Norlanosteryl	0.72	Lupeyl	0.1
31-Norcycloartenyl	0.54	24-Methylene-lano-stenyl-cyclolaudeny	4.0
Obtusifoliyl	2.07	24-Methylene-cycloartanyl	5.8
Cycloeucanlenyl	0.96	4,4′-Dimethyl-24-ethylidene-5α-cholest-7-en-3β-yl	0.6
Citrostadienyl	5.56	4,4′,14-Trimethyl-5α-cholest-7,24(25)-dien-3β-yl	0.2
Gramisteryl	1.23	4,4′-Dimethyl-24-methylene-5α-cholest-7-en-3β-yl	0.7
4,14,24-Trimethyl-cholest-7,22-dien-3β-yl	0.7	4,4′,14-Trimethyl-24-methylene-5α-cholest-7-en-3β-yl	10.0
Unidentified	0.18	Unidentified	1.5
4-Desmethylsterols			
Compound	Free sterol (mg/100 g fat)	Compound	Free sterol (mg/100 g fat)
Cholestanyl	1.1	Stigmasteryl	60.1
Champestanyl	0.3	Brassicasteryl	0.9
Stigmastanyl	1.6	5,23-Stigmastienyl	1.8
Cholesteryl	1.9	Δ^5-Avenastenyl	5.6
Campesteryl	18.7	Δ^7-Avenasteryl	0.7
Sitosteryl	123.3		

Table 4. Fatty acid composition (area%) of cocoa butter for some countries of origin

Country of origin	Ecuador	Brazil	Ghana	Ivory Coast	Malaysia	Java
Palmitic acid	25.6	25.1	25.3	25.8	24.9	24.1
Stearic acid	36.0	33.3	37.6	36.9	37.4	37.3
Oleic acid	34.6	36.5	32.7	32.9	33.5	34.3
Linoleic acid	2.6	3.5	2.8	2.8	2.6	2.7
Linolenic acid	0.1	0.2	0.2	0.2	0.2	0.2
Arachidic acid	1.0	1.2	1.2	1.2	1.2	1.2
Behenic acid	0.1	0.2	0.2	0.2	0.2	0.2

pattern for identification, it was pointed out (Grob *et al.*, 1994*b*) that by strong bleaching, all sterols and their esters can be removed.

The influence of the refining process on the sterol, sterol ester and sterol glycosides of palm oil was investigated (Homberg and Bielefeld, 1982*b*). During the refining process, all fractions show characteristic variation in content and composition. The content of tocopherol, tocophenol and tocotrienol is given in van Niekerk and Burger (1985) and Reddy and Prahakar (1994*b*). Palm oil is rich in γ-tocotrienol, followed by α-tocopherol and α-tocotrienol and practically free of δ-tocopherol.

Fatty acids

The fatty acid composition of palm oils, palm mid-fractions and related products is summarised in Table 7. Palm trees are not only subject to breeding for greater yields, there are also attempts to breed to produce fat with a composition of fatty acids more similar to cocoa butter. In Table 8 data are summarised for selected Malaysian palm trees proposed for further propagation, because of their favourable fatty acid composition. There are not only differences from tree to tree, there are underlying patterns for the fatty acid composition typical for a specific region. A survey with typical ranges of the fatty acid composition of palm oil of

Table 5. Typical triglyceride composition (area %) of cocoa butter (Podlaha *et al.*, 1984)

Country of origin	Samoa	Ivory Coast	Ecuador	Malaysia	Ghana	Nigeria	Bahia
POL	0.8	0.6	0.7	0.6	0.6	0.8	1.1
MOO, MMP	0.3	0.2	0.3	0.5	0.2	0.2	0.2
PPL	1.6	1.9	1.9	1.5	1.9	1.9	1.7
OOO	0.2	0.8	0.8	0.8	0.5	0.4	0.9
SOL	0.5	0.9	0.8	0.7	0.4	0.8	1.0
POO	2.2	4.4	3.5	2.7	2.6	3.2	5.5
PSL	2.8	3.6	2.8	2.8	3.2	3.4	3.4
PPO	16.4	15.9	15.3	13.8	15.2	14.8	14.0
SOO, PPP	3.7	6.0	4.8	3.8	4.5	5.1	8.4
SSL	2.1	1.8	1.5	2.0	2.1	1.9	2.1
PSO	38.3	36.6	36.3	36.6	37.3	37.4	34.6
OOA	1.6	1.0	1.2	1.6	1.4	1.2	1.5
PPS	0.4	0.4	0.3	0.6		0.7	0.3
SSO	26.8	23.8	26.9	28.4	26.8	26.4	23.7
SSP	0.7	0.8	0.9	1.0	1.3	0.4	0.2
SOA	2.2	1.6	2.1	2.5	2.2	1.9	1.6

Table 6. Typical composition of sterols, methylsterols, triterpenes, tocopherols, squalene and sesamolene in palm oil, palm mid-fraction and related products

References	Abu-Hadeed and Kotb, 1988 (wt%)	Homberg and Bielefeld, 1982*a* (area%)	Homberg and Bielefeld, 1990a (% of total fraction)	van Niekerk and Burger, 1985 (wt%)
Squalene	6.7	—	—	—
δ-Tocopherol	0.0	—	—	trace
γ-Tocopherol	6.7	—	—	23.3
Sesamolene	0.0	—	—	—
4-Desmethylsterols				
Brassicasterol	0.0	—	—	0.1
Campesterol	23.3	24.7	—	15.5
Stigmasterol	11.7	10.5	—	7.4
β-Sitosterol	46.7	59.2	—	44.4
Δ^7-Stigmasterol	0.0	0.2	—	—
Δ^5-Avenasterol	—	2.6	—	0.1
Cholesterol	—	1.6	—	0.1
Δ^7-Stigmastenol	—	—	—	9.0
4-Methylsterols				
Obtusifoliol	0.0	—	54.3	—
Citrostadienol	0.0	—	5.7	—
Gramisterol	—	—	6.1	—
Cycloeucalenol	—	—	4.3	—
4,4′-Desmethylsterols or triterpenes				
β-Amyrin	0.0	—	0.0	—
Cycloartenol	5.0	—	42.4	—
24-Methylencycloartanol	0.0	—	9.0	0.1

Table 7. Fatty acid composition of palm oils, palm mid-fractions and related products

C8	C10	C12	C14	C16	C16:1	C18	C18:1	C18:2	C18:3	C20	C20:1	Description	References
0.0	0.0	0.2	0.1	38.6	0.0	4.7	42.6	11.7	0.6	0.1	0.1	(wt%)	Abu-Hadeed and Kotb, 1988
0.0	0.0	0.0	1.0	42.5	0.0	5.0	39.1	10.0	0.0	0.0	0.0	(wt%)	de Jong and de Jong, 1991
—	—	—	—	51.4	—	4.7	32.8	8.7	—	—	—	Stearin, Indonesia (wt%)	Defense, 1985
—	—	—	—	49.3	—	4.9	33.8	9.6	—	—	—	Stearin, Malaysia A (wt%)	Defense, 1985
—	—	—	—	48.4	—	4.9	34.5	12.4	—	—	—	Stearin, Malaysia B (wt%)	Defense, 1985
—	—	—	—	68.8	—	5.1	19.1	4.5	—	—	—	Alfa-laval stearin, Indonesia, single stage fractionation (wt%)	Defense, 1985
—	—	—	—	66.2	—	4.8	21.6	5.0	—	—	—	Alfa-laval stearin, Malaysia A, single stage fractionation (wt%)	Defense, 1985
—	—	—	—	60.1	—	5.1	26.0	6.6	—	—	—	Alfa-laval stearin, Malaysia B, single stage fractionation (wt %)	Defense, 1985
—	—	—	—	40.4	—	4.3	41.1	11.9	—	—	—	Olein, Indonesia (wt%)	Defense, 1985
—	—	—	—	39.5	—	4.3	41.5	12.2	—	—	—	Olein, Malaysia A (wt%)	Defense, 1985
—	—	—	—	39.0	—	4.4	41.7	12.4	—	—	—	Olein, Malaysia B (wt%)	Defense, 1985
—	—	—	—	40.0	—	4.3	40.8	12.3	—	—	—	Alfa-laval olein, Indonesia, single Stage fractionation (wt%)	Defense, 1985
—	—	—	—	39.4	—	4.3	42.3	11.3	—	—	—	Alfa-laval olein, Malaysia A, single stage fractionation (wt %)	Defense, 1985
—	—	—	—	39.6	—	4.4	41.7	11.8	—	—	—	Alfa-laval olein, Malaysia B, single stage fractionation (wt%)	Defense, 1985
—	—	—	—	54	—	7.0	33.0	3.5	—	0.4	—	Palm mid fraction (area%)	Hogenbrink, 1984
—	—	0.3	1.1	43.7	0.1	4.5	39.3	10.1	0.2	0.3	0.2	Palm oil (wt%)	van Niekerk and Burger, 1985

Table 8. Fatty acid composition (area%) of selected Malaysian palm trees, being potential applicants for propagation by breeding due to their compositions (Pantzaris, 1990)

Fatty acid	14:0	16:0	18:0	18:1	18:2
No. 1	0.5	32.7	5.7	45.4	15.7
No. 2	0.5	32.0	9.0	48.8	9.7
No. 3	—	28.7	15.4	40.4	15.5
No. 4	—	31.5	7.1	54.1	7.3
No. 5	—	35.8	5.4	42.8	16.0

different regions was published (Reddy and Prahakar, 1994*b*).

In order to make the fatty acid composition even closer to cocoa butter, palm mid-fraction is interesterified with either palmitic or stearic acid. The fatty acid composition of a transesterified palm mid-fraction was indicated in several publications (Siler-Marinkovic and Mojovic, 1992; Hashimoto, 1993; Mojovic *et al.*, 1993; Siler-Marinkovic *et al.*, 1993). Using either palmitic or stearic acid and enzymes, which selectively affect the fatty acid in the 1- or 3-positions, it is possible to produce a cocoa butter-like fat in which the fatty acid composition resembles closely that of cocoa butter.

Triglycerides

Typical triglyceride compositions of palm oil and its fractions are summarised in Table 9. It is obvious that the triglyceride composition depends strongly not only on the type of fraction. Comparing rows five and six reveals that there are also big differences depending on the analytical technique used. Palm oils were characterised by the ratios of the triglycerides OOO, PLO, PLP, PPP, POP, POO (Aitzetmüller *et al.*, 1988). However, for the identification of the addition of palm oils, the analysis of fatty acid seems to be better suited, because palm oils can be easily detected for their lauric acid content. Therefore, it seems redundant to show these ratios here.

Results of the stereospecific analysis of the triglycerides were shown by Christie *et al.* (1991) and Christie (1994). In the sn-2 position, oleic acid is clearly dominant followed by approximately equal amounts of linoleic and palmitic acid. With respect to the sn-3 position, the sn-1 position is enriched in linoleic acid by a factor of three, in oleic acid by a factor of two and depleted in myristic acid by a factor of six and in palmitic acid by a factor of two.

The phospholipid composition was summarised by Goh *et al.* (1982). The authors determined phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositol and phosphatidylglycerol as major components. However, they stated that a low content of these compounds seems desirable to obtain better oxidation stability and bleaching properties.

Triglyceride composition grouped by carbon numbers for palm mid-fraction, palm oil, the stearin and the olein fraction were given in Hogenbrink (1984), Motta *et al.* (1987) and Reddy and Prahakar (1994*b*). The major components, present in equal amounts are C_{50} and C_{52} for palm olein, while C_{50} is predominant for the other fractions. The triglyceride composition of an interesterified product of a palm oil fraction and stearic acid is given in Macrae (1983, 1986). This interesterification leads to a product's content of SSS, POP, POS, SOS, SLnS and SOO resembling cocoa butter perfectly.

Illipé (*Shorea stenoptera*)

There is some confusion in the literature about the correct labelling of illipé fat and sal fat, respectively. Illipé is also called Borneo tallow, engkabang or tenkgawang tallow. This fat is obtained from the seed kernels of a number of trees that grow in Borneo, Java, Malaysia, the Philippines and other localities of this area. However, the most important species from which the fat is obtained is *Shorea stenoptera*.

Illipé is the European trade name for Mowrah butter (Banerji *et al.*, 1984), while in another reference it is referred to as the fat obtained from *Madhuca longifolia* and/or Illipé malabaricum only (Thomas, 1976). This reference assigns the name Mowrah butter to the fat obtained from *Madhuca latifolia*, which shows a very similar composition. The term 'illipé' was originally derived from Tamil names for nuts of *Bassia longifolia* (family Sapotacaea) and for Mowrah nuts (*Bassia latifolia*) produced in South India (Anderson, 1975). Illipé has since been applied to other oil-bearing nuts, with similar properties, originating from East Malaysia. In commerce it is now accepted that the term illipé stands for a particular commodity, namely the products from *Shorea stenoptera* (Nesaretnam and bin Mohd Ali, 1992). Therefore, in this section only references are given where the authors explicitly refer`to illipé.

Sterols and other unsaponifiables

The composition of sterols and other fractions of the unsaponifiables of illipé fat is summarised in Table 10.

Fatty acids

The fatty acid composition of illipé fat has some resemblance to cocoa butter as stearic acid predominates. The typical fatty acid composition of this fat is summarised in Table 11. As there was a lot of confusion about the plants to whom the name illipé was applied (see above) data of other species of *Shorea* are also given. In illipé fat, oleic acid and stearic acid are present in more or less equal amounts followed by palmitic acid. All other fatty acids are present as minor components (below 2%). The concentrations of 59 different fatty acids, covering unsaturated as well as branched fatty acids are given in Iverson and Harrill (1967).

Triglycerides

The composition of different species of *Shorea* and one commercial sample, separated according to carbon

Table 9. Triglyceride composition of palm oil and related products

LLP	LLO	LOO	LOP	LPP	OOO	POO	POP	PPP	SOO	PSO	PPS	Others	Description	References
0.6	—	0.6	7.5	7.5	2.3	29.2	42.8	4.6	1.1	3.5	0.3	—	(area%) oil	Bergqvist and Kaufmann, 1993
2.7	—	1.8	10.7	10.7	3.5	22.1	30.9	6.1	2.4	5.4	1.5	—	(area%) oil	Defense, 1985
2.4	0.5	1.5	3.4	12.5	3.3	19.6	37.0	8.5	1.0	4.3	—	—	(mol%) oil	Perrin and Naudet, 1983
1.0	—	1.0	7.7	7.0	3.4	24.4	34.2	9.2	—	5.3	0.8	6.0	(wt%) oil	Perrin and Prévot, 1986
1.6	0.4	1.0	8.1	10.3	2.4	19.2	27.0	11.6	2.0	5.7	0.5	10.2 (12 other triglyc. ident.)	GC rel. comp. (area%) oil	Rezanka and Mares, 1991
4.1	1.0	2.6	10.8	10.7	4.7	22.1	24.0	7.1	1.7	4.9	0.2	6.2 (6 other triglyc. ident.)	LC rel. comp. (area%) oil	Rezanka and Mares, 1991
1.6	0.3	1.3	8.2	1.6	3.9	22.5	31.8	7.0	2.4	5.6	1.5		(area%) oil	Sassano and Jeffrey, 1993
—	—	—	0.8	6.2	0.5	5.0	63.2	3.0	0.9	13.0	3.8	3.6 (6 other triglyc. ident.)	(area%) mid-fraction	Sassano and Jeffrey, 1993
2.2	0.4	2.0	12.7	11.2	6.7	38.0	16.9	0.6	3.6	2.1	—	3.6 (6 other triglyc. ident.)	(area%) wet olein	Sassano and Jeffrey, 1993
2.0	0.3	1.6	9.8	10.1	4.8	27.6	31.2	0.5	2.8	5.9	—	3.4 (6 other triglyc. ident.)	(area%) dry olein	Sassano and Jeffrey, 1993
1.0	—	0.8	5.5	7.1	2.6	16.3	30.0	22.1	1.5	4.4	—	8.7 (6 other triglyc. ident.)	(area %) dry stearin	Sassano and Jeffrey, 1993
—	—	2.2	12.6	10.7	4.6	27.5	28.0	—	3.3	5.1	—	6.0 (other triglyc. ident.)	(wt%) palm olein	Swe *et al.*, 1996

number, is given in Nesaretnam and bin Mohd Ali (1992). The content of C_{50} was found to be about 6–10%, and C_{52} and C_{54} are present in approximately equal quantities of about 40%.

Shea butter (*Butyrospermum parkii*)

Shea butter is often also called Karite butter, Galam butter and by other native names. It is obtained from the seeds of a tree mainly found in West Africa. As the fruits can be harvested only after 15 years, farming is not economically viable.

Sterols and other unsaponifiables

The content of unsaponifiables in the oil may consist of up to 11%, containing components similar to caoutchuk such as kariten (Table 12). The overall percentage of the unsaponifiables was determined to be of approximately 65% triterpene alcohols, approximately 8% sterols and approximately 27% hydrocarbons (Jacobsberg, 1977).

An overview of the non-glyceride saponifiables in shea butter can be found in Peers (1977). Triterpene alcohols and sterols are present as esters of both cinnamic acid and other fatty acids in a commercial sample of shea butter. Cinnamic acid was neither found in the free form, nor esterified to glycerol. These non-glyceride unsaponifiables were found to represent 6% of the shea butter, while the free sterols and triterpenes accounted for only 1% as weight.

Fatty acids

The typical fatty acid composition of shea butter as well as fractions of it is summarised in Table 13. This table reveals that the fatty acid composition of shea butter does not change only with the fraction being analysed. Geographical origin seems to have a big influence as well. The concentrations of 59 different fatty acids, covering unsaturated as well as branched fatty acids are given in Iverson and Harrill (1967).

Table 10. Sterol composition for Illipé (*Shorea stenoptera*)

References	Frega *et al.*, 1993*a* (area%)	Homberg and Bielefeld, 1982*a* (area%)	Soulier *et al.*, 1990 (area%)
4-Desmethylsterols			
Cholesterol	1.8	1.5	—
Brassicasterol	9.6	0.3	—
Campesterol	19.5	14.5	12.7
Stigmasterol	trace	7.5	4.2
β-Sitosterol	64.2	71.8	44.2
Δ^5-Avenasterol	0.8	2.4	—
Isofocusterol	—	—	3.6
Δ^7-Stigmasterol	—	1.0	—
Δ^7-Avenasterol	—	0.1	—
4-Methylsterols			
Obtusifoliol	—	—	0.5
24-Methylenelophenol	—	—	0.9
Cycloeucalenol	—	—	0.6
Citrostadienol	—	—	0.8
4,4′-Dimethylsterols or triterpenes			
β-Amyrin	—	—	3.1
Butyrospermol	—	—	2.2
Cycloartenol	—	—	1.1
α-Amyrin + lupeol	—	—	17.4
24-Methyleneparkeol	—	—	0.9
24-Methylenecycloartanol	—	—	4.1
Ψ-Taraxasterol	—	—	0.9
Cycloartanol	—	—	0.8
Others	4.1	—	2.0

Table 11. Fatty acid composition of illipé (*Shorea stenoptera*) fat and other *Shorea* species

12:0	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	Description	References
—	—	5.7	—	41.0	49.0	4.3	—	—	(wt%)	Banerji *et al.*, 1984
—	—	19.3	—	43.5	35.2	1.0	—	1.3	(% of total FA)	Bracco *et al.*, 1970
—	—	22.0	—	40	38	—	—	—	(wt%)	Meara, 1979
—	0.1	23.1	—	40.9	33.4	0.5	1.6	—	*Shorea singkawang* (area%)	Nesaretnam and bin Mohd Ali, 1992
—	0.1	22.1	1.1	39.4	35.8	0.6	1.8	0.1	(%) *Shorea mecistopterix* (area%)	Nesaretnam and bin Mohd Ali, 1992
0.1	0.1	16.0	0.2	46.7	33.2	0.9	0.2	0.2	*Shorea macrophylla* (area %)	Nesaretnam and bin Mohd Ali, 1992
—	—	19.9	0.1	43.7	35.7	0.4	—	—	Commercial sample (area%)	Nesaretnam and bin Mohd Ali, 1992

Triglycerides

By fractionated crystallisation the shea stearin may be obtained consisting mainly of 2-oleoyl-distearin and being used as CBE. The triglyceride composition of shea stearin was found to be 85% C_{54}, 11% C_{52}, 2.5% C_{56} and 0.6 C_{50} in (Hogenbrink, 1984). The composition of shea butter was found to be 86% C_{54}, 11% C_{52} and 3% C_{56} (Kanematsu *et al.*, 1978*a*).

The composition for interesterified products is given as an example in the patent application (Macrae, 1983). The fatty acids of such products had been rearranged using a 1,3-specific lipase and yielded an olein fraction that consists of approximately 40% SOO and approximately 20% SOS, as well as a stearin fraction consisting of predominantly (> 80%) SOS.

By computational simulation, 23 triglycerides were identified. SOS and SOO were shown to make up to 60% of the fat (Swadogo and Bezard, 1982).

Sal fat (*Shorea robusta*)

Sal fat is also called Borneo tallow or tenkgawang tallow. This fat is obtained from the seed kernels of a number of trees that grow in Borneo, Java, Malaya, Philippines and other localities of this area. However, there is some confusion in the literature between *Shorea robusta, Shorea stenoptera* and *Madhuca longifolia.* They are all referred to as borneo tallow, sometimes even illipé, depending on the date of publication [see 'Illipé (*Shorea stenoptera*)' for more details.

Sterols and other unsaponifiables

The typical composition of sterols and other fractions of the unsaponifiables of shea butter is summarised in Table 14. The unique occurrence of 3-keto triterpenes in sal seed fat was observed (Kolhe *et al.*, 1981).

Fatty acids

The fatty acid composition of sal fat has some resemblance to cocoa butter as stearic acid predominates. The typical fatty acid composition of this fat is summarised in Table 15. The fatty acid composition of the fractions of sal fat differs by only about 10% from the fatty acid composition of the whole sal fat (Chaudhuri *et al.*, 1983). Sal fat contains 2–4% of 9,10-epoxystearic acid and 9,10-dihydroxystearic acid (Bringi *et al.*, 1972; Bringi, 1976; Belvadi *et al.*, 1979). Such compounds

Table 12. Sterol content of shea butter

References	Derbesy and Richert, 1979	Abu-Hadeed and Kotb, 1988; Itoh *et al.*, 1974	Kanematsu *et al.*, 1978*a*
	Conc. (wt%)	(wt%)	(area%)
Sterols			
Cholesterol	1.5	—	2.2
β-Sitosterol	4.0	—	—
α-Spinasterol	43.1	43.0	48.5
Δ^7-Stigmasterol	40.3	37.0	49.3
24-Methyl-cholest-7-enol	—	6.0	—
Δ^7-Avenasterol	3.8	11.0	—
Others	—	3.0	—
4-Methylsterol			
Obtusifoliol	—	22.0	—
Gramisterol/Cycloeucalenol	—	4.0	—
Others	—	74.0	—
Triterpenes			
β-Amyrin	—	8.0	—
Butyrospermol	—	26.0	—
α-Amyrin	—	46.0	—
Lupeol + unidentified compound	—	16.0	—
Others	—	4.0	—

Table 13. Fatty acid composition of shea butter

Fatty acids											References
8:0	10:0	12:0	14:0	16:0	18:0	18:1	18:2	18:3	20:0	20:1	
—	—	—	—	5.7	41.0	49.0	4.3	—	—	—	Banerji *et al.*, 1984 (wt%)
—	—	—	—	4.0	58.0	33.0	3.0	—	2.0	—	Hogenbrink, 1984, Shea stearin (area%)
2.3	1.0	9.9	3.7	6.6	46.8	51.4	8.4	2.1	0.5	—	Jacobsberg, 1977, Ivory Coast (area%)
—	—	—	—	4.2	22.5	68.0	4.9	0.1	—	—	Jacobsberg, 1977, Tchad (area%)
—	—	—	—	3.8	44.1	43.8	6.65	1.55	—	—	Jacobsberg, 1977, Benin (area%)
—	—	—	—	4.0	43.2	43.9	6.6	0.3	1.6	0.4	Kanematsu *et al.*, 1978*a* (area%)
—	—	—	—	8.0	37.0	50.0	5.0	—	—	—	Meara, 1979 (wt%)

affect the supercooling properties (Reddy and Prabhakar, 1985). The fatty acid composition of sal fat can differ at least by about 5% (wt%, absolute). Typical ranges are stated to be C_{16} (2.2–8.3%), C_{18} (34.7–48.4%), $C_{18:1}$ (35.3–42.2%), $C_{18:2}$ (1.9–3.2%) and C_{20} (5.5–10.8%) (Lakshiminarayana, 1977).

The fatty acid composition of sal fat interesterified with palmitate and/or stearate is given in Sridhar *et al.* (1991). These fats resemble cocoa butter closely in their fatty acid composition, consisting of about 33% each of oleic and stearic acid, and about 24% palmitic acid.

Triglycerides

The triglyceride composition of sal fat is summarised in Table 16. Sal fat contains up to 9% triglycerides containing 2 mol stearic acid in the 1,3-position and 1 mol of either 9,10-epoxystearic acid or 9,10-dihydroxystearic acid in the 2-position (Bringi, 1976; Belvadi *et al.*, 1979). It seems that during storage the 9,10-epoxystearic acid is slowly converted to the 9,10-dihydroxystearic acid (Bringi, 1976). A total loss of the epoxy acid after 1 year of storage was observed. The triglyceride composition according to carbon numbers is given to be approximately 70% C_{54}, approximately 13% each for C_{52} and C_{56} and approximately 2% C_{50} (Kanematsu *et al.*, 1978*a*).

The variation of triglyceride composition typical for sal fat is given as SOS (42–52%), SOA (20%), POS (8–14%), AOA (1–14%), POO (0–5%) and AOO (0–4%) (Lakshiminarayana, 1977).

Kokum butter (*Garcinia indica*)

Kokum butter is also known as Goa butter. Kokum is an evergreen tree found in the tropical forests of India. The kokum seed (8–10 seeds per fruit) is the source for kokum butter. Traditionally, the oil is extracted by

Table 14. Typical composition of sterols and other fractions of the unsaponifiables of shea butter

References	Homberg and Bielefeld, 1982*a* (area%)	Kanematsu *et al.*, 1978*a* (area%)	Soulier *et al.*, 1990 (area%)
Sterols			
Cholesterol	0.9	trace	—
Brassicasterol	0.5	—	—
Campesterol	16.5	20.0	14.8
Stigmasterol	16.1	12.8	5.6
β-Sitosterol	61.5	67.2	40.5
Isofocusterol	—	—	3.2
Δ^5-Avenasterol	2.5	—	—
Δ^7-Stigmasterol	1.3	—	—
4-Methylsterols			
Obtusifoliol	—	—	0.7
24-Methylenelophenol	—	—	1.0
Cycloeucalenol	—	—	1.4
Citrostadienol	—	—	0.9
4,4′-Dimethylsterols or tritperenes			
β-Amyrin	—	—	9.2
Butyrospermol	—	—	0.0
Cycloartenol	—	—	7.1
α-Amyrin + lupeol	—	—	7.3
24-Methyleneparkeol	—	—	1.2
24-Methylenecycloartanol	—	—	2.7
ψ-Taraxasterol	—	—	2.7
Cycloartanol	—	—	0.0
Unknown	—	—	1.7

Table 15. Fatty acids in sal fat

Fatty acids									References
16:0	18:0	18:1	18:2	18:3	20:0	20:1	22		
7.6	42.6	37.0	3.5	1.3	8.0	—	—	(wt%)	Bhattacharyya and Banerjee, 1983
6.3	44.6	41.6	1.7	0.0	5.7	—	—	(wt%)	Bhattacharyya and Bhattacharyya, 1991
8.3	34.7	41.9	2.8	0.0	12.3	—	—	(wt%)	Banerji *et al.*, 1984
4.6	44.2	42.1	2.8	0.0	6.3	—	—	(mol%)	Baliga and Shitole, 1981 (from Hildtich and Stainsby, 1936)
5.2	42.8	40.4	3.8	0.8	7.0	—	—	(wt%)	Bringi *et al.*, 1972
6.0	43.0	40.0	2.0	—	7.0	—	—	(area%)	Hogenbrink, 1984
5.9	44.6	39.7	2.4	—	6.6	0.5	0.6	(area%)	Kanematsu *et al.*, 1978*a*
5.6	44.3	40.4	1.5	—	7.7	—	—	(mol%)	Sridhar *et al.*, 1991
4.6	43.2	42.0	2.2	1.3	6.7	—	—	(wt%)	Chaudhuri *et al.*, 1983

Table 16. Typical triglyceride composition (wt%) of sal fat (Sridhar and Lakshminarayana, 1991)

Triglyceride	%	Triglyceride	%
POP	4.8	POO	3.5
POS	16.0	SOO	14.9
SOS	36.3	AOO	0.6
SOA	9.0	SLO	0.6
AOA	1.0	OOO	2.0
PLP	4.2	PSS	1.4
SLP	5.0	Others	1.4

boiling the kernels in water and the oil is skipped off the top. Nowadays solvent extraction is also used (Sampathu and Krishnamurthy, 1982).

Sterols and other unsaponifiables
No reliable thorough investigation of the sterol content and content of the unsaponifiables of kokum butter could be found in the literature.

Fatty acids
The fatty acid composition typical for kokum butter is given in Table 17. The range of composition of fatty acids in kokum fat is stated to be C_{14} (0–1.2%), C_{16} (1.7–5.8%), C_{18} (51–61%), $C_{18:1}$ (36.8–41.5%) and $C_{18:2}$ (0.5–1.7%) (Lakshiminarayana, 1977).

The composition of Kokum fat interesterified with palmitate and/or stearate was also investigated. Interesterified kokum was claimed to resemble cocoa butter especially well in both its fatty acid and triglyceride composition as well as its melting behaviour (Sridhar *et al.*, 1991).

Triglycerides
Only one publication could be found where the triglyceride composition of kokum butter is given in some detail: SOS (77.3%), SOO (12.1%), POS (8.1%) and SLO (2.5%) (Sridhar and Lakshminarayana, 1991).

The range of composition of triglycerides in kokum fat is given in Lakshiminarayana (1977). SOS was found to be 58–81%, POS 8–15% and SOO 14–21%.

Commercial blends

In commercial blends several vegetable fats or fractions of the fats are mixed in order to resemble cocoa butter as closely as possible. For example, by blending fractions of palm oil and shea butter with illipé butter, a typical West African cocoa butter could be matched closely (Cormeau, 1982). Some commercially used high-priced mixtures of tree-borne seed fats and mixtures of fractions of these fats are described in Chaudhuri *et al.* (1983). However, because of their high price, they are of moderate economic interest. A fairly extensive review was published by Keel (1977), covering the fatty acid and sterol composition of approximately 60 commercially available cocoa butter equivalents.

Sterols and other unsaponifiables
The composition of the sterols and other fractions of the unsaponifiables are summarised in Table 18. The cocoa butter equivalents are identified by their trademark.

Fatty acids
The fatty acid composition of some CBEs is given in Table 19. It can be seen that most of the fats are very similar in their fatty acid composition and resemble that of cocoa butter (Table 4). However, most of the CBEs cited here show a somewhat elevated content of palmitic acid.

Triglycerides
The triglyceride composition of some CBEs is given in Table 20. However, reference is only made for the three main triglycerides in the literature. It can be seen that the triglyceride composition is fairly different to that of cocoa butter (Table 5). A procedure for the application of relatively pure SOS and POS fats obtained from palm mid-fraction is described in Soeters (1982).

COCOA BUTTER REPLACERS

The fatty acid composition of some non-identified commercially available cocoa butter replacers is summarised in Table 21 with the corresponding triglyceride composition in Table 22.

COCOA BUTTER SUBSTITUTES

The fatty acid composition of a cocoa butter substitute made by selective hydrogenation and fractionation of palm olein is described in Leong and Lye (1992). The procedure yielded a stearin fat fraction suitable for

Table 17. Fatty acid composition of kokum fat

Fatty acids						References
14:0	16:0	18	18:1	18:2		
0.4	1.4	60.4	37.8	—	(wt%)	Banerji *et al.*, 1984
—	3.1	56.1	39.1	1.7	(mol%)	Baliga and Shitole, 1981
—	2.0	57.5	39.0	1.2	(mol%)	Sridhar *et al.*, 1991

Table 18. Sterol content (area%) of some commercially available CBEs (blended from different fractionated vegetable fats)

	Trademark						
	Coberine		Choclin		Hacofal	Kaobien	Illexao 30–92
References:	Gegiou and Staphylakis, 1981, 1985	Homberg and Bielefeld, 1982*a*	Gegiou and Staphylakis, 1981, 1985	Homberg and Bielefeld, 1982*a*	Homberg and Bielefeld, 1982*a*	Homberg and Bielefeld, 1982*a*	Homberg and Bielefeld, 1982*a*
4-Desmethylsterols							
Cholesterol	—	1.2	1.9	0.6	0.4	3.5	12.7
Brassicasterol	—	0.1	—	—	—	0.5	—
Campesterol	15.4	17.4	9.5	18.3	14.7	10.5	1.0
Stigmasterol	7.2	5.9	8.7	7.0	12.2	5.9	—
Sitosterol	65.5	67.4	49.3	65.3	67.5	21.4	3.0
Δ^5-Avenasterol	trace	4.2	—	4.5	3.9	—	—
Δ^7-Stigmasterol	11.9	1.5	29.0	2.1	1.0	20.7	31.5
Δ^7-Avenasterol	trace	0.1	1.6	0.1	—	0.5	0.6
Δ^7-Campesterol	—	0.1	—	0.1	—	3.2	3.4
Spinasterol	—	2.0	—	2.0	—	28.5	35.4
4-Methylsterols							
31-Norlanostenol	0.0	—	0.6	—	—	—	—
Lophenol	1.0	—	1.2	—	—	—	—
Obtusifoliol	38.7	—	11.3	—	—	—	—
31-Norcycloartenol	4.7	—	23.1	—	—	—	—
Gramisterol/cycloeucalenol	29.2	—	54.0	—	—	—	—
Ethyllophenol/unidentified	1.8	—	0.0	—	—	—	—
Citrostadienol	17.6	—	9.8	—	—	—	—
Others	7.0	—	0.0	—	—	—	—
Triterpenes							
Lanostenol	0.4	—	0.5	—	—	—	—
Lanosterol	29.9	—	30.8	—	—	—	—
Cycloartenol/α-amyrin	53.4	—	52.6	—	—	—	—
Lupeol	11.0	—	11.2	—	—	—	—
24-Methylene-cycloartanol	2.4	—	1.9	—	—	—	—

commercial coating fat. However, it was not possible to remove the waxy tail from the product completely. The fatty acid and the triglyceride composition of six commercially available cocoa butter substitutes have been investigated (Nesaretman and Kun, 1990). No significant differences between the fats were reported. They consist of approximately 50% lauric acid and 20% myristic acid. The triglyceride composition is dominated by C_{34}, C_{36} and C_{38}.

The fatty acid composition of clearly identified cocoa butter substitutes is given in Pongracz (1982) and Paulicka (1976). As a lauric CBS, the fatty acid composition is dominated by the content of lauric acid (approx. 50%) and myristic acid (approx. 20%).

The fatty acid composition of seven cocoa butter substitutes made from different vegetable fats is given in Table 23.

*CBS from sal fat (*Shorea robusta*)*

Sal fat can also be used for the production of a cocoa butter substitute (Reddy and Prabhakar, 1990). The fatty acid composition of two CBSs made of sal fat is given in Table 24 for two different samples. More information about sal fat is given in Sal fat (*Shorea robusta*).

Palm kernel oil

Palm kernel oil is obtained from the kernels of the palm, *Elais guineensis*. It is similar to coconut fat but contains more oleic acid.

Sterols and other unsaponifiables

The typical composition of the sterol content and other fractions of the unsaponifiables of palm kernel fat is shown in Table 25.

Fatty acids

The typical composition of fatty acids of palm kernel oil is given in Table 26. The concentration of 59 different fatty acids, covering unsaturated as well as branched fatty acids is given in Iverson and Harrill (1967).

Table 19. Fatty acid composition of some commercially available CBEs (blended from different fractionated vegetable fats)

Trademark	Fatty acids					References
	C 16:0	C 18:0	C 18:1	C 18:2	Others	
Coberine	32.0	28.2	36.1	2.0	1.7	van Dongen, 1991 (wt%)
	35.8	31.2	30.0	1.6	1.4	Gegiou and Staphylakis, 1985 (area%)
	31.8	29.8	33.5	2.9	1.1	Faulkner, 1981 (wt%)
	31.8	28.9	33.5	3.3	2.5	Cruickshank and Biol, 1979 (area%)
Choclin	38.7	22.2	35.1	2.1	1.8	van Dongen, 1991 (wt%)
	39.2	22.1	33.8	3.4	1.5	Gegiou and Staphylakis, 1985 (area%)
Calvetta	58.5	8.5	29.1	1.9	2.0	Gegiou and Staphylakis, 1985 (area%)
'Synthetic cocoa butter'	26.0	34.0	35.0	3.0	2.4	Fincke, 1977 (area%)
Illexao 30-93	14.0	46.0	36.0	3.0	1.0 (18:3)	Meara, 1979 (wt%)
'CBE A'	28.2	30.6	34.6	3.8	2.8	Pongracz, 1982 (area%)
Shea + palm fraction + illipé oil	32.3	30.2	33.0	3.0	1.4	Paulicka, 1976 (wt%)
CBE-A	31.3	31.0	32.6	n.d.	5.1	Talbot, 1991 (area%)
CBE-B	35.4	27.0	32.4	n.d.	5.2	Talbot, 1991 (area%)

Table 20. Triglyceride composition of some commercially available CBEs (blended from different fractionated vegetable fats)

Name	Triglycerides				References
	POP	POS	SOS	Others	
Coberine	35.0	19.0	28.0	18.0	van Dongen, 1991 (wt%)
Choclin	45.0	14.0	21.0	20.0	van Dongen, 1991 (wt%)
CBE-A	37.0	17.9	40.3	4.8	Talbot, 1991 (area%)
CBE-B	43.7	16.2	35.3	4.8	Talbot, 1991 (area%)

Table 21. Fatty acid composition (area %) of some non-identified, commercially available cocoa butter replacers (Nikolova-Damyanova and Amidzhir, 1992)

CBR	Fatty acids						
	14:0	16:0	18:0	18:1	18:2	18:3	20:0
A	0.8	42.0	22.5	31.3	2.8	0.6	0.0
B	1.3	53.5	18.7	25.0	1.5	trace	0.0
C	0.7	40.2	22.3	33.0	3.2	0.5	0.0
D	0.1	24.7	36.1	35.4	1.4	2.1	2.1

OTHER OILS AND FATS

Besides the fats described above, the use of a wide variety of plant fats is proposed in the literature. Those fats are proposed as CBAs either directly or after appropriate fractionation or interesterification. Due to numerous references no attempt was made to state explicitly the composition of fatty acids, triglycerides or the unsaponifiables for each fat individually. The appropriate references are given in Table 27.

The following list gives reviews of fats and oils being proposed as CBAs, but not thoroughly characterised, as well as reviews about other constituents of oils and fats mentioned in the previous sections.

Reviews

- Compositional data (triglycerides, fatty acids, unsaponifiables) as well as data on isotopic ratios of fats of 45 cocoa butters, 15 CBEs and several other vegetable fats, CBSs and CBRs (Eiberger, 1996).
- Fatty acid composition of 58 butters from different plants of the potential for their use in the food industry (Banerji *et al.*, 1984).
- Fatty acid, triglyceride and phospholipid composition of oils of 10 edible seeds from North Vietnam (Imbs and Pham, 1995).
- Sterol composition of 19 different vegetable oils (Itoh *et al.*, 1973).
- Fatty acid and triglyceride composition of baku, Lauracea, Myristacaceae seed fat and *Stillingia* tallow (Meara, 1979).
- Content of total hydroxy fatty acids for 76 different oils and fats (Schwartz and Rady, 1992).

Special constituents

- Free sterols and olefinic degradation products in refined sunflower, peanut, safflower, grape seed, soybean, rapeseed, corn and walnut oils (Grob *et al.*, 1994*a*).
- Occurrence of artificial *trans*-polyunsaturated fatty acids in walnut oil (Wolff, 1993).

Table 22. Triglyceride composition (area%) of some non-identified, commercially available cocoa butter replacers (Nikolova-Damyanova and Amidzhir, 1992)

CBR	Triglycerides			
	POP	SOP	SOS	SOA
A	58.1	14.8	26.8	0.0
B	73.8	9.0	17.2	0.0
C	52.3	18.3	26.2	0.0
D	24.7	26.7	41.2	7.3

Table 23. Fatty acid composition (wt%) of seven commercially available CBSs made from different vegetable oils and fats (Paulicka, 1976)

Fatty acids	Hard butters from palm and shea fractions and whole refined illipé oils				Hard butters from hydrogenated, fractionated cotton seed and soybean oil		
	Sample no.				Sample no.		
	1	2	3	4	1	2	3
12:0	0.0	0.4	0.3	0.2	0.6	0.2	0.2
14:0	1.1	0.7	0.2	0.4	0.7	0.6	1.0
16:0	53.1	40.9	4.3	32.3	18.7	17.5	23.4
16:1	0.2	0.0	0.0	0.0	0.4	0.4	0.4
17:0	0.2	0.0	0.0	0.0	0.2	0.0	0.0
18:0	5.9	21.3	54.3	30.2	13.3	14.4	11.7
18:1	33.0	32.3	35.4	33.0	62.1	66.1	62.0
18:2	5.9	3.5	4.5	3.0	3.4	0.4	1.1
18:3	0.2	0.0	0.0	0.0	0.1	0.0	0.0
20:0	0.4	0.9	1.0	0.8	0.5	0.4	0.0

Table 24. Fatty acid composition (area %) of two cocoa butter substitutes from sal (*Shorea robusta*) fat (Reddy and Prabhakar, 1990)

	Fatty acids				
	16:0	18:0	18:1	18:2	20:0
Sample 1	7.0	47.8	36.9	trace	8.2
Sample 2	6.9	50.8	35.0	trace	6.8

Table 25. Typical composition of sterols and other fractions of the unsaponifiables of palm kernel fat

References	Abu-Hadeed and Kotb, 1988 (wt%)	Homberg and Bielefeld, 1982*a* (area%)	Homberg and Bielefeld, 1990*a* (area%)
Others			
Squalene	1.2	—	—
δ-Tocopherol	0.0	—	—
γ-Tocopherol	1.8	—	—
Sesamolene	0.0	—	—
4-Desmethylsterols			
Brassicasterol	0.0	—	—
Campesterol	1.3	10.7	—
Stigmasterol	1.4	13.7	—
β-Sitosterol	6.4	67.1	—
Δ^7-Stigmasterol	0.0	0.3	—
Δ^5-Avenasterol	—	5.5	—
Cholesterol	—	1.2	—
4-Methylsterols			
Obtusifoliol	0.3	—	41.0
Citrostadienol	0.1	—	14.4
Cycloeucalenol	—	—	14.7
Gramisterol	—	—	5.5
4,4′-Dimethylsterols or triterpenes			
β-Amyrin	0.1	—	2.0
Cycloartenol	2.0	—	63.5
24-methylencycloartanol	0.4	—	19.5

- Typical triglyceride composition of hydrogenated palm, pamlolein, peanut and other plant oils as determined by packed-column GC (Fincke, 1980).

Processing and interesterification

- Influence of the three refining processes (bleaching, De Laval, Zenith) on the unsaponifiables (Johannsson and Hoffmann, 1979). Sterols were reduced to about one-third of the initial concentration, while the concentration of sterol esters remains unaffected. However, changes in the composition of fatty acids of the sterol esters were found.
- Composition of a calorie-reduced fat (Masterson *et al.*, 1994). Reduction of caloric intake is achieved by introducing behenic acid.

Table 26. Typical fatty acid composition of palm kernel oil

References	Abu-Hadeed and Kotb, 1988 (wt %)	de Jong and de Jong, 1991 (area%)
C8	2.4	5.7
C10	2.5	4.7
C12	36.9	46.1
C14	12.7	17.5
C16	7.0	9.2
C16:1	0.0	0.0
C18	1.7	3.0
C18:1	14.4	11.5
C18:2	2.2	2.2
C18:3	trace	0.0
C20	0.1	0.0
C20:1	0.0	0.0

- Fatty acid composition of mahua (*Madhuca longifolia* or *M. indica*), dhupa (*Vateria indica*) and mango (*Mangifera indica*) interesterified with palmitate and/or stearate (Sridhar *et al.*, 1991).
- Production of a cocoa butter-like fat from the interesterification of totally hydrogenated cottonseed and olive oils (Chang *et al.*, 1990).

CONCLUSION

Cocoa butter is the only continuous fat phase in chocolate and is therefore responsible for the dispersion of the other constituents. Efforts have been made to find an alternative to cocoa butter and to replace parts of the cocoa butter in chocolate, for economic and technological reasons.

A wide variety of plant fats have been investigated for their potential as cocoa butter alternatives. Their compositional data with respect to triglycerides, fatty acid and sterol and other fractions of the unsaponifiables are given in this report for the individual analysis of plant fats. Compositional data reflecting typical ranges for the individual fats not included in this review are comprehensively published elsewhere (citations given).

There is no other naturally occurring fat with the same physical properties as cocoa butter. It is brittle at room temperature and is completely and fast melting at body temperature. Thus, all possible alternatives are made by blending and/or modifying fats. The major methods for modification of the fats are fractionated crystallisation and interesterification of the fat as well

Table 27. Sterol, fatty acid and triglyceride composition of other vegetable oils and fats

Origin of fat	Fatty acids	Triglycerides	Sterols and other unsaponifiables
Aceituno (*Siamrouba glauca*)	Lewy-van Séveren, 1953		
Allenblackia	Meara, 1979; Fincke, 1975;	Meara, 1979; Fincke, 1975	
Almond	Aitzetmüller and Ihrig, 1988; Rugraff *et al.*, 1982; García-López *et al.*, 1996	Aitzetmüller and Ihrig, 1988; Caboni *et al.*, 1991; Fincke, 1980; Letter, 1993; Rugraff *et al.*, 1982	Frega *et al.*, 1993*a*; Rugraff *et al.*, 1982
Avocado	Lozano, 1983	Lozano, 1983	Frega *et al.*, 1993*a*
Bacaba (*Oeno carpus distichus*)	Filho *et al.*, 1995	Filho *et al.*, 1995	
Borneo tallow	Kanematsu *et al.*, 1978*a*	Kanematsu *et al.*, 1978*a*	Kanematsu *et al.*, 1978*a*
Ciphea	Wolff *et al.*, 1983		
Coconut	Abu-Hadeed and Kotb, 1988; Homberg and Bielefeld, 1982*a*; van Niekerk and Burger, 1985; Saccà *et al.*, 1991	Kemper *et al.*, 1988	Abu-Hadeed and Kotb, 1988; Frega *et al.*, 1993*a*; van Niekerk and Burger, 1985
Coincya (*Brassicaceae*)		Vioque *et al.*, 1994	
Corn	Abu-Hadeed and Kotb, 1988; Homberg and Bielefeld, 1990*a*; Homberg and Bielefeld, 1990*b*; Konishi *et al.*, 1993; van Niekerk and Burger, 1985; Trathnigg and Mittelbach, 1990; Zeitoun *et al.*, 1991	Caboni *et al.*, 1991; D'Alonzo *et al.*, 1982; Damiani *et al.*, 1994; Frega *et al.*, 1990; Kemper *et al.*, 1988; Kaufmann and Herslöf, 1991; Letter, 1993; Rezanka and Mares, 1991; Zeitoun *et al.*, 1991; Itabashi *et al.*, 1991; Itabashi *et al.*, 1990	Abu-Hadeed and Kotb, 1988; Biedermann *et al.*, 1993; Frega *et al.*, 1993*a*; Frega *et al.*, 1992; Homberg and Bielefeld, 1990*b*; van Niekerk and Burger, 1985; Gordon and Griffith, 1992
Cotton seed	Abu-Hadeed and Kotb, 1988; van Niekerk and Burger, 1985; Zeitoun *et al.*, 1991	D'Alonzo *et al.*, 1982; Fincke, 1980; Frega *et al.*, 1990; Letter, 1993; Rezanka and Mares, 1991; Semporé and Bézard, 1991	Abu-Hadeed and Kotb, 1988; Frega *et al.*, 1993*a*; van Niekerk and Burger, 1985
Cyperus esulentus		Oderinde and Tairu, 1992	Oderinde and Tairu, 1992

—*continued*

Table 27—*contd*

Origin of fat	Fatty acids	Triglycerides	Sterols and other unsaponifiables
Dhupa fat (*Vateria indica*)	Baliga and Shitole, 1981; Lakshiminarayana, 1977; Sridhar *et al.*, 1991	Baliga and Shitole, 1981; Lakshiminarayana, 1977; Sridhar and Lakshminarayana, 1991	
Grape seed oil		Caboni *et al.*, 1991; Frega *et al.*, 1990; Kemper *et al.*, 1988; Rezanka and Mares, 1991	Biedermann *et al.*, 1993; Grob *et al.*, 1994*b*; Frega *et al.*, 1993*a*; Frega *et al.*, 1992; Gordon and Griffith, 1992
Hazelnut	Homberg and Bielefeld, 1982*a*; Rugraff *et al.*, 1982; Saccà *et al.*, 1991	Caboni *et al.*, 1991; Casadei, 1987; Damiani *et al.*, 1994; Fincke, 1980; Frega *et al.*, 1990; Rugraff *et al.*, 1982	Frega *et al.*, 1992; Rugraff *et al.*, 1982; Gordon and Griffith, 1992
Linseed	Trathnigg and Mittelbach, 1990	Bergqvist and Kaufmann, 1993; Kemper *et al.*, 1988	
Madhuca longifolia	Senaratne *et al.*, 1982		
Mango fat (*Magnifera indica*)	Baliga and Shitole, 1981; Banerji *et al.*, 1984; Lakshiminarayana, 1977; Lakshiminarayana *et al.*, 1983; van Pee *et al.*, 1981*b*; Sridhar *et al.*, 1991; Chaudhuri *et al.*, 1983	Baliga and Shitole, 1981; Fincke, 1980; Lakshiminarayana, 1977; van Pee *et al.*, 1981*a*; Sridhar and Lakshminarayana, 1991; Chaudhuri *et al.*, 1983	
Microorganism	Beavan *et al.*, 1993; Hassan *et al.*, 1993; Hassan *et al.*, 1994; Kayle and Ratcliff, 1992	Beavan *et al.*, 1993; Kayle and Ratcliff, 1992; Roux *et al.*, 1994	
Mowrah fat (*Bassia latifolia*, *Madhuca latifolia*)	Baliga and Shitole, 1981; Bhattacharyya and Banerjee, 1983; Lakshiminarayana, 1977; Meara, 1979; Sridhar *et al.*, 1991; Fincke, 1975	Baliga and Shitole, 1981; Fincke, 1980; Lakshiminarayana, 1977; Fincke, 1975; Chaudhuri *et al.*, 1983	
Mahua	Chaudhuri *et al.*, 1983		
Oat		Frega *et al.*, 1990	

—*continued*

Table 27—*contd*

Origin of fat	Fatty acids	Triglycerides	Sterols and other unsaponifiables
Oenotera		Caboni *et al.*, 1991	
Papaya	Nguyen and Tarandjiiska, 1995	Sridhar and Lakshminarayana, 1991	
Pauta pulp (*Oenocarpus bataua*)	Filho *et al.*, 1995	Filho *et al.*, 1995	
Peanut	de Jong and de Jong, 1991; Filho *et al.*, 1995; Homberg and Bielefeld, 1990*a*; van Niekerk and Burger, 1985; Trathnigg and Mittelbach, 1990; Zeitoun *et al.*, 1991; Chiou *et al.*, 1995	Caboni *et al.*, 1991; Fincke, 1980; Frega *et al.*, 1990; Filho *et al.*, 1995; Perrin and Prévot, 1986; Semporé and Bézard, 1991; Semporé and Bézard, 1986; Zeitoun *et al.*, 1991	Biedermann *et al.*, 1993; Frega *et al.*, 1993*a*; Frega *et al.*, 1992; van Niekerk and Burger, 1985
Phulwara	Meara, 1979; Reddy and Prahakar, 1994*b*; Reddy and Prabhakar, 1994*a*	Meara, 1979	
Pine seed			Frega *et al.*, 1993;
Poppy seed		Kemper *et al.*, 1988	
Pumpkin seed		Kemper *et al.*, 1988	
Rapeseed	Abu-Hadeed and Kotb, 1988; Homberg and Bielefeld, 1990*a*; de Jong and de Jong, 1991; Trathnigg and Mittelbach, 1990	Bergqvist and Kaufmann, 1993; Caboni *et al.*, 1991; D'Alonzo *et al.*, 1982; Kemper *et al.*, 1988; Kaufmann and Herslöf, 1991; Perrin and Prévot, 1986	Abu-Hadeed and Kotb, 1988; Biedermann *et al.*, 1993; Grob *et al.*, 1994*b*; Frega *et al.*, 1993*a*; Gordon and Griffith, 1992
Rice		Frega *et al.*, 1990	
Safflower (*Carthamus tinctorius*)	Konishi *et al.*, 1993; Zeitoun *et al.*, 1991	Caboni *et al.*, 1991; Christie *et al.*, 1991; Christie, 1994; D'Alonzo *et al.*, 1982; Zeitoun *et al.*, 1991	Frega *et al.*, 1993*a*; Gordon and Griffith, 1992
Sesame	Abu-Hadeed and Kotb, 1988; Homberg and Bielefeld, 1990*a*	Caboni *et al.*, 1991; D'Alonzo *et al.*, 1982; Frega *et al.*, 1990; Kemper *et al.*, 1988	Abu-Hadeed and Kotb, 1988; Frega *et al.*, 1993*a*

—*continued*

Table 27—*contd*

Origin of fat	Fatty acids	Triglycerides	Sterols and other unsaponifiables
Soybean	Abu-Hadeed and Kotb, 1988; de Jong and de Jong, 1991; Homberg and Bielefeld, 1990*a*; van Niekerk and Burger, 1985; Neff *et al.*, 1992; Zeitoun *et al.*, 1991; Mohamed and Rangappa, 1992	Bergqvist and Kaufmann, 1993; Caboni *et al.*, 1991; D'Alonzo *et al.*, 1982; Fincke, 1980; Frega *et al.*, 1990; Fellat-Zarrouck *et al.*, 1988; Kemper *et al.*, 1988; Kaufmann and Herslöf, 1991; Neff *et al.*, 1992; Palmer and Palmer, 1989; Perrin and Naudet, 1983; Rezanka and Mares, 1991; Zeitoun *et al.*, 1991; Neff and Byrdwell, 1995	Abu-Hadeed and Kotb, 1988; Biedermann *et al.*, 1993; Grob *et al.*, 1994*b*; Frega *et al.*, 1993*a*; Frega *et al.*, 1992; van Niekerk and Burger, 1985; Mohamed and Rangappa, 1992; Gordon and Griffith, 1992
Sunflower	Abu-Hadeed and Kotb, 1988; de Jong and de Jong, 1991; Homberg and Bielefeld, 1990*a*; Konishi *et al.*, 1993; van Niekerk and Burger, 1985; Trathnigg and Mittelbach, 1990; Zeitoun *et al.*, 1991; El-Shami *et al.*, 1994	Caboni *et al.*, 1991; Carelli and Cert, 1993; Christie *et al.*, 1991; Christie, 1994; D'Alonzo *et al.*, 1982; Damiani *et al.*, 1994; Frega *et al.*, 1990; Fellat-Zarrouck *et al.*, 1988; Kemper *et al.*, 1988; Perrin and Naudet, 1983; Perrin and Prévot, 1986; Rezanka and Mares, 1991; Zeitoun *et al.*, 1991	Abu-Hadeed and Kotb, 1988; Biedermann *et al.*, 1993; Grob *et al.*, 1994*b*; Frega *et al.*, 1993*a*; van Niekerk and Burger, 1985; El-Shami *et al.*, 1994; Gordon and Griffith, 1992
Thistle		Kemper *et al.*, 1988	
Tomato		Frega *et al.*, 1990	Frega *et al.*, 1993*b*
Walnut	Wolff, 1993	Kemper *et al.*, 1988	
Wheat germ	Homberg and Bielefeld, 1990*a*; Homberg and Bielefeld, 1990*b*	Caboni *et al.*, 1991; Frega *et al.*, 1990; Kemper *et al.*, 1988	Biedermann *et al.*, 1993; Frega *et al.*, 1993*a*; Homberg and Bielefeld, 1990*b*

as selectively breeding the plants. Several examples of the achievements of these modifications are given in this report.

Due to the huge number of different fats that can be used as cocoa butter alternatives, it seems difficult to establish one or just a few physical or chemical parameters suitable for the detection of other vegetable fats in chocolate. The application of finger-printing techniques seems to be indicated. A detailed review of the analytical techniques suitable for the detection of other vegetable fats in chocolate is published as Part B of this review (Lipp and Anklam, 1998).

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