From speciality to commodity

Increasing demand for cocoa butter-based confectionery has sent producers on a quest for alternatives to avoid the high cost of the original product or to improve melting properties. New crystallisation and separation technologies are being used to produce these speciality fats *Desmet Ballestra Group*

With increasing consumption of cocoa butter (CB)-based confectionery foods worldwide, demand for CB is far exceeding its availability, with high prices as a direct result.

In order to overcome the shortage and, at the same time, improve the physical properties of some CB sources, the confectionery industry is continuously looking for alternatives to either replace CB in their recipes or improve its melting properties. These alternatives are better known as speciality or confectionery fats.

Specialty fats belong to a unique category because they are substitutes for other types of high value-added exotic fats like CB, typically used in an extensive range of chocolate, confectionery, bakery and ice cream products.

Confectionery fats are designed to resemble the functional properties of CB and there are three types of CB alternatives – the cocoa butter equivalents (CBE), the cocoa butter substitutes (CBS) and the cocoa butter replacers (CBR).

Real chocolate is made using only CB or CB blended with a maximum of 5% CBE. Apart from a reduction in fat costs, the main advantage of adding CBE is to improve the physical properties of the fat fraction in the chocolate.

CBE can be customised by a proper selection of its constitutive ingredients, such as palm mid fraction, shea butter stearin, illipe, sal, kokun and mango kernel fats.

When the melting profile – usually expressed as a solid fat content (SFC) profile – of the CBE is well above the CB SFC profile, it becomes a cocoa butter improver (CBI).

Since CBE is fully compatible with CB (due to its high concentration of POP, POS and SOS triglycerides), the amount of CBE that can be incorporated into a CBE-based chocolate is a flexible parameter, allowing producers to make chocolate products with a minimum amount of CB.

CBS-based chocolates are the most widely consumed products of the three. A CBS-based chocolate does not require tempering. The main sources of CBS are palm kernel and coconut stearin.

Due to shorter chain triglycerides (lauric and myristic types), the compatibility of CBS with CB is very low, typically 5%. Commercially available CBSs are usually post-hydrogenated, fully or partially depending on the application.

The latter is progressively being abandoned in favour of the *trans*-free version.

CBR-based chocolates were, for a long time, considered the best economical alternative to real CB-based chocolate. The main sources for CBR are palm, soyabean and rapeseed oils. CBRs are non-tempering fats and they have a partial compatibility with CB with a typical tolerance of 20% of CB.

The specific functionality of CBR is due to the presence of *trans* fatty acids (35-45%), which today are under fire from health conscious consumers and experts. To overcome this, CBRs with lower *trans* fat content (5-8%) are now being developed.

From a processing point of view, all vegetable fats used in these applications are mostly fractionated (ideally with dry, optionally with solvent processes), possibly hardened (preferably with full hydrogenation), or even interesterified (chemically or enzymatically, randomly or selectively) to match the product specifications.

Fractionation technology

When applied to speciality fats, the term *'fractionation'* refers to a selective fractional crystallisation of triglycerides, followed by the separation of the solid from the remaining liquid fraction.

The fractional crystallisation is carried

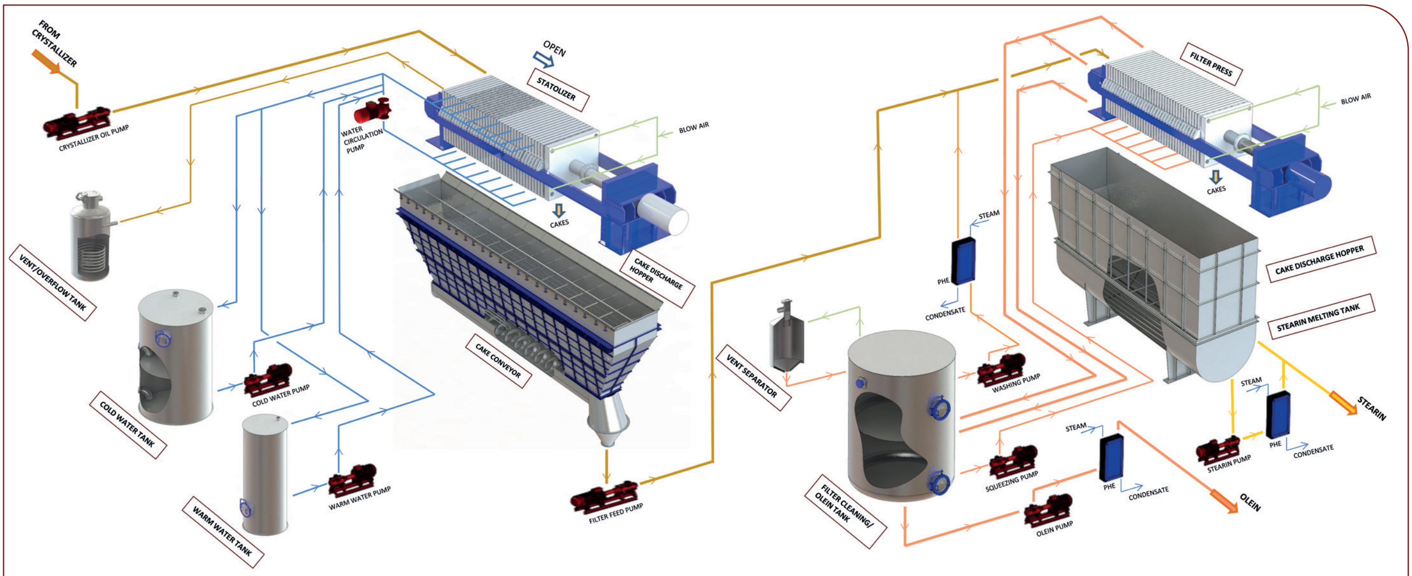

Figure 1: Operation schematic of the Statolizer process in dry fractionation

Source: Desmet Ballestra

	Cocoa Butter Equivalents				Cocoa Butter Substitutes						
					PKO Single-stage Statolizer		PKO Double-stage Statolizer			CO Single-stage Statolizer	
	HPMF Statolizer	HPMF Solvent	SBS Solvent		PKS	HPKS (CBS1)	PKS (CBS2)	PKS	HPKS (CBS3)	CS IV ~5	CS IC ~3
IV	33.4	32.8	31.0	IV	7.0 →	< 1	4.8	7.4 →	< 1	4.6	2.5
% (HPLC)				% (GC)							
DAG	2.4	1.0	1.2	C8:0	<1.5	<1.5	<1.5	<2.5	<2.5	4.5	2.8
POP	67.4	68.6	0.8	C10:0	2.2	2.6	2.2	2.8	3.1	4.7	4.2
POS	12.0	15.1	12.1	C12:0	54.5	53.4	54.9	56.3	55.9	48.3	47.9
SOS	1.2	1.9	76.1	C14:0	23.2	22.2	25.6	19.6	19.3	25.2	28.8
				C16:0	9.8	9.3	10.1	8.9	8.8	9.9	11.0
				C18:0	2.2	10.5	2.0	2.0	10.9	2.6	2.8
				C18:1	6.9	-	4.7	7.5	-	3.6	2.1
SFC (%@°C)	Parallel IUPAC 2 150 b (tempered)			SFC (%@°C)	Serial IUPAC 2 150 a (non-tempered)						
10	91	94	94	10	92	99	97	92	99	91	96
20	85	88	93	20	87	98	95	83	96	72	90
25	73	79	93	25	75	92	85	63	84	40	71
30	42	47	92	30	34	50	56	16	42	1	17
35	1	0	86	35	0	5	1	0	5	0	1
40	0	-	9	40	-	0	0	-	0	-	0

Source: Desmet Ballestra

Table 1: Parameters of some hard palm mid fractions (HPMF), shea butter stearin (SBS), palm kernel stearins (PKS), hydrogenated palm kernel stearins (HPKS), and coconut stearins (CS) obtained from dry (Statolizer) or solvent (acetone) fractionation

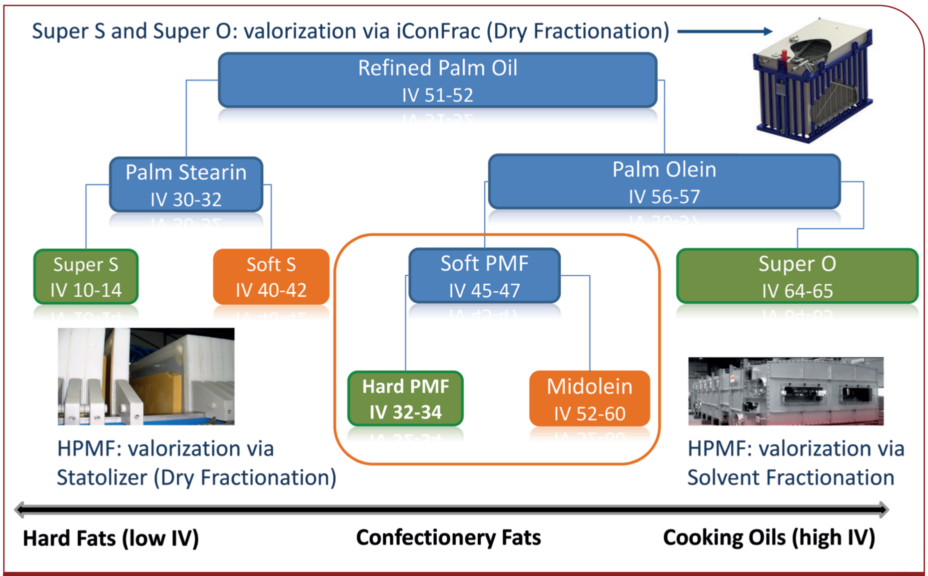

Figure 2: Multi-stage dry fractionation process of palm oil

Source: Desmet Ballestra

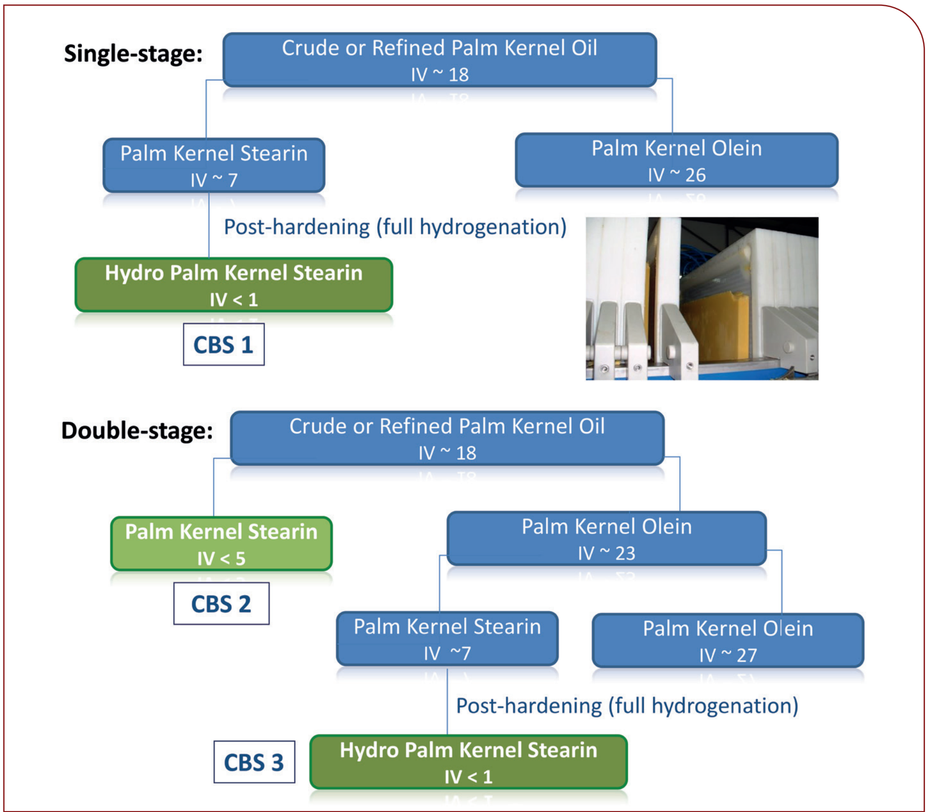

Figure 3: Single- and double-stage dry (Statolizer) fractionation process of palm kernel oil

Source: Desmet Ballestra

out by controlled cooling of a melted fat (dry fractionation) or after it has been diluted in an organic solvent (solvent fractionation).

Dry fractionation is a sustainable and well proven process as it does not use chemicals, produces no effluent and experiences no oil losses. Different crystalliser types with appropriate and specific designs are commercially available on the market, as well as different separation processes, with the membrane filter press and the vacuum belt filters most widely used in dry and solvent fractionation, respectively.

Dry fractionation can be implemented in continuous mode with the iConFrac process – developed by Desmet Ballestra – the operation of which is based on interconnected Mobulizers. The technology was developed in response to demand for enhancing overall performance with higher olein yields and higher fractions quality, at lower utility consumption.

Desmet's Statolizer is another technology dedicated to static dry crystallisation (*see Figure 1, previous page*). The fully automated system was developed in response to issues with traditional panning and pressing and solvent fractionation technologies.

The Statolizer can handle highly viscous crystal slurries and it is applied to CBE (hard palm mid fraction or HPMF) and CBS (palm kernel and coconut stearin). Membrane press filters, working up to 30 bars of squeezing pressure, are the most powerful tools for separating olein and stearin fractions in dry fractionation.

Solvent fractionation is less popular due to its higher production cost and capital investment, possible safety hazards and environmental issues. However, certain high-grade products can only be made using solvent fractionation.

Traditionally, the fat to be processed is diluted in a solvent, usually acetone, at a specific ratio, typically 3:1 to 4:1 (solvent/oil). Adding a solvent dramatically lowers the viscosity of the crystallising mass and results in a much quicker crystallisation.

In solvent fractionation, there is no real standard plant and each is designed for its specific purpose. The most important aspect of the process is the washing stage during filtration, which allows entrained olein in the stearin cake to be washed out into the olein filtrate stream. Counter-current horizontal vacuum belt filters enable the filter cake to be washed with fresh and cold solvent after main filtration.

Rather than sending these streams to solvent recovery, recycling them to the front of the process allows for a second chance to recover final traces of olein and reduces solvent consumption. These filters are totally enclosed so that they can operate in a fully explosion proof environment.

Practical approach

Cocoa butter

The most abundant triglycerides in CB are POP, POS and SOS. Globally, there is a wide variety of CBs, which are considered soft or hard depending also on the quantity of tri-saturated triglycerides (StStSt) present. Fractionation of CB can be done dry or in solvent.

When fractionation is conducted in dry conditions and under shear, the crystal slurry viscosity rapidly increases, which necessitates early filtration. The triglyceride composition of stearin and olein fractions and the operation yield (10-20%) obtained this way are far from those obtained from solvent fractionation.

However, with the Statolizer technology, static crystallisation can be carried out beyond the viscosity limits, allowing a time-dependent and more powerful demixing of the three mono-unsaturated triglycerides, as evidenced by the solid fat content profile of the corresponding stearin and the operation yield (>50%), which are getting close to solvent fractionation.

Cocoa butter equivalents

HPMF and shea butter stearin (SBS) are often used as ingredients for CBE, with shea butter increasing the SOS content, while palm oil is the source of POP.

HPMF is produced through multi-stage fractionation of refined palm oil (*see Figure 2, previous page*). Palm oil fractionation makes it possible to cover a wide range of food products, from hard fats to confectionery fats and cooking oils.The first two steps are easily completed by dry fractionation under shear and the iConFrac continuous process can be used for them.

However, when it comes to concentrating the POP in the HPMF, a certain viscosity develops that forces producers to turn to alternative technologies, like the Statolizer, or solvent fractionation for the last step. Acetone is generally preferred due to lower energy consumption and better selectivity.

Indeed, symmetrical triglycerides tend to experience higher crystallisation in acetone compared to non-symmetrical ones. Furthermore, diglycerides – being more soluble in acetone – will concentrate in the mid olein, allowing for better reduction in HPMF.

Today, high grade HPMF can be obtained from palm oil using the Statolizer technology in the last fractionation step (*see Table 1, pg6*). Compositional and thermal properties tend to largely approach what the acetone process can do.

However, the dry route remains a less attractive option for performance yield. Further developments are aimed at specifically improving the yield as the dry fractionation route is by far the most sustainable one. For some feedstocks, like shea butter and the highest quality speciality palm oil-based end products, dry fractionation is difficult and the solvent technology is, to date, still the preferred route (*see Table 1, pg6*).

Due to high latent heat release from the crystallisation of SOS (the major triglyceride of shea butter), dry crystallisation is often not manageable, no matter what the crystalliser's design. Using the acetone process for shea butter fractionation has three advantages:

- Better crystallisation heat dissipation under diluted conditions
- Adjustment of the diglyceride level in the stearin
- Possible upstream removal of the karitene by precipitation in the solvent. Shea butter is characterised by its 4-5% level of karitene (poly-isoprenic hydrocarbon fraction), which cannot be easily removed by conventional refining processes. Having a negative impact on the crystallisation properties of SBS, the karitene content has to be reduced for edible product applications.

The solid fat content profile of HPMF is completely different from that of SBS, the latter being much harder and having a melting point between 35 and 40°C. Adequate selection of the relative proportions of the two components and possible addition of other tropical fats makes it possible to modulate the melting properties of CBE according to final product specifications.

Cocoa butter substitutes

CBS, mainly derived from palm kernel oil (PKO) or coconut oil (CO), is particularly high in lauric and myristic fatty acids. However, CO has a lower iodine value (IV) due to a lower oleic content, compensated for by more caproic and myristic fatty acids. Both PKO and CO can be fractionated in their crude, semi or fully refined states. For PKO (*see Figure 3, previous page*), the Statolizer allows consistent production of palm kernel stearin IV~7 in a single-stage process. This palm kernel stearin can be used as a CBS after full hydrogenation (CBS 1, IV < 1) (*see Table 1, pg6*).

A double-stage process route allows for the production of unhardened yet high quality CBS 2 (IV <5). This unhardened palm kernel stearin has outstanding melting and crystallisation properties when compared to the traditional (single-stage), fully hydrogenated stearin fraction. The absence of post-hydrogenation is considered a plus for those who aim to produce clean and green CBS.

An increase in total stearin yield can be achieved through successive fractionation of the corresponding palm kernel olein into a second palm kernel stearin IV ~7 and a higher IV palm kernel olein.

After post-hardening (IV < 1), this second palm kernel stearin has the characteristics of a good CBS (CBS 3), although it is a little softer. The reduced hydrogenation capacity is another important benefit of the double-stage static fractionation process of PKO.

For CO, it is possible to obtain, in one single-stage process with the Statolizer technology, stearins with an IV varying between 2 and 5 (*see Table 1, pg6*). This IV is lower than that of a typical palm kernel stearin, which is around 7.

However, the corresponding solid fat content profiles are softer, essentially at 30°C and this cannot really be improved after full post-hydrogenation.

For this reason, CO is a less suitable feedstock for use in normal substitute chocolate coatings. Other applications are biscuit filling creams or chocolate centres, where the rapid melt gives a pleasing cooling sensation in the mouth.

Cocoa butter replacers

Good CBR can be obtained through dry fractionation of partially hydrogenated soft oils. This can easily be done using the iConFrac process.

When starting with, for example, partially hydrogenated soyabean oil (IV around 77), the olein can be re-fractioned, producing a stearin (CBR), which has a steep melting profile and a high *trans* isomers content of more than 40%. However, the negative image of *trans* fatty acids in food products and regulations put in place to mitigate them have made these types of products less and less desirable.

Conclusions

CB alternatives are mostly manufactured from fractionated tropical fats, selected based on their final applications. Some are blended in variable proportions, used as they are or post-hydrogenated. The current tendency is to avoid *trans* isomers in food formulations and favouring low or zero *trans* products.

Fractionation technology has progressed, particularly in the last decades, so that the majority of these products can today be obtained using the dry process route.

Another recently developed approach is lipase-catalysed CBE production, resulting in structured lipids with a high amount of symmetrical SOS triglycerides.

This process, however, remains quite costly, considering the enzyme price and the post-treatments (distillation, fractionation) necessary for purification and quality improvement.

Through innovation and creativity, confectionery fats have evolved from a speciality to a commodity. New directions in both crystallisation as well as separation are being explored and it is only a matter of time when the results reach the level of industrial reliability and efficiency. ●

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