Trans fat-free production strategies for margarine

Palsgaard has examined how crystallizers can step in to fill the production performance gap left by slowly crystallizing, trans fatty acid-free margarines.

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PUBLIC ENEMY: TRANS FATS

In the early nineties, a landmark Harvard Medical School paper[1] concluded that trans fatty acids present a significant health risk, with higher risks of cardiovascular disease already registered at daily intake levels of just 5 grams to 6 grams. The impact of the study was powerful and, at least in Europe, instantaneous. Since 2004 in Denmark, for example, oils and fats used in food products have been permitted a maximum of 2% non-animal trans fat content.

The US, on the other hand, has been somewhat slower to react, though it introduced mandatory labelling for trans fats in 2006. Most recently however, in June 2015, the U.S. Food and Drug Administration (FDA) finalized a determination that trans fats are not generally recognized as safe, and set a three-year time limit for their removal from all processed foods.

LIFE WITHOUT TRANS FATS

Without trans fats, which is commonly derived from partly hydrogenated fats, it's much more difficult to consistently produce high-quality margarine. In fact, every part of the production process becomes more sensitive to a variety of factors that were comfortably handled by partially hydrogenated oils in the past.

One such factor is the higher melting point of other fat types. For optimum flavor release, it's best to use fats that melt at approximately mouth temperature: around 35° C (95 °F). In the old world, trans fats fitted the bill perfectly. In the new one, the only economically feasible, readily available fat type is palm oil, fractions of palm oil, or interestified fat types – but all lack comparable functionality.

The melting point of a fat also affects the ability of manufacturers to work with the fat during the production process. In a trans-fat-free world, you get a mixture of high melting point fractions and liquid oil, giving a higher melting point and a tendency toward softer products. Perhaps the most important phenomenon, however, is the slower crystallization speed of trans fat alternatives.

SLOWER CRYSTALLIZATION, LOWER CAPACITY

Generally, manufacturers simply cannot produce as much margarine from the same production lines as before. Process parameters require adjustment to handle slower crystallization, and most often, investments in new tube chillers are demanded or, for example, the combination of two machines where only one was needed before. Whichever route is chosen, final product quality just won't be the same.

Lower production capacity is one effect of slower crystallization. Another is that crystallization continues to develop for longer than the usual 24 or so hours during pre-storage, changing its structure over an extended period of time and resulting in a more brittle product. Storage, therefore, and storage temperature variations, have a much greater effect. In pre-storage, an attempt might be made to to reduce brittleness and ensure consistency by varying temperatures from, for example, 21 degrees for the first 5 days then reducing to 16 degrees thereafter. For some, new pre-storage facilities that can enable the required temperature control may be required.

CRYSTALLIZERS AND EMULSIFIERS

Manufacturers now need to come up with trans-fat-free recipes that give margarine's batch-by-batch quality the best possible chance of success. Our research and experience indicates that crystallizers can do much to ease the production process. To discover how they can help, we examined how various process parameters affect the speed and nature of crystallization for puff pastry margarine.

When chilling begins in the margarine production process, the first crystals appear, creating a 'seat' for more to build upon, finally arriving at a much firmer mass that must be broken down somewhat, restoring plasticity.

To tackle this problem, we used one of our pilot plants to start the seating earlier in the process, allowing more time in the machine to reduce post-crystallization. Longer time in the equipment, however, means greater effect from the pin machine and the following tube chillers, resulting in a quite different product.

Our trials compared hydrogenated, interesterified fat, and non-hydrogenated fat in puff pastry margarine. Hydrogenated fat performed best, crystallizing quickly. Far slower to crystallize, non-hydrogenated fats such as palm oil performed worst. In fact, both before and after the pin machine the latter was hopelessly overworked, and would be impossible to pack or, for that matter, to eat. The interesterified fat medium crystallized well, but again was all too easy to overwork.

THE SOLUTION OF CHOICE

A key aim is to determine a crystallizer whose melting point makes it easy to use in production. We found this can be achieved with steric acid (18), combined with behenic acids.

Tribehenic and monobehenics have the most extreme melting points for crystallizers. Other triglyceride compositions, on the other hand, with behenic acids can produce a lower melting point, making them easier to handle in production. Any of these acids can easily be purchased, but constructing such triglycerides is no walk in the park. Locating the behenic acids in the right place on the chain requires more than a little expertise!

The melting points of various fatty acids, triglycerides and crystallizers can be seen in Table 1.

Table 1:
Melting points of fatty acids, triglycerides and crystallizers

	TRIVIAL NAME	MELTING POINT	TRIVIAL NAME	MELTING POINT
C12:0	Lauric acid	44.4°C (112°F)	Trilaurin	46.1°C (115°F)
C14:0	Myristic acid	54.4°C (130°F)	Trimyristin	55°C (131°F)
C16:0	Palmitic acids	62.7°C (145°F)	Tripalmetin	65°C (149°F)
C18:0	Stearic acids	69.4°C (157°F)	Tristearin	72.2°C (162°F)
C22:0	Bebenic acids	80°C (176°F)	Tribehenic	82.2°C (180°F)
C18:1 n-9 cis	Oleic acid	16.1°C (61°F)	*Crystallizer : C22 –C18*	61.1°C (142°F)
C18,1 trans	Elaidic acid	43.8°C (111°F)	*Crystallizer : C16 –C18*	57.2°C (135°F)
C18:2 n-6 cis	Linoleic acid	-6.6°C (20°F)	*Crystallizer : C16 –C18-C22*	58.8°C (138°F)
C18:3 n-3 cis	Linolenic acid	-12.7°C (9°F)	*Crystallizer : C18*	72.2°C (162°F)

FACT BOX: The effect of trans fatty acid reduction

- Higher melting point
- Slow crystallization of the fat types
- Easier to overwork the fat product
- Post crystallization
- Change structure over time
- Storage: more sensitive to temperature variations

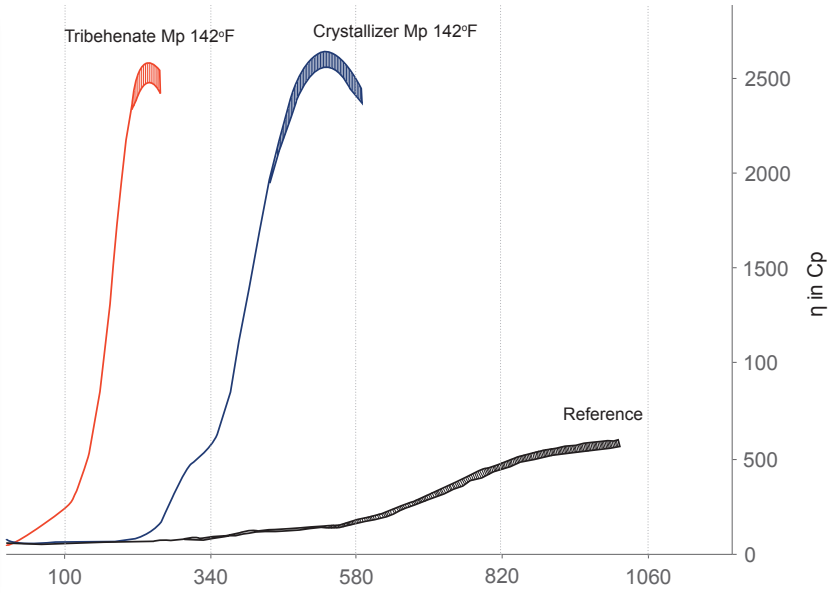

Figure 1:
Crystallizing effect of crystallizer compared with tribehenate

CRYSTALLIZING EFFECTS

Using Tribehenate Mp, with its 82 °C (180 °F) melting point, speeds up crystallization greatly in comparison with our reference (40% palm oil, 40% palm stearin and 20% liquid soya oil without crystallizer), as can be seen in Figure 1.

The Mp crystallizer we tested almost matches the speed of Tribehenate Mp, but with a lower melting point of 61 °C (142 °F). Both solutions far outstrip the performance of the reference. The tests also revealed that using crystallizers forms more beta prime crystals, which have a better absorbing effect than other crystal types.

SFC VALUES WITH AND WITHOUT CRYSTALLIZER

Moving on, we tested a similar puff pastry margarine recipe as in the previous trials, this time adding 1.7 grams of crystallizer. The Solid Fat Content (SFC) values resulting from this addition are depicted in Table 2.

The trials demonstrated a surprising result: While 1.7% crystallizer is not a large portion of the recipe, its effect was strong, quickly getting the seating in place upon which to build further crystals.

CRYSTALLIZERS AND PRODUCTION CAPACITY

Next, we examined the effect of crystallizers on production capacity. We tested two capacity levels, with and without crystallizers added. The study demonstrated that the more crystallizers you add, the higher the bar pressure and therefore the better you are able to maintain or increase capacity. Without adding crystallizers, you would need to reduce capacity, allowing the blend to remain in the tube chillers for longer. So, while adding crystallizers will increase

Table 2:
SFC values in puff pastry margarine blends with and without crystallizer

		TRIAL 3	TRIAL 4	TRIAL 5	TRIAL 8	TRIAL 9	TRIAL 10
Oil blend:	Palsgaard® 6111	1.70	1.70	1.70	0.00	0.00	0.00
	Palm stearin	40.0	42.00	45.00	40.00	42.00	45.00
	R. palm fat mp 42°C	0.00	0.00	0.00	0.00	0.00	0.00
	RBD. palm oil	40.00	42.00	45.00	40.00	42.00	45.00
	Liquid soya oil 6°C	18.30	14.30	8.30	20.00	16.00	10.00
		100	100	100	100	100	100
Melting point:		56.20	56.90	56.20	51.70	50.80	52.80
Avr. SFC % 10°C		61.90	63.00	67.20	52.00	55.40	59.8
Avr. SFC % 20°C		50.00	51.70	54.80	40.20	42.00	43.9
Avr. SFC % 30°C		31.70	32.20	34.20	21.00	22.40	24.80
Avr. SFC % 40°C		21.00	21.80	22.70	12.40	13.00	13.90

recipe costs, there's a worthwhile trade-off in better utilization of production equipment.

We also decided to look more closely at the effect of different crystallizer dosages on production capacity, moving from zero to 0.5%, 1%, 1.5% and, finally, right up to 2% (See Figure 2). To make things more interesting, we simultaneously tested the effect of two different rotation speeds: 400 RPM and 800 RPM.

In Figure 3, the colored bars represent the four tube chillers in our pilot lab production setup. We were able to confirm that applying crystallizers does indeed increase viscosity by the end of the process, but the difference they make is nothing extraordinary.

THE FINAL PRODUCT PERSPECTIVE

We were also curious to learn what might happen if we were to conduct a baking test on the final product itself, experimenting with tube rotation speeds at the same time. So we measured the effect on ten puff pastries of increasing crystallizer dosages from zero to 2%, switching between three different rotation speeds. (See Figures 4 and 5).

Most production machinery has a fixed rotation speed, so this isn't a workable parameter for many. Yet rotation speed strongly affects puff pastry expansion results, performing best at around 10 to 11 times expansion from dough thickness to final baked puff pastry. Introducing crystallizers smooths out the effects of rotation speeds, enabling a good expansion result not only with different process parameters but also on different machines.

ARE CRYSTALLIZERS ALWAYS NECESSARY?

But have we too narrowly pursued crystallizers as the only feasible solution to slower crystallization? Are they, in fact, always necessary?

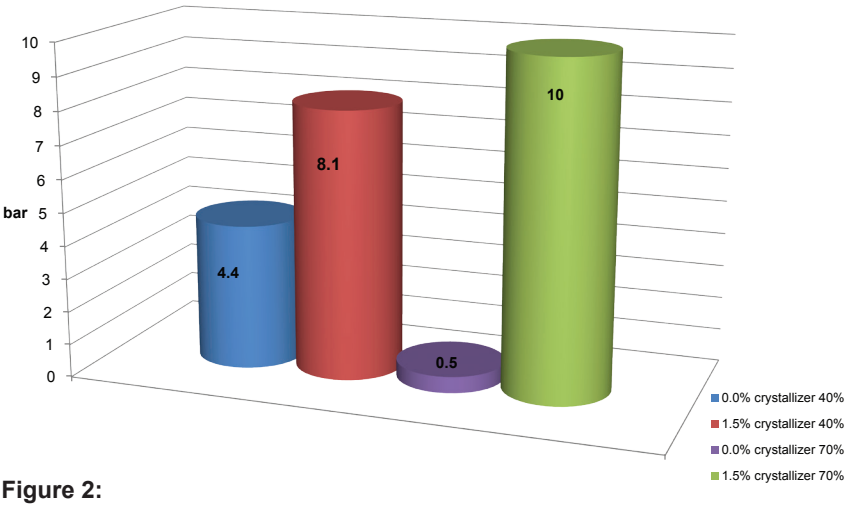

Figure 2:
The effect of crystallizer doses on production capacity

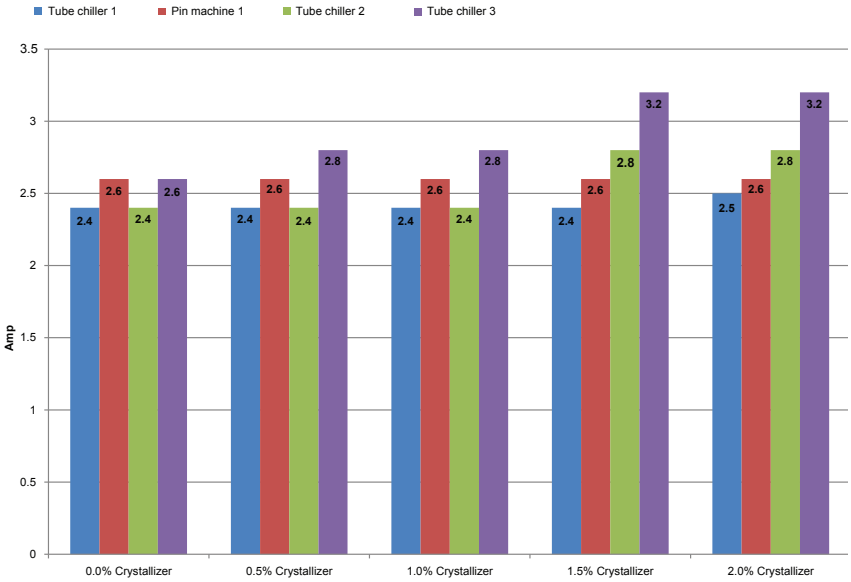

Figure 3:
The effect of crystallizer doses at 400 RPM

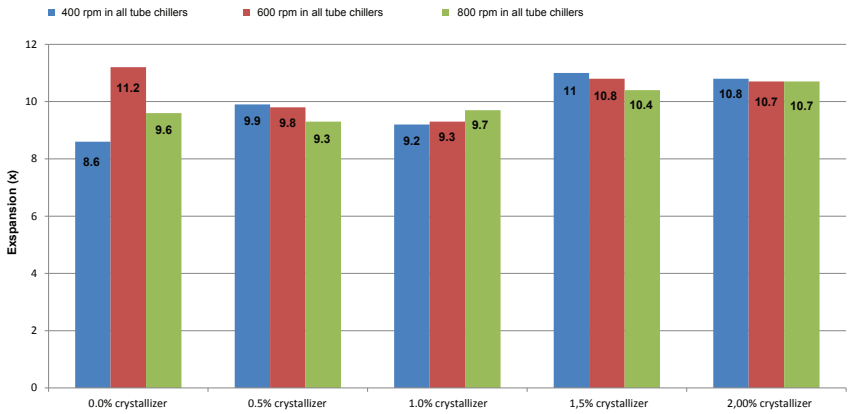

Figure 4:
The effect of different process parameters on puff pastry expansion

It is possible to create recipes that perform just as well as, or at least comparably to the performance of a trans fat-containing formulation. Cake margarines, for example, which use fast-crystallizing fat types such as palm oil or coconut oil fat, have nothing to be gained by adding crystallizers. But with cheaper fat types, small amounts of crystallizers can make a significant difference.

Manufacturers will need to take a look at their equipment line-up, too. Up-to-date machinery may not need crystallizers at all. But most likely, older machinery won't be enough to maintain current capacity and product quality on the new, trans-fat-free playing field – at least, not without applying crystallizer dosages as high as 2%. However, even after an upgrade to more modern equipment, 0.5% to 1% crystallizer content may still add benefits.

MAKING THE MOST OF IT

Palsgaard is busy helping its customers work their way through the hurdles to arrive at a roadmap for process, recipe and equipment adaptations. And we have all the equipment needed to play with every production parameter, taking samples at many different points and conducting trials that simply wouldn't be feasible in a live production environment.

[1] American Journal of Epidemiology. 2005 Apr 1;161(7):672-9.
Dietary fat intake and risk of coronary heart disease in women: 20 years of follow-up of the nurses' health study.
Oh K1, Hu FB, Manson JE, Stampfer MJ, Willett WC.

Figure 5:
Puff pastry baking tests

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