Original Article

Quality of margarine: fats selection and processing parameters

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Optimum processing conditions on palm oil-based formulations are required to produce the desired quality margarine. As oils and fats contribute to the overall property of the margarine, this paper will review the importance of β' tending oils and fats in margarine formulation, effects of the processing parameters - emulsion temperature, flow-rate, product temperature and pin-worker speed - on palm oil margarines produced and their subsequent behaviour in storage. Palm oil, which contributes the β' crystal polymorph and the best alternative to hydrogenated liquid fats, and the processing conditions can affect the margarine consistency by influencing the solid fat content (SFC) and the types of crystal polymorph formed during production as well as in storage. Palm oil, or hydrogenated palm oil and olein, in mixture with oils of β tending, can veer the product to the β' crystal form. However, merely having β' crystal tending oils is not sufficient as the processing conditions are also important. The emulsion temperature had no significant effect on the consistency and polymorphic changes of the product during storage, even though differences were observed during processing. The consistency of margarine during storage was high at low emulsion flow-rates and low at high flow rates. The temperature of the scraped-surface tube-cooler is the most important parameter in margarine processing. High temperature will produce a hardened product with formation of β-crystals during storage. The speed of the pin-worker is responsible for inducing crystallization but, at the same time, destroys the crystal agglomerates, resulting in melting.

Key Words: crystal polymorph, margarine, crystallization, SFC, consistency.

Introduction

Margarine and table spreads are water-in-oil emulsions. The aqueous phase consists of water, salt and preservatives. The fatty phase, which contributes to the polymorphic behaviour of margarine, is a blend of oils and fats. Lecithin, distilled monoacyl glycerol and diacylglycerol are common emulsifiers added together with flavouring, colouring agents and antioxidants.

A good margarine should not suffer oil separation, discolouration, hardening, sandiness, graininess and water separation.[1] The oils and fats, process conditions and handling methods used should be selected so as not to produce a strong crystal network[2], crystal migration and transformation of β'- to β-crystals. The major effort in margarine production should be for the product to be in the β'-crystal form as it would then be smooth, creamy and homogenous. The β-crystal form, on the other hand, will produce a margarine that is post-hardened, brittle, grainy, sandy, oiled out and greasy.[3]

The solidification of oils and fats in margarine processing is not a simple process. Therefore, the main activity in margarine production is crystallization of the oils and fats. The processing parameters, such as emulsion temperature, agitation, flow rate of emulsion, cooling temperature and working are critical[4], thus, their effects on the crystallization of oils and fats and the crystalline nature of the final product are discussed in this paper. This article will review several aspects of margarine fats selection, which includes the chemical and physical properties and crystal behaviour of the oils and fats, preparation of food grade oil, the modification processes, production of the margarines, new developments in margarine formulations and product properties.

Factors controlling the selectivity of oils and fats for margarine

Chemical composition

An oil/fat is mainly comprised of triacylglycerol (TAG) molecules. Three fatty acids are attached to a glycerol backbone to constitute a TAG molecule. The number of carbons in the fatty acid chains, the degree of saturation and the dominant fatty acids are the important factors affecting the TAG properties.[5] The fatty acid content (FAC) can be determined by gas liquid chromatography (GLC).[6] When a

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fatty acid chain contains one double bond it is *mono-unsaturated*, while a chain with two or more double bonds is *polyunsaturated*.[7] The number of double bonds in a fatty acid ester radical will significantly affect both the physical and chemical properties of the TAG to which it is attached. As the number of double bonds decreases or the chain length increases, the melting point of the fatty acids increases progressively.[4] The FAC has a great influence on the physical properties of the oil/fat as discussed below. The degree of unsaturation of a fat is determined by its Iodine Value (IV). Principally, IV is the amount of iodine (in g) absorbed by 100g of the fat under the test conditions. It does not predict the likely product behaviour, which is better done by either the SFC or differential scanning calorimeter (DSC).[8] The temperature at which the lowest TAG melts is the slip melting point (SMP), which is influenced by the chain length (the longer the chain, the higher the SMP), degree of unsaturation (more unsaturation gives a lower SMP) and *trans* fatty acid content (TFA) (unsaturated TFAs give a higher SMP than the corresponding *cis* acids).

Solid fat content (SFC)

The solid attributes of a margarine fat through a temperature range is characterized by its SFC or solid fat index (SFI) profile. SFC is an important property of an oil or fat, and is the ratio of the solid to the total phase at a particular temperature. SFC is measured by nuclear magnetic resonance (NMR) spectroscopy as the number of protons in the solid state over the total number of protons in the fat, i.e. in both solid and liquid states.[4] The SFI is determined by a dilatometer, and is a measure of the specific volume of a liquid oil or liquid/solid mixture subject to a temperature increase.[9]

The consistency of margarine at any temperature can be predicted from its SFC[1] or SFI at that temperature. The SFC and crystal components are responsible for the consistency of the margarine.[1] Moziar *et al.*,[10] however, felt that texture and consistency are not correlated with the SFC, but instead with other factors such as the processing conditions and crystal lattice of the product. Figure 1 shows the SFC profiles of selected margarines. They are represented by the different curves achieved by re-blending several oils and fats with different characteristics.[6,11,12]

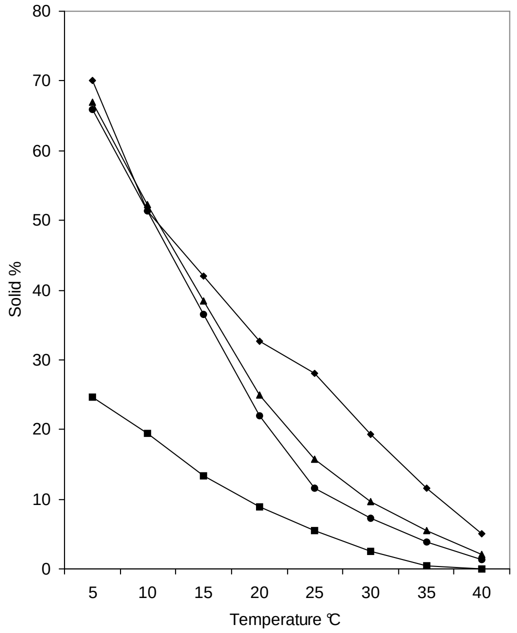

Figure 1. Typical SFC profiles of different margarines: --■-- table refrigerated[1], --◆-- pastry[2], --●-- palm oil[3]. --▲-- table non-refrigerated[1]. Source: [1]Berger[11], [2]deMan and deMan[6], [3]Hui[12]

Polymorphic form

According to Nawar,[5] polymorphic forms are the solid phases of the same chemical composition with different crystalline structures, but which yields identical liquid phases on melting. Timms[13] stated that polymorphs are the different forms of the solid state. According to Talbot[14] polymorphism is the ability of TAG molecules to exist in a number of crystal forms. TAGs can crystallize in different polymorphs with the four major forms being sub-α, α, β' and β.[4] However, the fat crystals in margarine and shortening are only in β' and β forms.[6] A pure TAG would be most stable in the β form, but a mixture of TAGs will be most stable in the β' form.[6] According to Nawar,[5] transformation from one polymorph to another can occur in the solid state without melting. The change is from the lowest to the highest melting point, that is, α → β' → β, or towards the more stable form. When the crystal formed transforms β'→ β, the SMP increases by 2-3°C.[6]

Nawar[5] listed several factors that influence polymorphism, for example, purity of the fatty acids, temperature, rate of cooling, presence of crystal nuclei and the type of solvent used. The β'-crystal polymorph occurs as single needle-shaped crystals about 5–7 μm long, while the β-crystal polymorph is 20-30μm long. The smaller the crystal, the smoother is the product, while bigger crystals will impart a coarse, grainy and brittle texture.[6]

The individual oil and fat crystallizing naturally will be in the predominant form as shown in Table 1. According to deMan and deMan[6] and Peter,[6] the product characterristics, especially during storage, are to a large extent influenced by the crystallization habit and the polymorphic behaviour of the high melting acylglycerols. In margarine and shortening, β'-crystals are desired for a better product with a smooth mouth-feel, and better entrapment of liquid oil because of the spherulitic structure formed.[4] Hence, in formulating blends with good β'-crystal stability, Peter[7] suggested to strongly avoid having mainly one type of TAG or closely similar TAGs. A range of fatty acid chain lengths should always be present in a blend. Blends with hydrogenated palm oil were reported to produce excellent shortenings.[15] Palm oil, besides having an SMP (32-36°C) close to body temperature, has two other important advantages: it is stable and influences other oils to crystallize stably in the β' form.[15]

Table 1. Crystal polymorphic tendency of selected oils and fats

β-crystal form	β'-crystal form
Cocoa butter	Cottonseed
Soybean oil	Palm oil
Corn	Rapeseed oil
Coconut	Tallow
Lard	Milk fat

Source: Hui[12]

Table 2. Contribution of TAG carbon numbers to the formation of β'-and β- crystals in margarine

TAG composition	Probable contribution of TAG (%)	
	β'-crystal form	β-crystal form
C50	7.6-12.8 %	2.2-3.1 %
C52	20-42.6 %	15.9-19.9 %
C54	46.6-51.1 %	68.9-69.2 %

Source: deMan *et al*[4]

The palmitic acid content, distribution and positioning of palmitic and stearic acids on the TAG molecule, degree of hydrogenation and randomisation determine the crystallization habit of the fat. Closely related TAGs contribute to the β-crystal form, while heterogeneous acids are stable in the β' form. Palmitic acid in the *sn*-1 or 3 of the TAG helps stabilize the fat in this form. deMan and deMan[6] suggested that the combined factors of fatty acid diversity, palmitic acid content and its position in the TAG influence the crystallization in β'- or β-crystal form. Corn oil and soybean oil are low in palmitic acid. Both therefore tend to crystallize in the β form (Table 2). However, palm oil, cottonseed oil and butter are high in palmitic acid and, therefore, have a β'-crystallizing tendency. They suggested that for an oil or fat to be in the β'-crystal form it should have diversified fatty acid chain lengths. Therefore, mixing oils and fats with C18 and C16 chains should improve the margarine formulation. deMan *et al.*,[4] studied the blends of commercial margarines to determine the relationship between their TAG carbon numbers and polymorphic forms.

Table 3 shows that a margarine tends to be in β-crystal form when TAG C50 is <4%, C52 <20% and C54 >68% of its composition. Palm stearin, the hard fraction of palm oil, is high in C48 TAG, or tripalmitin (PPP). PPP is β-crystal tending.[13] However, the liquid fraction of palm oil is high in C50 and C52, both of which are β'-crystal tending.[6] Such crystal type is desired in margarine and shortening. A study by Yap *et al.*,[8] on various palm oil fractions showed that palm stearin is least stable in the β'-crystal form followed by palm oil. Hydrogenated oils are generally accepted as promoters of β'-crystallization and are, in fact, the most stable promoters of all. deMan *et al.*,[4] and Yap *et al.*,[15] compared fully hydrogenated oils with liquid oils and palm oil with liquid oils in polymorphic studies. They found that a mixture of liquid oil and palm and palm oil was the most stable in the β'-crystal polymorph. Another study by Souza *et al.*,[16] on the chemical and physical properties of high melting acylglycerols (HMG) in commercial margarines revealed that margarines made from canola oil exhibited the β-crystal form whereas canola/palm oil and soybean oil/corn oil margarines showed β'-crystallization. At 15°C, margarines with <11% palmitic acid (C16: 0) were in the β-crystal form, while those with ≥17% were in the β'-crystal form. Margarines with >70% C54 were β tending while those with ≤50% were in β'-crystal form.

Table 3. Crystal polymorphs contributed by the major TAGs in palm oil

TAG	Content (%)	Crystal polymorph
PPP	8	β-2
POP	33	β-3
PPO	6	β'-3
PlinP	9	Sub β-3
POO	39	β'-3
OOO	5	β-2

The overall polymorphic form of palm oil is β'-2 with some β-2
Abbreviations: P, palmitic acid (C16:0); Lin linolenic acid (C18: 3); O, oleic acid (C18: 1). Source: Timms[13]

A further study on the polymorphic stability of shortenings found that addition of palmitic acid from the hard fat of palm oil to a formulation with β-crystal tendency maintained the product in the β'-crystal form.[8] Addition of 20% palmitic acid to the formulation did not change its β-crystal form, but with 30% palmitic acid the product turned into the β'-crystal form.

Category of margarines

Since its development, margarine has been endlessly modified and improved, giving rise to the range of products now available in the market. Margarines can be categorized by their hardness and melting point of their fats - hard and medium plastic margarines for baking (bakery margarine), and medium plastic and soft margarines for the table (table margarine).

Bakery margarine

Bakery margarine is used like shortening - as bakery fat, and in short pastry, cakes, cookies, breads and pastries.[9] Bakery margarine, like its counterpart, shortening, has a wide plastic range. Thus, within limits, the products are inter-substitutable. Generally, however, bakery margarine is firmer and requires no refrigeration. It is formulated to withstand dough working and, at the same time, provide lubrication for cake leavening.[9] Premium bakery margarines produce a high cake volume and stable cream. Palm kernel oil (both unhydrogenated and hydrogenated) is commonly used in the products.

Table margarine

Table margarines are of two types - refrigerated and non-refrigerated - both spreadable at room temperature. Refrigerated margarine is either soft or block type. The soft type margarine is spreadable straight from the refrigerator and should not suffer any oiling out, while the block type should be sufficiently firm to retain its shape in packets.[5] Soft margarine is packed in plastic (polypropylene) *tubs*, as *sticks* or *blocks* wrapped in parchment, and the semi solid type in *cans*. Soft *stick* margarine is firm and maintains its shape at room temperature for a reasonable time.[5] This margarine has very similar consistency to butter and is formulated to have a steep SFC curve. *Can* margarine does not require refrigeration and is used as a spread on bread as well as for making bread, cookies and cream. *Can* margarine is formulated to have a wide plastic range for general use.

Characteristics of margarine

Margarine can be considered a bacteriologically safe product. The only concerns are the chemical and/or physical defects caused during or after production. The possible defects during production are lumpiness, watering, hardening, discoloration, mottling, saltiness and greasiness, while the defects in storage include sandiness, discoloration, hardening, oil separation and greasiness.[5] For margarines made with good raw materials, the defects can only be due to processing and handling. The overall product quality summarizes the product characteristics of spreadability, texture and consistency and polymorphic behaviour.[11]

Spreadability

This is probably the most important attribute for table margarines and spreads. To the consumer, *spreadability* is the ease with which the margarine can be applied in a thin, even layer on bread. According to deMan *et al*, [4] the penetration yield correlates very well with spreadability. To produce a spreadable margarine, three conditions are necessary: 1) the two phases of liquid and solid oils must coexist, 2) the solid crystals must be sufficiently finely dispersed throughout the entire mass to be effectively held together in the crystal matrix by internal cohesive force. In turn, the matrix should be able to prevent the entrapped liquid from seeping away, and 3) the proper proportions of solid and liquid should be at a certain temperature and the crystals should melt at below body temperature.[1,17] A product with 10-20% SFI at the ser-ving temperature will have good spreadability.

Consistency and texture

Consistency is the measure of smoothness, evenness and plastic state in margarine. It can range from *very soft*, like petroleum jelly, to soft, medium, firm, tough, hard and brittle. Texture is a measure of the structure. It varies from smooth to mealy or floury, grassy, granular or sandy and, finally, coarse and lumpy. According to Greenwell,[17] the consistency and texture of margarine is principally dependant on the processing techniques and the oil and fats used in its manufacture.

In cases where the oils and fats crystallize slowly, the margarine hardens during storage. This phenomenon is known as post-hardening.[4] Oils and fats having more than 30% of their TAGs as POP are slow to crystallize, and therefore susceptible to post-hardening.[4] Although POP has a melting point of 30°C, it crystallizes only at 20°C. The big difference between the melting and crystallizing points makes for a long crystallizing time (slow crystallization rate).

Post-hardening is caused by inappropriate processing conditions. A product over-stirred during supercooling produces excessive small crystals. The structure will be too compact, reducing the size of the capillaries in between the solids.[17] This increases interlocking of the framework, restricting movement of the solids. The viscosity then increases leading to an increase in brittleness.[4]

Mechanical work applied during fast cooling produces margarine with better consistency and stability. However, if the margarine has not had sufficient work, a large number of its primary bonds will still be intact and it will undergo considerable post hardening, becoming brittle and hard-textured.[11,17] Crystallizing the product as much as possible in the scraped surface heat exchanger (SSHE) will contribute greatly to good spreadability and consistency.

Oil separation

Oil separation occurs when the crystal matrix is inadequate to entrap the liquid oil. This occurs because of transformation of the crystals to the β-form.[11] The β-crystals continuously grow bigger (causing sandiness) until the network can no longer retain its lattice structure to entrap the liquid oil. The liquid oil then exudes from the product and the aqueous phase coalesces. The problem is serious for stick margarine but not for soft tub margarine. The susceptibility of a margarine to oil separation can be determined by placing a sample of defined shape and weight on a wire screen or filter paper at 27°C for 24-48 hours and then measuring the oil exuded.[11] Oil separation at a particular temperature has strong relation to the SFC.

Sandiness

According to Nawar,[5] deMan and deMan[5] and Timms,[13] the β' polymorph is the desired form in margarine and shortening. deMan and deMan[5] stated that β' has very small crystals so that it can incorporate a large volume of liquid oil in the crystal network giving a smooth, continuous and homogeneous product. It was also pointed out that the β'-crystal form gives the margarine surface a gloss in contrast to β, which produces a dull and mottled look. The β'-crystals not only provide a good texture to margarine but also contribute to good whipping characteristics. According to Nawar,[5] the small crystals help to trap and hold air during whipping.

In general, the β-polymorph is not desired in margarine, although desired in pastry margarine for pie-crust.[18] The β-crystals have the tendency to grow bigger and bigger into needle-like agglomerates. This is more common in homogenous TAGs. The large crystals impart a sensation of sandiness in the mouth.[4] Soft margarines are more prone to polymorphic transition than the hard ones because of the low SFCs in the soft oils used.[18] This usually occurs in formulations with oils and fats that favour the β-crystal form, inappropriate oil: solid ratios and processing conditions.[5] The β-crystal polymorph crystallizes at a higher tem-perature than the β'-crystals and produces margarine of stiff and hard consistency, which is ideal for piecrust and desirable in pourable shortening. The β-crystal polymorph will support formation of a solid suspension in liquid oil, making the product pourable.

Oil and fat blends

A blend is a simple mixture of different oils and fats in binary, ternary, etc. systems. The oils and fats used can be bulk oils, hydrogenated oils, interesterified oils or their combinations. The formulation of blends is made easier by classifying the oils and fats into various categories, *viz.* soft oils, semi-solid fats and hard fats (Table 4). The SFC and SMP are used to predict the suitability of blends for various uses and climatic conditions.[1] In addition, the recent ability to detect lard in blends with animal fats by Che Man and Mirghani[19] using the Fourier Transformed

Table 4. Selected oils and fats categorized by their SMPs

Soft Oil	Semi-Solid Fat	Hard Fat
Soybean	Butter oil	Palm Stearin
Cottonseed	Palm oil	Tallow
Sunflower	Lard	Hard fraction of butter oil
Rapeseed	Any oil hydrogenated to SMP 32-34°C	
Peanut		
Sesame		
Canola		
Palm olein		

Source: Berger[11]

Infrared (FTIR) spectroscopy has given a boost to margarine formulation. Using this method, the blends and ratios by any manufacturer can be easily deciphered.

According to Chateris and Keogh[1] a blend with 15-30% SFC at 10-30°C will make a spreadable margarine of good plasticity. Conversely, with 10-12% SFC in the same temperature range, the product will be greasy and waxy. A margarine formulation for temperate countries should have 20-25% SFC at 15-20°C. A SFC of 15% ensures a product of good consistency spreadable straight from the refrigerator. According to Hui,[11] to prevent margarine from oiling-off, or oil separation, 3-4% SFC at room temperature suffices. However, this requirement is only applicable to pourable (squeezable) margarine.

Margarine processing

Basic margarine processing comprising five operations - emulsification, cooling (supercooling), working (plastication), resting and packaging[18] - is briefly discussed below (Fig. 2).

Effect of emulsion temperature

The two most prominent changes during processing of margarine are an increase in the SFC and temperature of the product[2] due to the latent heat of crystallization released. When the holding temperatures of the emulsion were 40, 45 and 50°C, the SFCs in the tube cooler were 15.9, 13.9 and 15.6%, respectively.[2] However, the SFCs of the products at the exit of the pin-worker averaged 15.7, 14.1 and 15.8%, respectively. The 45°C and 50°C emulsions had only slightly higher SFCs in the pin worker than in the tube cooler. According to Miskandar *et al.*,[2] although the pin-worker promoted crystallization, the mechanical heat it generated, in addition to the latent heat of crystallization released, melted some of the meta-stable crystals. The mechanical action of the pin-worker also destroyed some of the crystal bonds creating an extremely large number of small crystals and increasing the SFC.[2] The penetration yield (g/cm^2) of the samples at emulsion temperature of 40°C exhibited the highest consistency at Week 1 but was unstable during storage, while the other two samples took one week to equilibrate (Fig 3.)

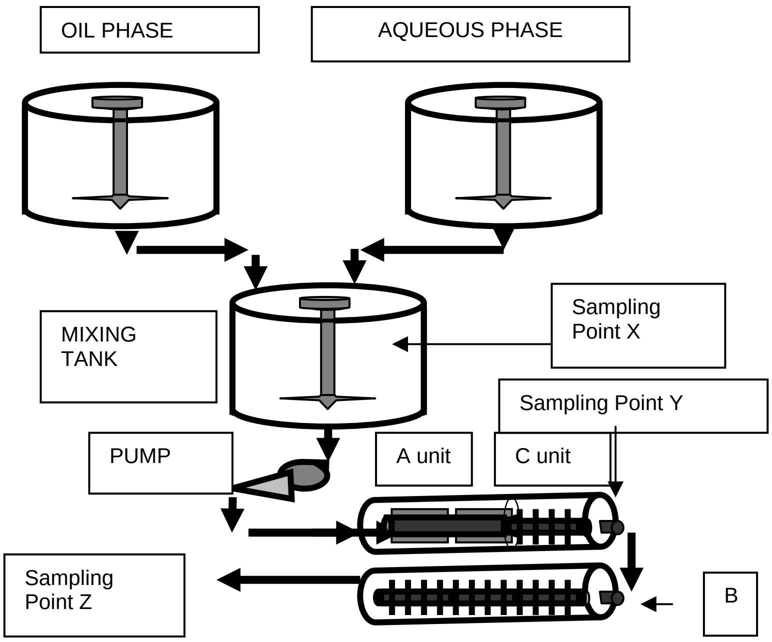

Figure 2. Schematic diagram of margarine processing. Source: Miskandar *et al.*[2]

In order for the product to melt cleanly without leaving any waxy aftertaste in the mouth, the SFC should be <3.5% at 33.3°C, and the product fully melted at 37°C.[11] A cooling sensation is another important criterion for table margarine. A steep melting profile between 15-25°C will give instantaneous absorption of the heat of crystallization and impart a cooling sensation to the tongue.[1]

Crystallization occurred earlier in the tube cooler causing minimum crystallization in the pin worker as indicated by its low product temperature. However, the crystallization in the tube cooler was not very homogenous and became somewhat undone by the agitation of the pin worker which broke some of the crystal agglomerates. The little crystallization as shown by the low product temperature, and

Table 5. Polymorphic transformation of palm oil margarines made at different emulsion temperatures during storage at 28°C

Margarine made at Emulsion Temp (°C)	Storage time			
	Wk 1	Wk 2	Wk 3	Wk 4
40	β’	β’	β’+β (β’>>>β)	β’+β (β’>>>β)
45	β’	β’	β’	β’
50	β’	β’	β’	β’

Source: Miskandar *et al.*[2]

the broken crystal bonds enhanced the formation of crystal aggregates that eventually led to formation of the bigger crystals as shown by the transformation of β’- to β-crystals at the end of the fourth week (Table 5).

Effect of emulsion flow rate

The speed the margarine emulsion passes through the scrape-surface tube and pin-worker system will affect the end product. Too slow a rate and the margarine becomes hard and brittle as the emulsion is too rapidly cooled.[13] The crystallization rate is so rapid that the crystals attach to each other too fast to orientate themselves in a better position.[13] Too high a rate gives insufficient cooling, promoting post-crystallization and hardening, especially in packet margarines.

The consistencies (penetration yield) of the margarine samples processed at different flow rates started off the same and developed along the same trend. However, with storage, they diverged in consistency due to the crystal arrangement and degree of crystallization although all of them had very similar such characteristics to those of industrial margarines. The high SFC with low flow rates caused the formation of a strong crystal network with narrow capillaries in between. This condition did not allow easy crystal movement and therefore caused the margarine to firm up until the third week. Only when some of the low melting acylglycerols started to melt during storage did the consistency gradually reduce. Palm oil, as the β’-crystal promoter,[22] was able to retain its polymorphic behaviour at different emulsion flow rates. Palm oil can also delay the transformation of β’-to β form, as was found by Yap *et al.,*[15] from blending palm oil with several other vegetable oils.

Effect of the scraped-surface tube cooler temperature

When a bulk oil crystallizes, the whole mass does not do so at the same time. Instead, the process starts at discrete sites where the temperature has fallen sufficiently for crystallization points, or nuclei, to form.[3] Thus, when a molten fat cools naturally, a granular product is produced due to the slow crystallization of the individual acylglycerols.[19] With faster cooling, the crystals become smaller and more uniform.[21] With instantaneous chilling, the high and low melting TAGs develop mixed crystals.[4] Furthermore, by stirring, the high and low melting TAGs will crystallize at the same time, causing rapid cooling.[3] Thus, an emulsion passing through a cooling surface at the lowest temperature will receive the greatest cooling to form the most nuclei and crystals, followed by the samples at increasingly higher temperatures. However, the sample on with lowest cooling surface will suffer the highest reduction in SFC in the pin-worker. As the cooled emulsion passes the tube cooler, crystallization will continue rapidly in the pin-rotor but with little net crystal growth as the mechanical action of the pin-worker will cause some crystal destruction to reduce the SFC.[9] Crystal development of the sample at higher temperatures will be less rapid in the tube cooler. However, there will be higher net development in the

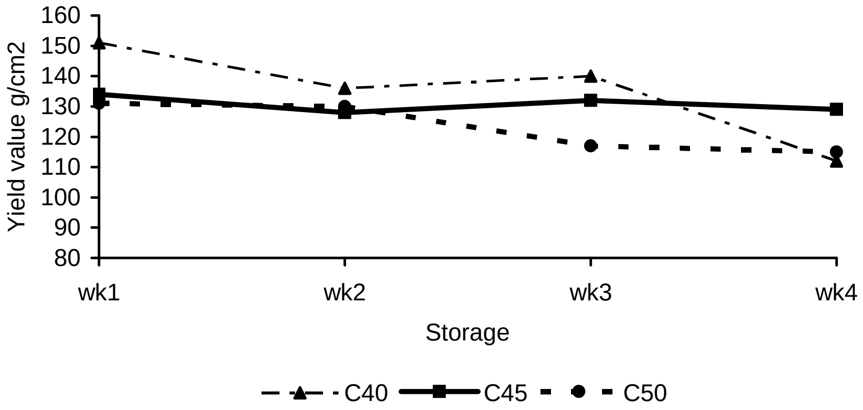

Figure 3. Penetration yields (consistency) (g/cm^2) of palm oil margarine processed under different emulsion temperatures

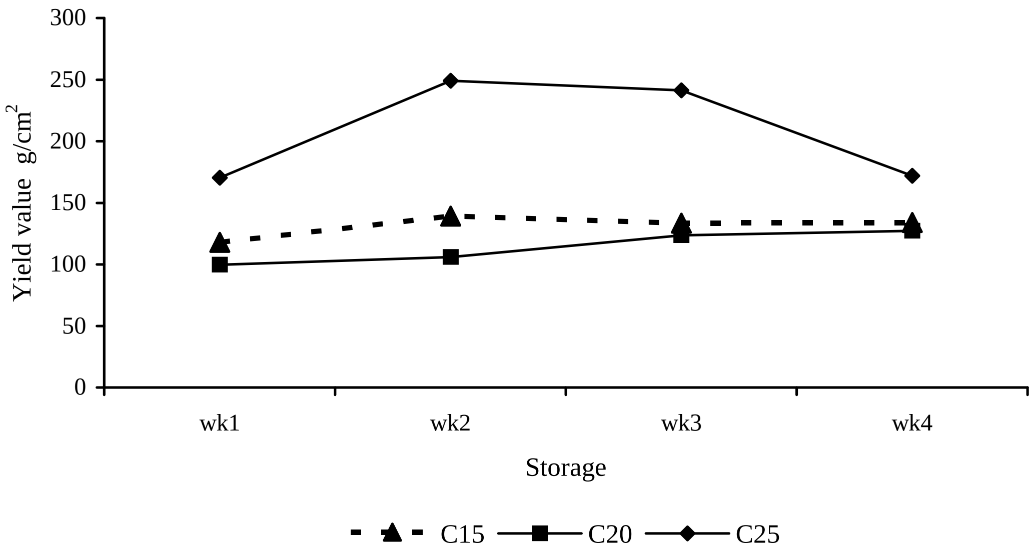

Figure 4. Penetration yields (consistency) (g/cm^2) of palm oil margarines processed at three tube cooler temperatures and stored at 28°C. Source: Miskandar *et al.* [3]

pin-worker. The least crystal development in the tube cooler will be in the samples at the highest temperature.

Destruction of the crystal agglomerates will reduce the crystal size and cause more even crystal dispersion. The penetration yields for these samples were low, but gradually increased with storage, producing a more consistent product (Fig. 4). The crystal polymorphic development of the margarines during storage was in mixtures of β'- and β-crystals with more β' in the sample at lower temperature, and predominantly β- crystals in the sample at higher temperature.

Effect of pin-worker speed

The pin-worker, besides further crystallizing the emulsion, also physically breaks up and works the crystals to improve the texture of the final product. Hui[22] reported that a high pin-worker speed gives a soft and overworked product in spreads. The mechanical work also raises the temperature in the pin-worker by 2°C or more by the latent heat of crystallization.[22]

As the emulsion passes through the tube cooler, it is super-cooled by the refrigerated tube surface, initiating crystallization. According to Hui,[22] differences in SFC suggesting an increase in retention time caused by the higher speed will be noticed. The rotation of the pin-worker will create resistance to the product flow. The rotating blade of the scraped surface heat exchanger will then force more emulsion to the refrigerated surface resulting in more heat being extracted. The emulsion will therefore cool more, reducing the induction time needed.

The high melting acylglycerols will start to solidify in the tube cooler and increase the SFC. The gradual increase in consistency occurring with a low pin worker speed is due to insufficient agitation of the crystal bonds. This will leave an increasingly stronger crystal network with storage. The sample produced from high pin worker speed, which subjects it to great agitation and crystal agglomerate destruction, will have a large number of very small crystals. The very small aggregates can form a very compact crystal structure that gives a hard product and heavy mouth feel.

Conclusion

Selection of oils and fats and the processing conditions, such as temperature, agitation and product flow-rates, should be done with great care in margarine processing. Characterization of the polymorphic tendency will assist in the selection of oils and fats. Margarines are today becoming more customized, catering to the demands by the new life style. The oils and fats for margarine can be modified to tailor-make the desired SFC for the product.

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Quality of margarine: fats selection and processing parameters
人造黄油的质量：脂的选择和生产参数

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以棕榈油为基础的适宜加工条件是生产品质优良的人造黄油所必需的。油脂对人造黄油的整个属性起着重要作用，本文概括了β趋向油脂在人造黄油加工；生产参数（乳化液温度，流量，生产温度和抽油速度）对棕榈油人造黄油及储藏过程性能影响的重要性。棕榈油对β多晶型物及最好选择性氢化油脂的贡献，和生产条件可以通过影响固体脂的含量（SFC）和在生产及储藏过程中晶体形成的类型改变人造黄油稠度。棕榈油，或者氢化棕榈油及棕榈液油，和β趋向油混合，可以改变β晶体的形态，然而仅仅存在β晶体油是不够的，生产条件也很重要。乳化液温度对产品在储藏过程中的稠度和多晶体改变没有显著性变化，虽然在生产过程中能够观察到差异。在储藏过程中，低流量的乳化液能产生高稠度的人造黄油，高流速的乳化液能产生低稠度的人造黄油。冷凝管表面刮擦温度是在人造黄油生产中的最重要参数。高温能通过在储藏过程形成β晶状体导致高硬度的产品；抽油速度具有诱导结晶，但同时，破坏晶体凝结，导致熔化。

关键词：多晶型物，人造黄油，结晶，固体脂含量，稠度