FORMULATION OF *TRANS*-FREE AND LOW SATURATED MARGARINE

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ABSTRACT

Palm stearin (POs) is a good choice for trans-*free hard stock. POs with various iodine values (IV) have distinct solid fat content (SFC) profiles useful in soft margarine formulation. Palm kernel oil (PKO) maintains the margarine with high consistency at low temperatures, but the margarine is soft at serving temperature. The study revealed that formulation work either using bulk oils and fats (sample 900), interesterified hard stock (sample 905) and simple blend of hydrogenated fat and soft oil (904) can achieve similar fatty acid composition, but not the same SFC profile. Sample 905 contains palm-based hard stock from an interesterified product of a fully hydrogenated POs (IV=0) and PKO blended with sunflower oil (SFO) containing 36.1% total saturated fatty acids. Margarine sample 1089 is* trans-*free and has a low saturated fat formulation. Despite its low saturated (17.8%) and polyunsaturated fatty acid (9%) content, its high monounsaturated fatty acid (73%) content stabilizes the crystal development during storage at 5°C, 10°C and 15°C for 25 days with no significant post-crystallization. POs is an excellent hard stock for formulating* trans-*free margarine with low saturated fat content.*

Keywords: palm stearin, margarine, processing condition, SFC profile.

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INTRODUCTION

Margarine is a food product in plastic or liquid form (Haighton, 1976). It is a water-in-fat emulsion, in which water droplets are kept separated by the fat crystals (Haighton, 1976). Weiss (1983) categorized margarine according to demand by different consumers, based on hardness and melting point. A hard and medium plastic characteristic is for bakery margarine while medium plastic and soft is for table margarine. Table margarine is further classified into the distinct categories of tub and brick margarine (Weiss, 1983). Tub margarine has low solids at low temperature, thus enabling it to be spreadable directly from the refrigerator (Deman *et al.*, 1989). In addition, the fat blends should melt completely above 37°C for good oral melt down (Miskandar *et al.*, 2002; Kodali, 2005; Goli *et al.*, 2009). Brick margarine should have the properties similar to tub margarine, but with solid fat content (SFC) of 28% at 15°C to facilitate wrapping, and between 12% and 15% at 20°C to avoid oil out. To meet the melting profile of this margarine, hydrogenated oil is the most common oil used in the formulation.

However, there has been increasing awareness amongst consumers on the detrimental effects of consuming food containing *trans* fatty acid. As margarine and shortening are considered the main contributors of *trans* fatty acid in food, the demand for margarines with low saturates and low *trans* fatty acids is increasing.

Although US Food Drug Administration has recommended that saturated fatty acid (SAFA) content should be <33% and *trans* fatty acids <1%, reducing SAFA to <33% will normally compromise the physical product as SAFA contributes to the structure or body of the margarine by affecting its SFC which can be measured by nuclear magnetic resonance. Reducing SAFA will weaken the structure. Soft margarines packed in tubs and

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having very low SFC are prone to oil separation, graininess and greasiness. When margarine is produced, it should be allowed sufficient crystal formation for the desired consistency during filling. This can be achieved by setting the crystallization temperature at 30% SFC. Storage temperature is another important parameter that has to be managed to ensure the stability and spreadibility of the margarine over time.

To address the current demand for zero *trans* fatty acids in food formulations, especially in fat products such as margarines and shortenings, careful study needs to be conducted. The challenges for the oils and fats producers are mainly in the reduction of production capacities. This is mainly due to the slow crystallization properties of palm oil (Duns, 1985; Chong, 2001), that lead to quality problems such as post-crystallization in soft margarines, softening of the product in puff pastry margarine and shortening, no good lift in pastry products, collapsed creaming and inferior cake volume. Hydrogenated fats, on the other hand, despite of being the major source of *trans* fatty acid in fat products lead to good quality and desired product characteristics, such as beta prime margarine (Yap *et al.*, 1989), rapid crystallization (Moziar *et al.*, 1989) and stable consistency (Deman *et al.*, 1989).

This article reports on a study on palm stearin used as hard stock in the formulation of *trans*-free brick and soft margarines that are low in saturated fat and spreadable at refrigerator temperatures (5°C-10°C).

MATERIALS AND METHODS

Materials

Commercial table margarine samples (brick type) were used. A fully hydrogenated palm stearin, iodine value (IV) = 0, was purchased from Premium Vegetable Oil Sdn Bhd, Johor. Palm stearin (POs) of IV=14 was purchased from IOI Sdn Bhd, Johor, and sunflower oil (SFO) and palm kernel oil (PKO) from Mewah Oleo Sdn Bhd, Selangor. Other ingredients were an emulsifier [distilled monoacylglycerol 90% monoester, slip melting point (SMP) = 69°C)] from Danisco Ingredients (M) Sdn Bhd, Prai Industrial Estate, Pulau Pinang, Malaysia, water (filtered municipal supply) and vacuum-dried salt from a local sundry shop.

Experimental Methods

Fatty acid composition (FAC), SMP and SFC were determined according to Ainie *et al.* (2005). For the production of margarine: 80% fat phase, 0.3% emulsifier, 16% water and 2.0% salt were used. Oils and fats were melted in a Memmert drying oven (854 UL 80, Schwabach, Germany) at 65°C, then weighed accordingly for 50 kg production batches. The emulsifier was added to the fat phase at a ratio of 1:4. The water phase at room temperature (28°C) was then added slowly to the oil phase with agitation to form a good emulsion. The emulsion temperature was maintained at 55°C and held for 10 min in a mixing tank prior to processing in a perfector pilot plant (Gerstenberg and Agger, Copenhagen, Denmark) at the Malaysian Palm Oil Board (MPOB). The tube cooler (A-unit) had a volume of 900 ml and a scraped cooling surface of 0.063 m^2 area. Three tube coolers were set at standard temperatures suitable to the end product consistency, based on individual test formulations. A pin worker (B-unit) with a volume of 3 litres was set before the third A-unit. The emulsion was pumped into the A-unit (at a throughput rate of 45 kg hr^{-1}) where it was rapidly cooled. The scraper was rotated at 1000 rpm, whereas the pin worker stirrer speed was 275 rpm. In the production of brick margarine, the emulsion was allowed to form into a brick shape in a 3-litre resting tube placed after the third tube cooler before it was wrapped and tempered. Soft margarine was collected at the end of the processing line after the pin worker.

The samples for analyses were placed in 5°C, 10°C and 15°C incubators for 30 days. The consistency was determined by the penetration test (Haighton, 1965; Deman *et al.*, 1989) using a cone penetrometer (Stanhope-Seta, Surrey, England) with 40° cone, a weight of 79.03 g and a penetration time of 5 s. Calculations were made according to Haighton (1965), *i.e.* $KW/P^{1.6}$, where K = 5840, W = 79.03 + added weight, and P = mean of the penetration readings. Six readings were taken from each sample every day, using different sub-samples. Microscopic examination for crystal distribution was carried out as described by Miskandar *et al.* (2004).

Storage Study

A storage study was conducted at 5°C, 10°C and 15°C for 30 days.

RESULTS AND DISCUSSION

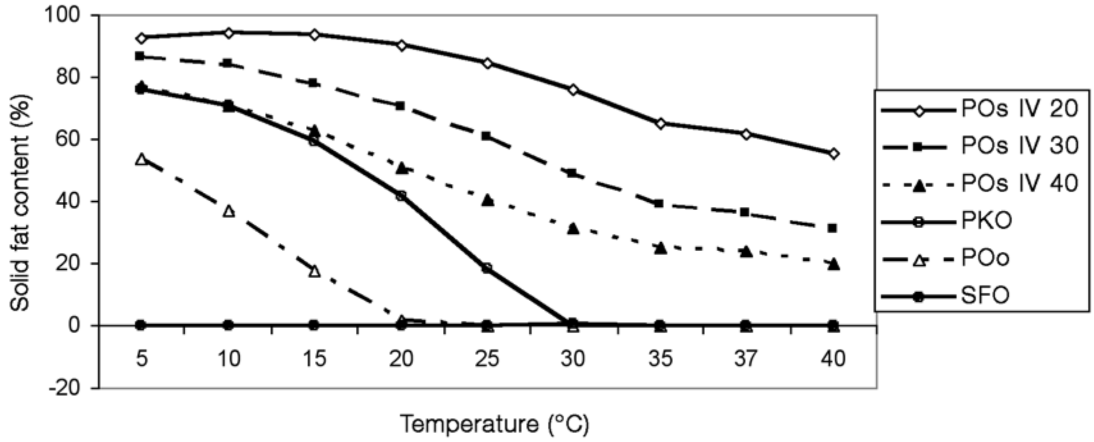
SFC profile is one of the physical properties important in margarine formulation. It provides the physical data that reflect the overall features of the product and which are important for processing.

Effects of Solid Fat Content Profile of Individual Fats on Margarine Formulations

In a margarine formulation involving simple blending or interesterifying several oils and fats, the shape of the curve of SFC to the function of temperature is able to show the expected melting profile of the final product (Kodali, 2005). The overall performance of the margarine, such as during packaging and storage as well as eating quality, is also predicted from the profile. Thus, the individual SFC profile of selected oils and fats as shown in *Figure 1* will contribute significantly to the behaviour of the final blend. Sunflower oil (SFO) has a flat SFC profile with 0% SFC from its initial temperature at 5°C; thus, it is liquid in nature at 5°C and this helps to provide the soft texture to the margarine. SFC of palm olein (POo) declines sharply from its initial SFC of 52% at 5°C to 0% at 22°C. PKO on the other hand has an almost flat SFC from 5°C to 15°C (75%-65%), thereafter declining sharply to 0% at 33°C. PKO is able to maintain the consistency of the margarine at lower temperatures (5°C-15°C), and to soften the margarine texture at serving temperature (25°C-30°C). To achieve such an SFC profile in a conventional soft margarine formulation, partially hydrogenated soft oil is commonly used. The SFC profile of POs with varying IV shows that each IV produces a SFC profile with distinct properties. POs of IV = 40 has the lowest range of SFC profile, while POs of IV = 30 is distinctly positioned between IV = 40 and 20. POs of IV = 20 produces a flat-shaped SFC profile at 5°C-20°C, while generally the other two fats produce flat-shaped SFC profiles at 35°C-45°C. Combining the individual physical attributes of selected oils and fats will lead to the cumulative physical effects required by different margarines, and will be the subject of discussion in this article.

Effects of Solid Fat Content (SFC) Profile on the Quality of Selected Margarines

The quality of margarines for various categories of usage depends on their crystallizing and melting behaviour (Aini and Miskandar, 2007). *Figure 2* shows the SFC profiles of selected margarines in comparison to PO and POs of IV = 30. SFC of soft margarine is in the range of 25%-30% at 5°C,



Note: POs = palm stearin, PKO = palm kernel oil, POo = palm olein, SFO = sunflower oil.

Figure 1. Solid fat content profile of palm stearin of various iodine values (IV) for hard stock.

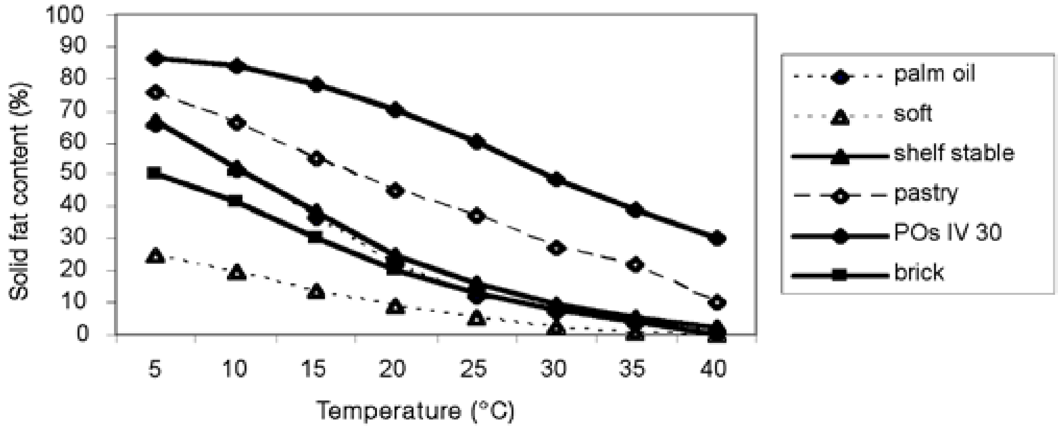


Figure 2. Solid fat content profiles of selected margarines and palm products (soft margarine), shelf stable, pastry and brick are the selected types of margarine.

indicating that the product is suitable for use in temperate countries and requires refrigerated conditions for storage. The range of SFC ensures that hardening will not occur at low storage temperatures. The sample of a brick type margarine has a higher SFC range of 47%-60% at 5°C, 38%-50% at 10°C and 19%-26% at 20°C. Such a profile ensures that the product can be easily wrapped, maintains its brick shape (with no significant softening at 20°C) and is readily spreadable at refrigerator temperatures (5°C-10°C). SFC of shelf-stable and pastry margarines are not critical at 5°C and 10°C. As shown in *Figure 2*, the sample contains SFC of >50% at 5°C-15°C, much higher than the previous two samples as the margarines are normally kept and handled at room temperatures above 28°C. However, shelf-stable margarine has 20%-25% SFC at 20°C, a complete melt at 37°C for ease of spreading and working at room temperature, and melts cleanly during consumption. The pastry margarine sample has a flatter SFC profile than the other margarines at a temperature range of 20°C-40°C with a SFC range of 65%-70% to 30%-40%. Such a profile will provide a long plasticity range to the margarine. Plasticity in pastry margarine is critical, as it allows the dough to be folded and rolled several times, and finally producing the desired flaky texture in the final product.

Effects of Hard Stock on Solid Fat Content (SFC) Profile

The rule to follow in a margarine formulation is to know the chemical composition of the oils and fats. Other than assisting in the selection of oils and fats, such knowledge will help one predict the structural behaviour and the health impact of the selected oils and fats (O'Brien, 2004; Aini and Miskandar, 2007).

Table 1 shows the FAC of samples 900, 904 and 905. Sample 900 is formulated through simple blending of POs (IV=14), PKO and SFO. It contains 35% SAFA, 22.7% monounsaturated fatty acids (MUFA) and 42.3% polyunsaturated fatty acids (PUFA). Sample 905 is an interesterified product of a fully hydrogenated POs of IV = 0 with PKO as hard stock, and blending it with SFO. When FAC of samples 900, 904 and 905 is categorized based on their degree of saturation, namely, saturated, monounsaturated and polyunsaturated fatty acids, one can see that the FAC groups are not significantly different (*Table 1*). The results show that formulations using bulk oils and fats, interesterified hard stock and simple blending with hydrogenated fat could achieve a similar fatty acid composition.

According to Miskandar *et al.* (2004), there is also a direct relationship between FAC and the SFC profile of fat blends from the same source. However, when the blends are from different oil sources such as in samples 900, 904 and 905, although FAC shows similarities, the SFC profiles of the sample blends as a function of temperature as shown in *Figure 3* are not directly related. However, *Figure 3* shows several interesting and noteworthy results, especially in sample 900. This sample contains the lowest content of SAFA, the highest content of MUFA and the lowest PUFA content by only small differences in comparison to samples 904 and 905, but it has the lowest SFC profile at 5°C-30°C.

Sample 900 produces a sharp decline in its SFC from 24% at 5°C to 3% at 20°C. SFC is maintained at 3% at 20°C-30°C, before declining to 0% at 37°C. Sample 905, with the highest content of SAFA and the lowest MUFA content, produces SFC with a gradual slope from 28% at 5°C to 2% at 35°C, before declining to 0% at 37°C. Sample 904 with SAFA and MUFA contents in between the two previous samples and containing the highest content of

TABLE 1. SELECTED OILS AND FATS BLENDS WITH SIMILAR RATIOS IN THE RESPECTIVE FATTY ACID GROUPS

Sample code	Selected oils and fats			Fatty acid group			
	Hard stock	Semi-solid	liquid	SAFA	Mono-unsaturated	Poly-unsaturated	*Trans* fat
Com	NA	NA	NA	40.9	32.6	18.3	8.2
900	POs (IV=14)	PKO	SFO	35.0	22.7	42.3	0
904	fhPOS (IV=0)	PKO	SFO	35.5	19.5	45.0	0
905	IE[fhPOS (IV=0):PKO]	NIL	SFO	36.1	19.3	44.6	0

Note: NA = not available; POs = palm stearin; PKO = palm kernel oil; SFO = sunflower oil; fhPOs = fully hydrogenated oil; IE = interesterified; SAFA = saturated fatty acid.
Com. = commercial margarine.
900 = simple blend of palm stearin, IV=14 and other oils and fats.
904 = simple blend of hydrogenated POs, IV=0 blended with other oils and fats.
905 = interesterified of hydrogenated POs, IV=0 with PKO blended with other oils and fats.

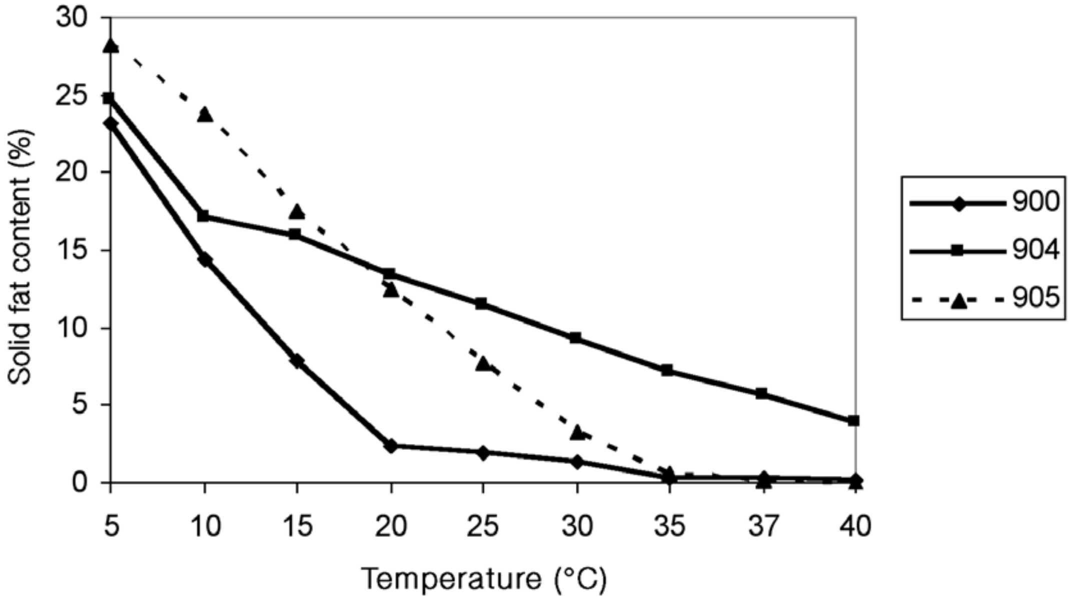


Figure 3. Solid fat content as a function of temperature [margarine samples 900 with palm stearin (POs) of iodine value (IV) = 14 as hard stock; 904 with POs of IV = 0 as hard stock; and 905 with interesterified POs of IV = 0 and palm kernel oil (PKO) as hard stock].

TABLE 2. SELECTED BLENDS WITH LOW SATURATED FATTY ACID (SAFA)

Sample code	Selected oils and fats			Fatty acid group			
	Hard stock	Soft oil	liquid	SAFA	Monoun-saturated	Poly-unsaturated	*Trans* fat
1073	POs IV=20	POo	SFO	33.3	32.5	34.2	0
996	POs IV=20	PKO	SFO	23.4	21.8	54.3	0
1089	POs IV=20	POo	HOSFO	17.8	73.2	9	0

Note: HOSFO = high oleic sunflower oil; POo = palm olein with IV = 58.
PKO = palm kernel oil.
SFO = sunflower oil.

PUFA, produces a sharp slope from 24% at 5°C to 17% at 10°C, and forms a gradual slope thereafter to 3% at 40°C.

The SFC profile indicates that a non-interesterified blend containing POs of IV = 0 has left a significant tailing effect at temperatures from 30°C-40°C. On the other hand, POs with a high IV (of 14) results in a much lower SFC (no tailing effect) at the same temperature range, although blends 900 and 904 have similar SFCs at 5°C-10°C. The SFC profiles show that they have similar hardness at 5°C-10°C but are significantly different at temperatures above 10°C. This indicates that although the three blends have very similar FAC, the fats and oils that make up the formulation (in this case it is the hard stock) will influence the product properties.

Effects of Monounsaturated Fatty Acid (MUFA) on Solid Fat Content (SFC) Profile of Low Saturated Fatty Acid (SAFA) Formulation

FAC affects SFC profile in formulations with the same type of hard stock. Formulations of samples 1073, 996 and 1089 as shown in *Table 2* contain palm stearin of the same IV, but comprise different oils and fats in the semi-solid and liquid portions. The three formulations contain three different levels of SAFA: 33.3%, 23.4% and 17.8%, respectively.

The amount of SAFA present in the formulation significantly affects the SFC at 5°C, which is in agreement with sample 905 as shown in *Figure 3*. Sample 1073, as shown in *Table 2*, contains the highest SAFA and also with the highest SFC (32%) at 5°C; however, SFC reduces tremendously

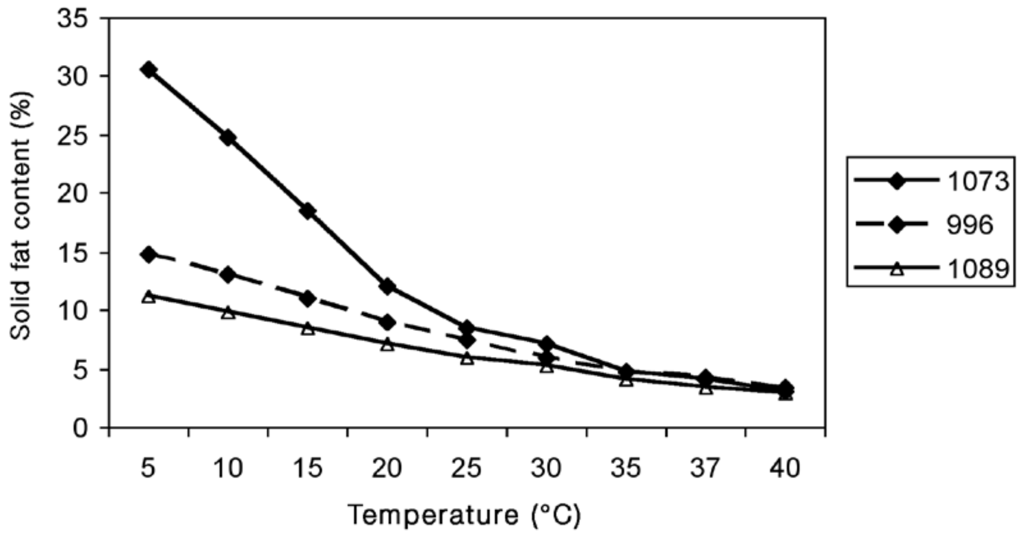


Figure 4. Solid fat content (SFC) as a function of temperature (samples 1073, 996 and 1089 have SFC of margarines for various applications).

showing a sharp declining curve to 10% at 25°C as shown in *Figure 4*. The sharp decline is probably due to the POo content in 1073. The SFC of POo at a temperature range of 5°C-22°C (*Figure 1*) significantly affects this profile. However, SFO in the blend reduces the SFC content, as shown by the curve that gradually declines to 4% at 40°C.

Sample 1089, which contains the least amount of SAFA fat, produces the lowest SFC at 5°C, while sample 996, containing the second highest SAFA fat falls in between samples 1073 and 1089. Both samples, 996 and 1089, show a very similar trend in their SFC profile from 5°C to 40°C. The result shows that high oleic sunflower oil (HOSFO) and POo in the liquid portion of sample 1089 significantly contribute to the increase in MUFA composition (*Table 2*). Despite the low SAFA and PUFA contents in 1089, the high MUFA content has to a certain extent stabilized the SFC profile of sample 1089. The SFC profile that developed indicates that the product is reasonably soft at 5°C-10°C. This is in agreement with O'Brien (2004) who reported that MUFA loses its structural packing in the triacylglycerol (TAG) molecule and lowers SFC. On the other hand, SFO contributes to the high PUFA content in sample 996 and significantly reduces the structural packing of the blend, although PKO contributes a higher SFC than POo (*Figure 1*).

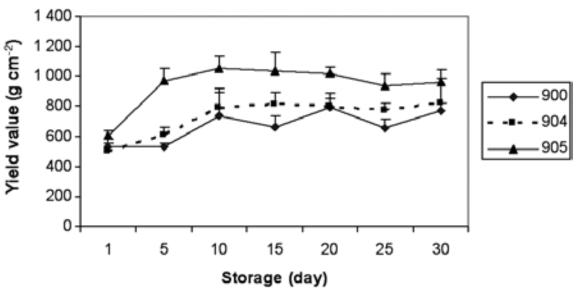
The cumulative effects of structural packing in samples 996 and 1089 contribute to the development of SFC profiles of the same trend. Thus, data on FAC and SFC are important tools in the oils and fats selection for margarine formulation and for predicting its physical properties, which is in agreement with Haighton (1965), Faur (1996) and Miskandar *et al*. (2002). Other than SFC profile, SMP and differential scanning calorimetry are also useful tools in formulation work as they can predict the physical properties of the margarine.

Effects of Hard Stock on Penetration Yield Values

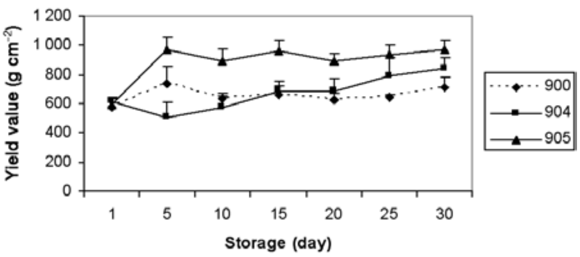
SFC profile plays an important role in the quality of margarine. Soft margarine experiences a wide range of temperature fluctuations as it leaves the factory for distribution, and before it reaches the consumer, *e.g.* temperature differences in the warehouse, transport chains, and in the dealer's and retailer's storehouses. Product handling by the consumer is another factor that a formulator has to consider when developing the margarine. The challenge to the formulator is to formulate a low saturated product and yet be able to come up with a product that can withstand this variation in temperatures.

In our brick margarine formulation sample 900 as shown in *Figure 5*, the hard stock provides sufficient SFC at 5°C-30°C (*Figure 3*). The SFC profile of the sample is sufficiently low at 5°C, allowing it to be spreadable at refrigerator temperatures (5°C-10°C), but sufficiently high to form the brick shape in a reasonably short time during production. The sample contains a constant amount of SFC at 20°C-35°C that keeps the product from softening at serving time, and has a minimum amount of SFC at 35°C-40°C allowing the characteristic of readily melting in the mouth to persist. The SFC profile is also able to stabilize the product during temperature fluctuations.

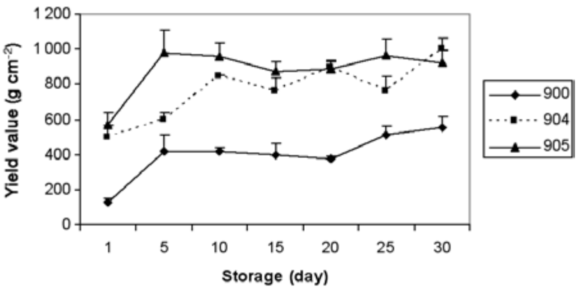
The optimum amount of POs in the formulation is able to maintain the desired SFC profile and produce a formulation with low SAFA and



a. Penetration yield value (g cm^{-2}) at 5°C for 25 days.



b. Penetration yield value (g cm^{-2}) at 10°C for 25 days.



c. Penetration yield value (g cm^{-2}) at 15°C for 25 days.

Figure 5. Yield values of table margarine samples 900. [palm stearin (POs) of iodine value (IV) = 14 as hard stock], 904 (POs of IV = 0 as hard stock) and 905 [interesterified POs of IV = 0 and PKO as hard stock] at 5°C, 10°C and 15°C.

trans-free fats as shown in *Table 1*. The results show improvements over the commercial sample (com) that contains 6.3% *trans* fatty acid and a total SAFA of >40%.

Effects of Palm Stearin (POs) (IV=14) as Hard Stock

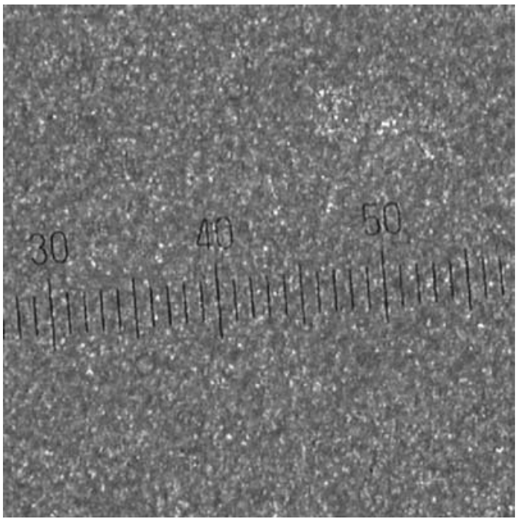
Sample 900 is formulated by a simple blending of POs (IV=14) as hard stock with PKO and SFO. It is formulated to contain a total SAFA <36% and with low SFC at 5°C to avoid hardening at storage temperatures (5°C-10°C). The SFC range of 23% (5°C), 14% (10°C) and 3% (20°C) produces a brick margarine that is spreadable with no significant softening at the desirable yield value of <800 g cm^{-2} at 5°C. *Figure 5* shows that sample 900 reaches its equilibrium in the second week of storage with no significant post-hardening. Consistency of the margarine at 5°C, 10°C and 15°C for a storage period of 30 days shows that the product experiences the hardening phenomenon in the first week of storage; however, this is a property very similar to other margarines (Faur, 1996; Miskandar *et al*., 2002; Goli *et al*., 2009). Thus, POs (IV=14) serves excellently as hard stock in the simple blending of the brick margarine formulation and is low in SAFA.

Effects of Fully Hydrogenated Palm Stearin (POs) as Hard Stock

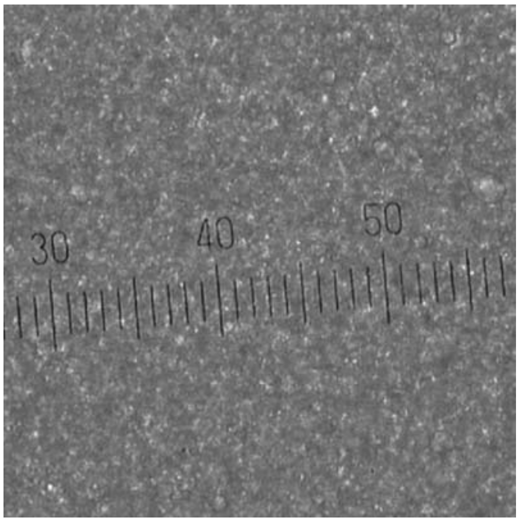
Sample 904 consists of a simple blend of fully hydrogenated POs (IV=0) with PKO and SFO. Sample 904 has a good consistency profile during storage at 5°C, 10°C and 15°C for 28 days (*Figure 5*). Following the normal hardening in the second week of storage, the product stabilizes promptly and maintains its consistency for the rest of the storage period. The result is somewhat of an improvement from what was achieved by Goli *et al*. (2009). Although, the average consistency at all storage temperatures is higher than for sample 900, sample 904 produces a smoother curve at 5°C and 10°C as shown in *Figures 5b* and *5c*, respectively. The smooth yield value curve during storage indicates that the margarine does not experience significant post-crystallization that leads to serious crystal agglomeration, softening and oiling-out. The results indicate that POs has a better performance in minimizing post-crystallization than a natural POs. However, the performance of hydrogenated POs at 15°C is not significantly different from that of the other POs for hard stock in low saturates brick margarine.

Effects of Interesterified Palm Stearin (POs) and Palm Kernel Oil (PKO) as Hard Stock

Sample 905 contains palm-based hard stock from an interesterified product of fully hydrogenated POs (IV=0) and PKO blended with SFO. The storage study at 5°C, 10°C and 15°C for 28 days shows that the consistencies of sample 905 reach their equilibrium as early as the first week of storage (*Figures 5a*, *5b* and *5c*). The products are stable with no significant (P>0.05) changes in texture and appearance at these temperatures, indicating that the interesterified blend produces homogeneous crystals with no significant post-crystallization during storage. Sample 905 is the most stable product at 5°C as compared to the other formulations, indicating that transformation of the crystal type and crystal development in an interesterified hard stock is minimized at 5°C-15°C.



Sample 900 day 25/5°C (100X magnification).



Sample 905 day 25/5°C (100X magnification).

Figure 6. Microscopic study of table margarine during storage. Crystals of standard size are homogeneously distributed (there was no significant formation of crystal agglomerates during storage at 5°C for 25 days).

Effects of Hard Stock on Crystal Development

Crystal and water droplet development in all samples during storage at all temperatures are not significantly different. Crystals and water droplets are homogeneously distributed at sizes <2 µm, as shown in *Figure 6*. This may be due to the efficient crystallization process during the production of these margarines in the perfector pilot plant that created good crystal matrices and minimized the movements of the crystals. This creates the condition of stillness that causes the slow growth of crystals. In most of the cases, such a condition can harden the margarine. However, as the formulations contain optimum amounts of solids from the selected oils and fats, crystals do not seem to form strong packing that can create serious hardening.

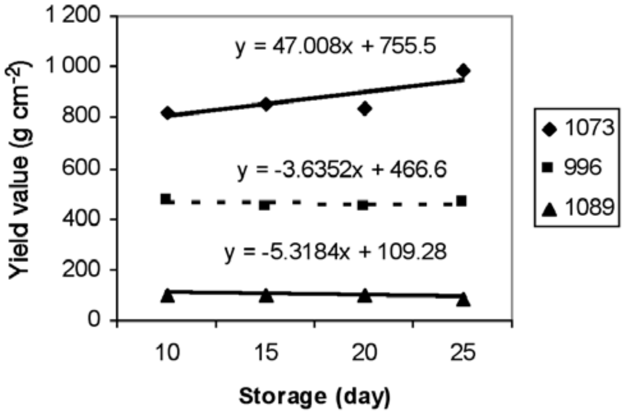
The results indicate that POs acts effectively as the backbone of the margarine, and POs, as hard stock, optimizes the total SAFA. POs provides the required solids at 20°C-30°C, thus preventing rapid softening of the product at serving time. The sharp melting properties of PKO, as demonstrated by its SFC profile (*Figure 1*), influences the 'melt in the mouth' properties of the product. PKO, due to its rapid crystallizing properties, assists in processing by increasing the rate of crystallization especially during brick shape formation to facilitate the wrapping process. SFO is liquid in nature and contributes to the softness of the product. The amount is optimized as to avoid oiliness or deformation of the product at serving time. The study also shows the suitability of the processing condition arrangements of the tube cooler 1, tube cooler 2, crystallizer, tube cooler 3 and the 3-litre resting tube placed in series to produce good brick margarine for use as a bread spread with a total SAFA content <36%.

Effects of Saturated Fatty Acid (SAFA) Fats on Penetration Yield Value

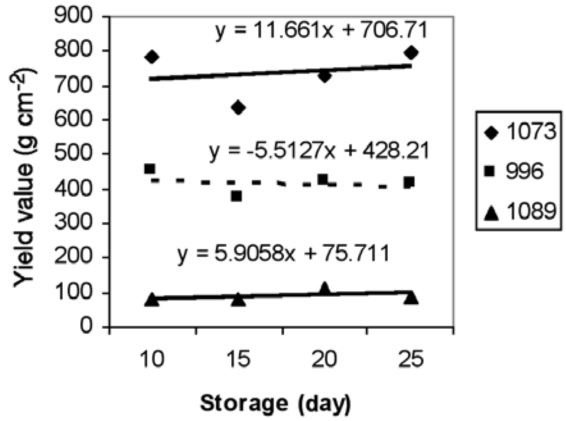
POs of IV = 20 is an excellent hard stock in our soft margarine formulations with SAFA contents of 33.3%, 23.4% and 17.8%. It mixes well by simple blending with POo and SFO. The soft margarines are soft at 5°C-15°C, with an average yield value of 1000 g cm^{-2}.

Effects of Saturated Fatty Acid (SAFA) at 5°C

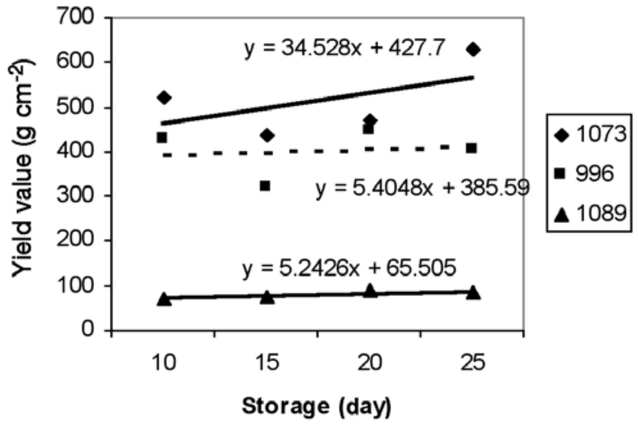
Sample 1073 is spreadable at 5°C with a yield value of 755.5 g cm^{-2} on the 10^{th} day of storage as shown in *Figure 7*. However, post-crystallization occurs during storage at an increment of 47.0 g cm^{-2} per week. It is expected that the yield value of the margarine will be 1131.5 g cm^{-2} after the second month of production; however, it will still be spreadable and consistent. Samples 996 and 1089 record yield values of 466 and 109 g cm^{-2}, respectively on the 10^{th} day of storage. The margarines are stable during storage with no significant post-crystallization. The negative values on the linear correlation formulae as shown in *Figure 7* indicate that post-crystallization is unlikely to occur. Storing the margarines at this temperature (5°C) for four weeks does not significantly cause post-hardening in the products. There is also no oiling-out, while the margarines are consistently soft and spreadable with no significant greasy



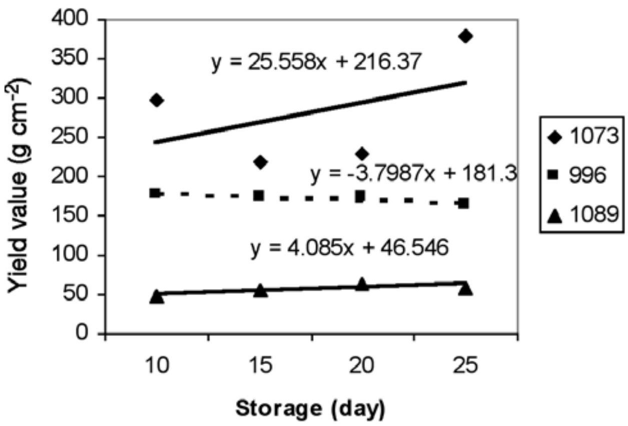
a. Penetration yield value (g cm^{-2}) at 5°C for 25 days.



b. Penetration yield value (g cm^{-2}) at 10°C for 25 days.



c. Penetration yield value (g cm^{-2}) at 15°C for 25 days.



d. Penetration yield value (g cm^{-2}) at 20°C for 25 days.

Figure 7. Penetration yield value of samples 1073, 996 and 1089 at 5°C, 10°C, 15°C and 20°C for 25 days' storage. The formulations contain similar hard stock, the soft and liquid portions for 1073 were palm olein (POo) and sunflower oil (SFO), for 996 were palm kernel oil (PKO) and SFO, and for 1089 were POo and high oleic sunflower oil (HOSFO).

appearance. POs (IV=20) has been an effective backbone for the soft margarine.

Effects of Saturated Fatty Acid (SAFA) at 10°C

The margarines are spreadable, without significant melting at 10°C, having average yield values below than 800 g cm^{-2}. Sample 1073 has the highest consistency with a yield value of 706.71 g cm^{-2} in the first 10 days of storage (*Figure 7*). The margarine is stable throughout the storage period with no significant post-crystallization. It is predicted that the margarine will still be spreadable at a yield value of 985.2 g cm^{-2} after six months' storage. The linear correlation formula of sample 996 in *Figure 7b* shows a negative correlation, indicating that there is no increase in product consistency during storage. Sample 1089 shows a positive correlation at an increment formula of 5.905x + 75.7 at 10°C during storage. This indicates that the product will have a hardness of 229.23 g cm^{-2} after six months' storage at 10°C. Thus, we can conclude that the margarine will still be good even after five months' storage. POs (IV=20) at the minimum level possible blended with soft oils is able to provide support to the margarine and prevent it from collapsing and melting. The phenomenon at storage temperatures of 15°C and 20°C follows the same trend as margarine stored at 5°C and 10°C, although the yield values are lower.

CONCLUSION

Combining POs as hard stock, with PKO as modifier and SFO as filler at optimum process conditions produce good brick (table) and soft tub margarines for use as bread spread. Although the formulations are *trans*-free and low in saturated fats, they manage to maintain their shape, texture and spreadiblity for a period of 30 days' storage at 5°C, 10°C and 15°C (refrigerator temperatures).

Interesterified hard stock produced the most homogeneous margarine; however, a simple blend using normal POs (IV = 20) can also produce good brick margarine with no significant post-crystallization after more than five months' storage at 5°C and 10°C.

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