The Influence of Interesterification of Structured Fats on the Properties of the Fat Blends

M. Tesařová, M. Zárubová, V. Filip, V. Spěváčková and J. Šmidrkal*

*Department of Dairy and Fat Technology, Institute of Chemical Technologyin in Prague, 166 28 Prague, Czech Republic. *E-mail: marketa.tesarova@vscht.cz*

Abstract: Consistency, rheology and melting/solidification characteristics of model fat blends (FB) on the basis of interesterified structured fats (SF) are discussed. SF were prepared by an alkaline catalysed random interesterification of fully hydrogenated coconut (FHCO) and high-erucic rapeseed (FHHERO) oils with variable molar ratio (2:1; 1.4:1; 1:1; 1:1.4 and 1:2) of the medium chain (M; C8:0–C14:0) and long chain (L; C16:0–C22:0) saturated fatty acids (FA) to find out, if stearic/arachic/behenic acids can substitute palmitic/stearic acids in SF. This substitution in SF is possible at molar ratios M:L 2:1 and 1.4:1 from the point of view of melting and solidifications characteristics as well as consistency and rheology for soft margarines. Lower molar ratios of M:L are suitable for FB of shortenings. The final ratio of saturated:unsaturated FA in FB for soft-margarines is 33:67 w/w.

Keywords: fat blend; structured fat; rheology; consistency; interesterification; behenic acid

INTRODUCTION

The lipid system known as FB is composed of SF and vegetable oil and is important in food products that contain a significant amount of fats – e.g. margarines, shortenings, confectionary and coating fats. The SF has an influence on the structure, the melting characteristic, the crystallisation behavior of the FB in the final food products (De Graef *et al.* 2007). Texture and rheological properties of the FB and the fat products are influenced by the composition and the amount of the SF, the amount of solid crystals of triacylglycerols (TAG), the crystal polymorfism, the three-dimensional distribution of the crystal network and the interaction inside of the crystal network as well (Marangoni & Narine 2002). The *trans* zero SF are prepared by the interesterification that is combined with the totally catalytic hydrogenation and the fractionation of nature oils. The substitution of partially hydrogenated SF by interesterified structured fats is possible for example on the basis of fully hydrogenated fats (FHF), i.e. based on middle (M) and long (L) length chain of saturated FA (Filip *et al.* 2004). Fats, that contain a higher amount of palmitic and/or stearic acid as fully hydrogenated zero erucic rapeseed oil and palmstearin, are suitable (Piska *et al.* 2006). The substitution of palmitic to stearic acid is healthy positive (Kelly *et al.* 2001), does not alter rheologic and crystallic properties of FB (Zárubová *et al.* 2009) and permits high content of 72–78% liquid zero rapeseed oil, i.e. unsaturated FA in fat blend of soft margarine.

The aim of this study was to verify a possibility of a substitution of a pair of stearic/palmitic by a combination of stearic/arachic/behenic FA in the SF from the point of view of structure and texture of FB and the maximal potential content of unsaturated FA in this fat blends.

MATERIALS AND METHODS

Coconut oil (MPD plus Rakovník, s.r.o., CZ), FHHERO (Aarhus-Karlshamm, CZ), zero-erucic rapeseed oil (ZERO; Setuza a.s., CZ; FA composition: C16:0 5.2%; C18:0 1.8%; C18:1 61.3%; C18:2 20.9%; C18:3 9.6%; C20:0 0.6%; C22:0 0.4%, C22:1 0.2% w/w).

SFs were prepared by a random alkaline catalysed interesterification of binary mixtures of FHF. Hydrogenation conditions of coconut oil: 180°C, 0.2% Ni, catalyst Nysosel-222, Engelhardt Ltd.; H_2 flow rate 120 l/min at atmospheric pressure. Composition of FA of FHF: FHCO (C8:0 5.6%; C10:0 5.1%; C12:0 45.4%; C14:0 19.1%; C16:0 10.6%; C18:0 13.5% w/w); FHHERO (C 16:0 3.9%; C 18:0 36.2%; C 20:0 9.5%; C 22:0 48.0% w/w). Both FHF were mixed in variable ratios (Table 1) and interesterified with sodium methoxide (Zárubová *et al.* 2009).

The FBs were prepared by blending of prepared SF with ZERO in a constant ratio 25:75 w/w. The liquid FB were controlled crystallised (Piska *et al.* 2006) in the duplicated glass container of volume 300 ml (rate of teflon stirrer 50 rpm, temperature of the cooling medium – ethanol was set at 10°C, initial temperature of FB was 80°C). Crystallised FBs were stored at 10 ± 0.2°C for 7 days. The consistency (the yield stress value and the penetration), the solid fat content (SFC; ISO 8292/1994), the melting point (ISO 6321/1994) and the solidificatin point (CSN 58 8775/1994) of the fat blends were measured.

The yield stress value (Piska *et al.* 2006) was obtained by the rotary rheometry using Haake Rheostress RS 80 (Haake Mess-Technik GmbH, Germany; the sensor plate-plate PP 20 – diameter 20 mm and a gap 1 mm). The yield stress was measured in the controlled stress mode (CS) at the temperature 10, 15 and 20°C and the selected deformation was 0.01.

The penetration was determined by the texture profile analysis using TA.XT.plus texture analyser (Stable Micro Systems Ltd. Godalming, UK; the cone angle 40°; temperature: 10; 15; 20°C). The test mode compression was: test speed 1 mm/s, force 1 N, hold time 20 s.

The composition of FA was determined by CGC/FID (Zárubová *et al.* 2009).

RESULTS AND DISCUSSION

Melting and solidification characteristics of fat blends

All characteristics are primary dependent on the molar ratio of M and L chain fatty acids of the use SF (Table 1). Decreasing molar ratio M:L influences increasing of melting and solidification points and SFC values of FB (Tables 2 and 3). It is notable that fat blends FB3, FB4 and FB5 have two solidification points (Table 3). Possible explanation could be bimodal distribution of TAG of SF (Zárubová 2008). The substitution of palmitic/stearic acids by stearic/arachic/behenic acids, i.e.long chain FA in SF, is possible at molar ratios M:L 2:1 and 1.4:1 from the point of view of melting and solidification characteristics for soft margarines application. Next decrease of molar ratio to values 1:1; 1:1.4 and 1:2 increases considerably melting and solidification behavior of FB and SFC profile too. It means that fat blends FB3, FB4 and FB5 are not suitable for margarines (but suitable for shortenings).

Table 1. The ratio of fully hydrogenated oils used for mixture preparations

SF (molar ratio M:L)	FHCO (% w/w)	FHHERO (% w/w)
SF1 (M:L = 2:1)	72	28
SF2 (M:L = 1.4:1)	60	40
SF3 (M:L = 1:1)	48	52
SF4 (M:L = 1:1.4)	38	62
SF5 (M:L = 1:2)	29	71

Rheology and consistency of fat blends

The obtained data of yield stress value by rotary rheometry and the depth of penetration by texture profile analysis were dependent principally on the composition of the SF (i.e. on the molar ratio M:L) and less on the temperature (Figure 1–3). The yield stress value of all FB had proportional increasing tendency with the decreasing amount of molar

Table 2. The melting point and the solidification point of fat blends

Fat blend	Melting point (°C)	Solidification point (°C)
FB1	31.1 (28.4/31.3)[a]	17.7 (15.2/16.2)[a]
FB2	34.4 (32.3/36.2)[a]	19.2 (17.1/19.5)[a]
FB3	39.7	30.2; 19.8
FB4	42.1	32.8; 20.5
FB5	46.3	38.3; 32.8

[a]the values of fat blends prepared on the basis of fully hydrogenated palmstearin or ZERO (Zárubová 2008)

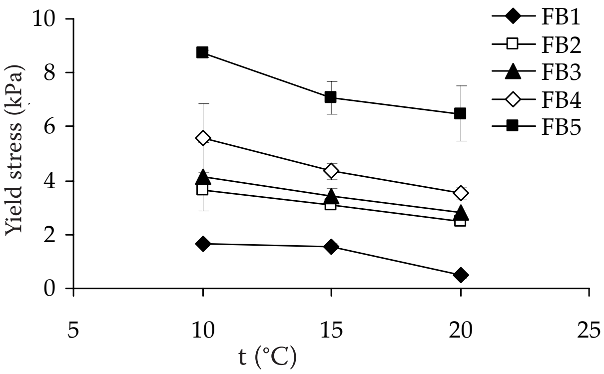

Figure 1. The dependence of the yield stress value of model fat blends on the temperature

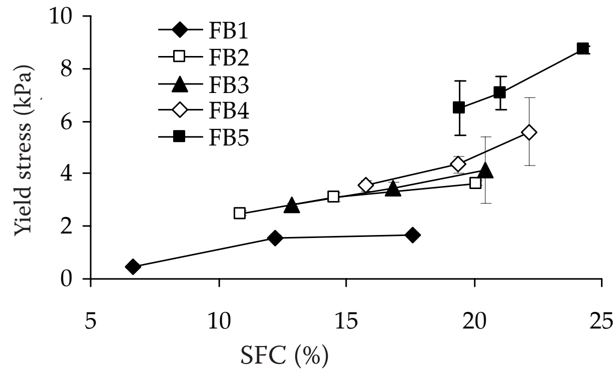

Figure 2. The dependence of the yield stress value of model fat blends on the SFC

Table 3. The solid fat content values of model fat blends at different temperatures

Fat blend	10°C	15°C	20°C	25°C	30°C	35°C	40°C
FB1	17.62	12.22	6.65	1.97	0.12	0	0
FB2	20.09	14.55	10.84	6.18	3.19	0.19	0
FB3	20.43	16.81	12.87	9.99	6.72	4.10	2.20
FB4	22.15	19.40	15.75	12.97	10.66	7.83	5.52
FB5	24.29	21.02	19.44	15.28	13.30	10.55	7.54

ratio M:L of SF (with the exception of differences between FB2 and FB3) at all temperatures. The depth of penetration had proportional increasing tendency with the decreasing amount of molar ratio M:L of SF only for FB1 and FB2 (molar ratio M:L 2:1 and 1.4:1) at all of temperatures (Figure 3). Additional decreasing of molar ratio M:L of SF had not significant influence on decreasing of the depth of penetration.

Dependences of the yield stress value and the depth of penetration on SFC give another and more complex view (Figures 2 and 4) on consistency and rheology of FB. The yield stress value is relatively independent on SFC in a broad range at higher molar ratios M:L of SF, but it is dependent on SFC in a narrow range at small molar ratios. Dependences of the depth of penetration on SFC are in the opposite to the yield stress value dependences on the SFC (Figure 4). Substitution of palmitic/stearic acids by stearic/arachic/behenic acids, i.e. long chain FA in SF, is possible at molar ratios M:L 2:1 and 1.4:1 from the point of view of consistency and rheology for soft margarines (Piska *et al.* 2006).

The substitution of palmitic/stearic acids by stearic/arachic/behenic acids, i.e.long chain FA

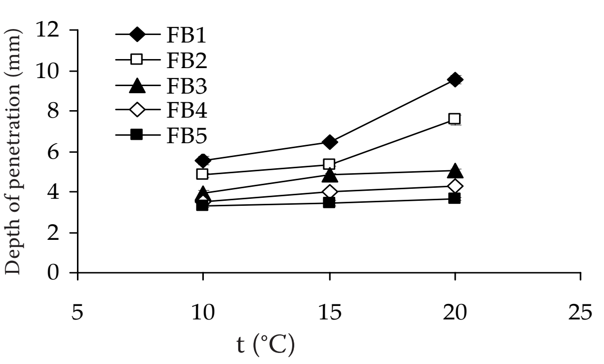

Figure 3. The dependence of the depth of penetration of model fat blends on the temperature

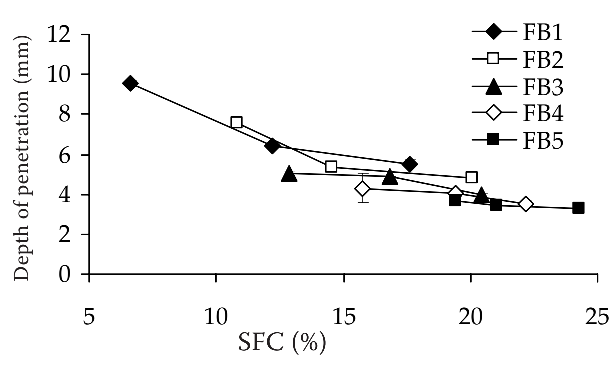

Figure 4. The dependence of the depth of penetration of model fat blends on the SFC

in SF, is possible at molar ratios M:L 2:1 and 1.4:1 from the point of view of melting and solidifications characteristics as well as from the point of view of consistency and rheology for soft margarines at the ratio of saturated:unsaturated fatty acid 33:67 w/w.

Acknowledgements. This work was supported by funding from the Ministry of Education, Youth and Sports of the Czech Republic (Project No. MSM 6046137305).

References

De Graef V., Foubert I., Smith K.W., Cain F.W., Dewettinck K. (2007): Crystallisation behaviour and texture of trans-containing and trans-free palm oil based confectionery fats. Journal of Agricultural and Food Chemistry, **55**: 10258–10265.

Filip V., Zárubová M., Piska I., Šmidrkal J. (2004): Fat blends on the base of structural triglycerides. Czech Journal of Food Sciences, **22**: 76–79.

Kelly F.D., Sinclair A.J., Mann N.J., Turner A.H., Abedin L., Li D. (2001): A stearic acid-rich diet improves thrombogenic and atherogenic risk factor profiles in healthy males. European Journal of Clinical Nutrition, **55**: 88–96.

Marangoni A.G., Narine S.S. (2002): Identifying key structural indicators of mechanical strength in network of fat crystals. Food Research International, **35**: 957–969.

Piska I., Zárubová M., Loužecký T., Karami H., Filip V. (2006): Properties and crystallization of fat blends. Journal of Food Engineering, **77**: 433–438.

Zárubová M. (2008): Crystallisation of triglycerides in fatty bases. [Dissertation Thesis.] ICT, Prague.

Zárubová M., Filip V., Kšandová L., Šmidrkal J., Piska I. (2009): Rheological and crystalline properties of trans-free model fat blends as affected by the length of fatty acid chains. Journal of Food Engineeering doi:10.1016/j.jfoodeng.2008.08.030.. (In Press, Corrected Proof)