Physicochemical Properties, Crystallization Behavior and Oxidative Stabilities of Enzymatic Interesterified Fats of Beef Tallow, Palm Stearin and Camellia Oil Blends

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Abstract: Properties, crystallization behavior and oxidative stabilities of enzymatically catalyzed interesterified fats were investigated in this study. Interesterified fats were catalyzed by Lipase Lipozyme RM IM, through reaction from beef tallow (BT), palm stearin (PS) and camellia oil (CO) under the mass ratio of 7.55: 2.45: 4 (BT: CO: PS) using 3.65% (w/w) of Lipozyme RM IM at 72.6°C for 3.85 h. After reaction, interesterified fats with 36.8°C sliding melting point (SMP) was obtained. Physicochemical properties (fatty acid profile, triacylglycerol profile, solid fat content (SFC), melting and crystallization curve, polymorphic forms) of interesterified fats were characterized. Results proved that interesterified fats blends after interesterification were improved with desirable β' type crystals and preferable SFC. Triacylglycerol constituent of interesterified fats displayed a decrease in OOO, PSS/SPS, LLL, SSS and increased in PSO/POS/SPO, POO/OPO, POP/PPO, PLO/PLP/PPL by comparison of physical blends without interesterification. Additionally, it is estimated that interesterified fats have a moderate antioxidative stability about 352 days-shelf life at 20°C through the traditional accelerated oxidation test. In conclusion, interesterified fats with desirable properties could be suitable for plastic fats use.

Key words: interesterified fats, enzymatic catalysis, characterization, oxidative stabilities

1 Introduction

Trans fatty acids (TFAs) is one of the food safety risk factors and associated with some dyslipidemia diseases due to lipoproteins level disorder such as cardiovascular disease, obesity, hepatocirrhosis, type II diabetes, atherosclerosis and other diseases¹-³. In food industry, TFAs is inevitably exist in plastic fat (i.e., margarines, shortenings, cold fats and bakery fats) produced by partial hydrogenated oil since the partial hydrogenation process. Recently, with zero-trans fatty acid, interesterified fats, which is restructured in regard to fatty acids composition and/or positional distribution, has been widely acknowledged as an alternate to the partial hydrogenated oil for plastic fat and favored by consumers. Interesterification is to change the physicochemical properties of oils and fats by causing redistribution of acyl groups and rearrangement of fatty acids in triacylglycerol (TAG)⁴. Enzymatic interesterification, as compared to the chemical catalyzation, is superior with its unique reaction mechanism and environmentally friendly react condition and is getting more and more applications for compensate the defects in the production of hydrogenated oils and fats.

Enzymatic interesterification of hard animal fats and liquid plant oils blends would provide the desirable sliding melting point (SMP), polymorphism, appreciate crystallization behavior and solid fat content (SFC), which its parameters will influence functionality. It has been suggested that interesterified binary blends of fully hydrogenated palm oil (FHPO) and soybean oil (3:4, w/w) via lipase Novozym-435 so as to prove its appropriate physicochemical properties and polymorphs⁵. Studies showed that the interesterified ternary system of FHPO, Cinnamomum camphora seed oil and coin seed oil blends were promising in shortening for food product⁶. Evaluation of interesterified fats on health is vital for application of structured fats in food industry since the stereospecificity and chain lengths of fatty

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acids within TAG molecules determine not only the physical behavior as dietary fats but also the metabolic fate during lipid digestion and biological processes\(^7\). \"Evidence\" also observed form studies that the benefited metabolic effects of interesterified fats attribute to the increase in TAG content that is readily absorbed by the body\(^2\). The generally accepted hypothesis is that medium/long chain TAGs could result in a significant reduction in fat accumulation\(^3\). This study was initiate to enzymatically prepare interesterified fats (IF) by beef tallow (BT), palm stearin (PS) and camellia oil (CO). CO is one of consumed edible oils with a high concentration of unsaturated fatty acids, such as linolenic acid, and is an ideal choice for the supply of unsaturated fatty acids group for preparation of plastic fat\(^14,15\). BT is one of the traditional edible fats with special flavor substances, nutrients, fat content, and crisp performance, but exhibits unfavorable physicochemical properties and the phenomenon of sanding during transportation or storage, and is generally considered less valuable than other animal fat and not suitable for daily consumption, so the enzymatic interesterification of BT with vegetable oils can obviously improve its properties\(^16\). Furthermore, with the high SMP and a useful source of plant hard fat, PS could be used directly for edible purposes by interesterification\(^20\). By ternary system of BT, CO and PS through enzymatic interesterification, it is expectable to obtain structured fat with nutrients and function, which could retain the advantages of raw materials and avoid the disadvantages of single oils/fats effectively. Then the physicochemical properties include fatty acids and TAG profile, SFC, melting and crystallization behavior, polymorphic forms of the enzymatic synthesized IF were characterized, and the shelf life of synthesized IF was estimated by oxidative stability tests. Information from this study may useful to design a desirable trans-free plastic fat stock.

2 Materials and methods

2.1 Materials and reagents

Beef tallow was supplied from Chongqing Shuaike Co., Ltd. (China). Camellia oil was purchased from Anhui Qihang Co., Ltd. (China). Palm stearin were collected from Key Laboratory for Agricultural Products Processing of Anhui Province (China). Lipozyme RM IM, an sn-1,3-specific lipase, was purchased from Novozymes A/S ( Bagsvaerd, Denmark). N-Hexane (purity > 95%), HPLC grade methanol and Potassium hydroxide used for GC analysis were purchased from Sigma-Aldrich. All other reagents were of analytical grade.

2.2 Enzymatic interesterification

Before interesterification, BT and PS were heated and melted. The experiment following Box-Behnken Response Surface Method was designed on the basis of single factor experiments. The effects of mass ratio (BT: CO: PS, 6:4:4, 7:3:4, 8:2:4), enzyme concentration (w/w, 3.0%, 3.5%, 4.0%), reaction time (3, 4, 5 h), and reaction temperature (60, 70, 80 72.6°C) on the SMP were investigated. A response surface regression model was established and the optimum condition were determined as follows: blends of BT, CO and PS (7.55:2.45:4, w/w, total weight 60 g) were interesterified using Lipozyme RM IM (3.65%, w/w), and conducting in an orbital-shaking water bath with agitation of 200 rpm at 72.6°C for 3.85 h. Reaction was stopped by removing the immobilized lipase. And then IF was purified by removing free fatty acids and monoglycerides and other impurities using liquid-liquid extraction. The purification was carried out in pear-shaped separatory funnels (250 mL) at 60°C. IF (20 g) were weighed into pear-shaped separatory funnels accurately, mixed with an equal mass of ethanol solution, and left to rest for 2 h. After this treatment, the two phases became clear, with a well-defined interface, and IF was discharged from the lower end of the separatory funnel, the alcohol residual was removed by steaming\(^21\).

2.3 Sliding melting point detection

SMP of IF was detected by the AOCS Official Method Cc 3-25\(^20\). We have optimized the reaction and the actual SMP of IF is 36.8°C.

2.4 Fatty acid composition

Transmethylate to fatty acid methyl esters (FAMEs) prior to determination of fatty acid composition of raw materials, physical blends and IF. A Shimada GC 2010 (Shimadzu Co., Kyoto, Japan) equipped with DB-wax column (30.0 m × 0.25mm, 0.25 μm film thickness, Agilent Technologies Co., Ltd.) was used. The helium carrier gas (99.999% purity) flow rate was set to 0.8 mL min\(^{-1}\). The column temperature was programmed to increase from 100°C to 200°C at 2°C min\(^{-1}\), and held at 100°C, 200°C for 1 min, respectively. Then heated from 200°C to 250°C at 3°C min\(^{-1}\) and held for 6 min. FID at 250°C and 1 μL of sample was injected into GC in split mode with a split ratio as 10:1. The fatty acid composition was calculated as mol% by comparison with relative percentage of fatty acids.

2.5 Triacylglycerol composition

The triglycerides composition of raw materials, physical blends and IF was analyzed by reverse-phase Waters 1525 Binary HPLC (Waters Co., Milford, MA, USA) equipped with a Waters XBridge C18 column (250 mm × 4.6 mm × 5 um) and a Hypersil Gold column (250 mm × 4.6 mm × 5 um). The HPLC coupled with a Waters 2424 ELSD detector and Waters 2707 Autosampler. Samples were dissolved in Acetone to analysis at a 2 mg min\(^{-1}\) concentration. The in-
projection volume was 10 μL and the column was equilibrated at 25°C. The flow rate was set to 1 mL min⁻¹. Mobile phases A and B were methyl alcohol and Acetone, the following gradient was employed and was linear except where noted otherwise: hold at 70% A 0 min; 70% B-50% A 0-20 min; 50% B-30% A, 20-40 min. The total run time was 50 min.

2.6 Solid Fat Content Determination
SFC of raw materials (except for CO), physical blends and IF was measured by mq-one pulsed nuclear magnetic resonance (p-NMR) analyzer (Bruker Co., Rheinstetten, Germany). In addition to the CO, other samples were put in a p-NMR dedicated glass tube and completely melted by heating at 70°C for 30 min to eliminate the crystal memory. Then the thawed oil was transferred into the thermostat and SFC was measured after it was held at 0°C for 90 min. The measurements were carried out every 5°C from 5°C to 50°C, and all of the temperatures were maintained for 30 minutes before each detection.

2.7 Crystal structure detection
The crystal structure of raw materials (except for CO) physical blends and IF was determined by X-ray diffraction (XRD) scans (Bruker Co., Rheinstetten, Germany) at 24°C. The scanning range of the XRD scanner was 16 to 32° at 2° min⁻¹.

2.8 Determination of Melting and crystallization behaviors
Differential scanning calorimetry (DSC; TA Co., America) was used to analyze the melting and crystallization behavior curve of samples. 7-15 mg of samples was weighed and put in an aluminum pans as reference, and an empty aluminum pan was used as a quality control. The operation procedure was as follows: firstly, for the crystallization curve measurement, the temperature is raised to 80°C at 10°C min⁻¹ and held for 10 min to eliminate crystal memory; then the temperature was lowered to -30°C at 5°C min⁻¹ and held for 10 minutes. The melting curve was determined by raising the temperature to 80°C again at 5°C min⁻¹ and held for 10 min. The nitrogen flow rate was set to 50 mL min⁻¹. The data was processed by TA Universal Analysis 2000 software.

2.9 Oxidative stabilities
The oxidative stabilities of samples was measured every two days by the peroxide value (PV), which uses acetic acid/chloroform (3:2, v/v), standardized Na₂S₂O₃ as lipid solvent and titrant, respectively, and automatic titrator was used for the iodometric. Physical blends and IF (100 g) were weighed into test tubes accurately, sealed and placed in an oven at 60°C for 30 d oxidation tests. The shelf life of samples was predicted based on oxidation kinetics equation: ln(PV) = 0.07569T - 3.05259, which was derived from the PV.

2.10 Statistical analysis
Both of SPSS 18.0 and one-way analysis of variance (ANOVA) were used for statistical analysis and all of the data were presented as mean ± SD. p < 0.05 was considered to be statistically significant.

3 Results and discussion
3.1 Fatty acid composition
Fatty acid composition of BT, CO, PS, physical blends and IF are listed in Table 1. The considerable amounts of unsaturated fatty acids (USFA), such as oleic acid(C18:1, 78.98%), linoleic acid (C18:2, 9.27%) and linolenic acid (C18:3, 0.34%), were found in CO. High level of palmitic acid (C16:0, 60.59%) was presented in PS. The proportion

| Fatty acid | BT | CO | PS | Physical blends | IF |
|------------|----|----|----|-----------------|----|
| C14:0      | 2.93 ± 0.11a | ND | 1.27 ± 0.01a | 1.95 ± 0.07a | 1.95 ± 0.01a |
| C16:0      | 23.74 ± 0.24d | 8.57 ± 0.07a | 60.59 ± 0.46b | 31.12 ± 0.40b | 30.24 ± 0.12b |
| C18:0      | 26.58 ± 0.17c | 2.21 ± 0.03b | 5.25 ± 0.08b | 1.01 ± 0.01a | 0.92 ± 0.01c |
| C18:1      | 34.43 ± 0.27d | 78.98 ± 0.21c | 26.63 ± 0.19b | 16.61 ± 0.07c | 15.82 ± 0.07c |
| C18:2      | 3.24 ± 0.06c | 9.27 ± 0.02c | 5.87 ± 0.15b | 43.61 ± 0.29b | 44.60 ± 0.41c |
| C18:3      | 0.30 ± 0.02b | 0.34 ± 0.01b | ND | 5.32 ± 0.03a | 5.54 ± 0.17a |
| SFA        | 53.25 ± 0.52d | 10.78 ± 0.10d | 67.11 ± 0.55c | 34.08 ± 0.48b | 33.11 ± 0.14a |
| MUFA       | 34.43 ± 0.27d | 78.98 ± 0.21d | 26.63 ± 0.19b | 16.61 ± 0.07c | 15.82 ± 0.07c |
| PUFA       | 3.54 ± 0.08c | 9.61 ± 0.11e | 5.87 ± 0.15c | 48.93 ± 0.32b | 50.14 ± 0.58b |

Values with the same letter in a row are not significantly different (p > 0.05); BT, beef tallow; CO, camellia oil; PS, palm stearin; IF, interesterified fats; SFA, saturated fatty acids; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; ND, not detected under this analysis condition.

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of fatty acids after interesterification were similar with that before interesterification in the BT, PS and CO blends. The major fatty acids in IF were C18:2, which accounted for about 44.60% of the total fatty acids followed by C16:0 (30.24%), C18:1 (15.82%) and C18:3 (5.54%). By comparison of IF, the proportion of polyunsaturated fatty acid (PUFA) in BT was significantly decreased and this was similar as the findings of Yu et al.24. From the fatty acids profile that no isomeric acid was produced and the content of various fatty acids did not change significantly after interesterification and this might attribute to the exchange of fatty acids between or within the TAG molecules themselves, and the TFA were not detected in IF.

3.2 TAG composition

Table 2 displays the triacylglycerol profiles of BT, CO, PS, physical blends and IF. The analysis of triglycerides composition are important evidences for explaining whether the fatty acid composition in TAG had changed, and the interesterification had occurred or not, which could evaluate the functionality of oil/fats effectively25. As shown in Table 2, the major TAG species of CO had equivalent carbon number ECN 48 (OOO, 71.71%; POO/OPO, 16.39%), and the predominant TAG species in BT were POO/OPO (24.09%), POP/PPO (19.23%), PSO/POS/SPO (16.66%), respectively. As to PS, the major TAG species were POP/PPO (33.42%), PPP (17.43%), POO/OPO (15.96%), PLO/PLP/PPL (12.14%) and PSO/POS/SPO (8.57%). The interesterification led to significant changes in the contents of TAGs in physical blends, although it did not change the fatty acid composition. During interesterification, a clear reduction occurred in OOO, PSS/SPS, LLL and SSS in physical blends while an increase in PSO/POS/SPO, POO/OPO, POP/PPO and PLO/PLP/PPL, especially, i.e. SSS and OOO, decreased to 1.69% and 5.62% from 14.38% and 18.35%, respectively, and a new TAG specie of OLO/LOO was previously detected in IF after interesterification.

3.3 Solid Fat Content

The solid fat content is important for characterizing the properties of the IF products at different temperatures, which is relevance to the spread-ability at the lower storage temperature (4-10°C), the stability and ability to resist liquid segregation at room temperature (20-22°C), and the mouth feel at 33-38°C.26-28. From Fig. 1, the SFC of all samples decreased significantly with an increase in temperature, especially at over 15°C. A gradual decreasing tendency was observed for SFC of all samples as the temperature increased since the solid fat crystals melted when reached SMP, in which the SFC of IF reduced to 0-0.49% at 40°C so in favor of improving mouth feel and avoid sandy. IF showed lower SFC than three ingredients and among which a 10-16% difference from the SFC of physical blends at 0-40°C. The SFC of PS, BT, physical blends and IF showed that their mainly solid form are all at lower storage temperature. SFC of BT, physical blends and IF differed slightly between 15 and 25°C, which were 19.66, 18.71, and 17.66%, respectively, indicating that they have similar cooling effects. In particular, the temperature range

| ECN | Triacylglycerol | BT | CO | PS | Physical blends | IF |
|-----|-----------------|----|----|----|----------------|----|
| 42  | LLL             | ND | ND | ND | 6.23 ± 0.01    | 4.46 ± 0.03 |
| 46  | OLO/LOO         | 0.93 ± 0.01 | 6.56 ± 0.07 | 0.89 ± 0.05 | ND | 11.75 ± 0.12 |
| 48  | PLO/PLP/PPL     | 4.07 ± 0.02 | 7.17 ± 0.46 | 1.42 ± 0.02 | 18.35 ± 0.23 | 5.62 ± 0.05 |
| 46  | OOO             | 3.90 ± 0.01 | 7.19 ± 0.46 | 1.42 ± 0.02 | 18.35 ± 0.23 | 5.62 ± 0.05 |
| 48  | POO/OPO         | 24.09 ± 1.05 | 16.39 ± 0.11 | 15.96 ± 0.50 | 15.06 ± 0.12 | 15.58 ± 0.13 |
| 48  | POP/PPO         | 19.23 ± 0.31 | 0.97 ± 0.07 | 33.42 ± 1.52 | 6.14 ± 0.11 | 9.63 ± 0.01 |
| 48  | PPP             | 4.76 ± 0.07 | ND | 17.43 ± 0.31 | ND | ND |
| 50  | SOO/OSO         | 8.65 ± 0.40 | 2.16 ± 0.01 | 1.52 ± 0.05 | ND | ND |
| 50  | PSO/POS/SPO     | 16.66 ± 1.20 | ND | 8.57 ± 0.22 | 12.74 ± 0.07 | 24.86 ± 0.46 |
| 50  | PPS/PSP         | 4.05 ± 0.09 | ND | 4.10 ± 0.19 | 0.27 ± 0.01 | 0.11 ± 0.01 |
| 52  | SOS             | 4.79 ± 0.03 | ND | ND | ND |
| 52  | PSS/SPS         | 2.38 ± 0.01 | ND | ND | 16.40 ± 0.11 | 6.42 ± 0.26 |
| 54  | SSS             | 1.45 ± 0.10 | ND | ND | 14.38 ± 0.01 | 1.69 ± 0.07 |

Values with the same letter in a row are not significantly different (p > 0.05); BT, beef tallow; CO, camellia oil; PS, palm stearin; IF, interesterified fats; P, palmitic acid; S, stearic acid; O, oleic acid; L, linoleic acid; Equivalent carbon number (ECN) = Carbon Number - 2 × Double Bonds; ND, not detected under this analysis condition.
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in which SFC of IF significantly decreased shifted to 10-20°C in the low temperature range from 42.84% to 23.73%, which may attributed to the saturated fatty acid composition in TAG (i.e., the content of SSS decrease, SUS and SUU increase) had changed. It was demonstrated that what was referred to as the “desirable plastic range of fats” should have the properties that the SFC contains roughly 15-35% solids at 25°C. So with a wider plastic range and an ideal SFC curve, IF is suitable for plastic fats application.

3.4 Crystal structure analysis

Polymorphism is regarded as the vital criteria to evaluate the physical characteristics of fats (such as the sensory quality and lubrication), which analyzed by X-ray diffraction. There were mainly α, β, β three types of crystalline crystal form of fat, with its melting point and stability gradually increased and each crystal short pitch was significant. The α crystal characterized as formed during the rapid cooling and short pitch at 4.15Å. The β crystal has a strong short spacing at 4.6Å and gives rough, sandy texture. The β form is the most ideal crystal form, which could form a close crystal network to endowing the lipids with soft and smooth solid fats. It was reported that β crystal is associated with lower SFC and higher palmitic acid level. Smaller, finer and evenly distribution of β form melt more quickly under the influence of temperature.

Fig. 1 Solid fat content (SFC) of beef tallow (BT), palm stearin (PS), camellia oil (CO), physical blends and interesterified fats (IF).

Fig. 2 X-ray diffraction (XRD) patterns of BT, PS, physical blends and IF. (A) XRD patterns of BT. (B) XRD patterns of PS. (C) XRD patterns of physical blends. (D) XRD patterns of IF.
Diffraction spectrum (Fig. 2) of both physical blends and IF in d = 4.6Å have appeared absorption peak and accompanying with two peaks at d = 3.8Å, 4.2Å for β, and no α crystal (Fig. 2C, 2D) indicated that β’ crystal form increased while β crystal form decreased during interesterification and the main crystal form of IF is desirable β’ type. In contrast, diffraction angle 2θ at d = 4.15Å of BT (Fig. 2A) showed a relatively strong α crystal diffraction peak and two relatively weak β and β’ crystal diffraction peaks at d = 4.6Å, 3.8Å, respectively, and the coexistence of β’ and β crystal form contained in PS from diffraction peaks at d = 3.8-4.3Å and 4.5Å (Fig. 2B). These changes to IF in crystal form may attribute to the changes in fatty acid composition during interesterification.

3.5 Melting and crystallization behaviors

DSC melting and crystallization curves of BT, PS, physical blends, IF are depicted in Fig. 3 and temperature of phase transition points (T) are showed in Table 3. From Fig. 3A, it was found that BT, PS and IF has two major crystal peaks at nearly 5-30°C and the transition point temperatures were BT (T1 = 28.03°C; T2 = 5.12°C), PS (T1 = 29.24°C; T2 = 4.93°C), IF (T1 = 27.48°C; T2 = 13.95°C), respectively, and this may attribute to the fact that the high-melting point components of the sample precipitate to form crystals, the second exothermic peak area was larger than the first peak and the degree of supercooling increases as the temperature decreases further. The crystals formed are loose and unstable\(^{36,37}\). Crystallization curves of IF displayed lower exothermic peaks compared with physical blends may be induced by the rearrangement of fatty acids and a single smaller crystal peaks at T2 (13.95°C) implied the new triglycerides were produced. In addition, IF has lower crystallization onset temperature (To) compared to BT (30.19°C) and PS (33.97°C) and physical blends (42.71°C).

From melting curves presented in Fig. 3B, the major endothermic peak (Tc) of BT, PS, physical blends and IF were
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46.41 °C, 52.26 °C, 43.12 °C and 37.37 °C, respectively, which consistent with the detection results of SMP. Two-three endothermic peaks appeared in BT (T<sub>1</sub>, 32.60; T<sub>2</sub>, 12.03 °C) and PS (T<sub>3</sub>, 46.44; T<sub>4</sub>, 30.47; T<sub>5</sub>, 12.28 °C) due to the different distribution of USFA. The melting offset temperature (T<sub>c</sub>) of IF was 40.65 °C, lower than T<sub>c</sub> of BT (50.21 °C), physical blends (52.71 °C) and PS (56.73 °C). It is clear that the endothermic peaks for low melting point and high melting point are weakened or even disappear after interesterification. The endothermic peak of the physical blends observed at T<sub>c</sub> (3.36 °C) was related to the CO enriched in OOO TAG. This phenomenon can be explained by the decrease in the content of SSS-type TAGs (such as OOO, PPP and SSS) and the increase in the content of SUS- (POP and PPO) and SUU-type (POO and OPO)/TAGs, which was in consist with the analysis of triglycerides.30

3.6 Oxidative stabilities

Storage oxidation stability is essential for IF. As the specific oxidation value of hydroperoxide of fatty acid with oxygen, peroxide value (PV) is used to evaluate the oxidation stability of lipids. Physical blends and IF were stored for 30 days at 60 °C. PV change of physical blends and IF for 60 °C at 30 days was presented in Fig. 4. It is indicated that physical blends and IF exhibited better initial quality with lower PV value on day 0, and both increased slowly over the following 18 days despite that was in the oxidation induction periods. Compared with physical blends, there was a significant increment in the PV of IF, i.e. from 0.25 and 0.26 g/100 g on day 24 to 0.34 and 0.51 g/100 g on day 30, respectively, and the inflection point of oxidation appears after 24 days. These results showed that interesterification decreased the oxidation stability of the blends, which was due to the considerable part of the loss of γ-tocopherol in the raw materials and alteration of TAG molecular structure following interesterification and distillation, as has been confirmed by other reports.30-41 It was reported that oil/fats enriched in monounsaturated fatty acids have longer shelf life.42, 43 The oxidation kinetics equation \((R^2 = 0.99): \ln (PV) = 0.07569T-3.05259\) were derived from the peroxide values of IF, where PV and T represent peroxide values and time respectively. It is known that permissible peroxide value of oil/fats should not above 0.25 g/100 g.44 The linear regression equation: \(\ln (0.25) = 0.07569T-3.05259\) clearly showed that the shelf life of IF at 60 °C was 22 days. On the basis of chemical kinetics rules, the reaction rate increases by 1 time for every 10 °C increase for general chemical reaction. It is estimated that the shelf life of IF at 20 °C was 352 days, which was lower than ordinary oils. In summary, the key property of IF that have to be ameliorated is their storage oxidation stability.

4 Summary

In conclusion, interesterified fats were enzymatically catalyzed from BT, PS and CO blends. Physicochemical properties include fatty acid composition, TAG composition, SFC, melting and crystalization behaviors, crystal structure type were comprehensively investigated. IF showed desirable properties that they had decreased SFC and lower SMP which may improve the mouth feel when compared with physical blends of the ingredient oils or fats. The main crystal form of interesterified fats is desirable β' type. A 352 days-shelf life at 20 °C of IF was estimated by the traditional accelerated oxidation test indicated that IF have a moderate antioxidative stability. Thus, the above acceptable appearance of IF demonstrated that it is feasible to utilize IF as an alternate to the partial hydrogenated oil for trans-free plastic fats stocks.

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