Hard fats improve technological properties of palm oil for applications in fat-based products

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ABSTRACT

Palm oil is widely used in food industry. In many applications, palm oil is hindered by its slow crystallization rate and post-processing formation of large clusters of crystals. In order to overcome these drawbacks, addition of fully hydrogenated vegetable oils, known as hard fats, to palm oil is here proposed. Hard fats can behave as modifiers in the crystallization process due to their homogeneous triacylglycerol profiles. Hard fats from five different vegetable oils were added to palm oil, at the concentration of 1, 3, and 5 g/100 g of blend: palm kernel (PKO), palm (PO), cottonseed (CO), soybean (SO), and crambe (CR). An increase in the solid fat content and critical microstructure alterations affected positively the consistency and could be related to the small changes in the triacylglycerol composition, more precisely to the concentration of acyl groups present and their solubility in the liquid oil. Blends with PKO showed no appreciable improvements. Otherwise, addition of PO, CO, SO, and CR resulted in a significant effect on the rate of crystallization, and leading to a higher hardness and increase of the thermal resistance of palm oil intended for applications in fat-based products.

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1. Introduction

Palm oil is an edible vegetable oil extracted from the mesocarp of the fruit of the palm species, *Elaeis guineensis*. Melting temperature range of palm oil is 32—40 °C and, at room temperature, approximately 28 °C, its consistency is semi-solid (Lin, 2002). In terms of fatty acids profile, the palm oil composition is relatively simple and may vary according to the crop growth conditions, such as temperature, humidity and soil. On average, palm oil contains equals quantities of saturated and unsaturated fatty acids, C18:1 and C18:2 among the unsaturated fatty acids, and C16:0 and C18:0

as saturated fatty acids (Sue & Pantzaris, 2009). Crude palm oil has 94—98 g/100 g of triacylglycerols (TAGs) (O'Brien, 2009).

The crystallization behavior of palm oil is associated to a number of practical issues in food industry. Its slow crystallization rates, for instance, can result in a disordered crystal packing and jeopardize texture and post processing stability, with direct impact on the quality of plasticized products if the palm oil level exceeds 15—25 g/100 g (O'Brien, 2009). Compared to partially hydrogenated fats with similar melting point, palm oil crystallizes more slowly (Bergel, 2001). Symmetrical TAGs, such as saturated-unsaturated-saturated molecules (SUS) present in palm oil can induce the increase in hardness in refrigerated margarines, a phenomenon known as post hardening (Clercq, Danthine, Nguyen, Gibon, & Dewettinck, 2012). Consequently, studies are focused on the adjustment of palm oil and its fractions for uses in food products (Oliveira et al., 2015).

Technological properties of palm oil can be modified by the addition of lipid crystallization modifiers. Studies carried out over the past years, about the influence of emulsifiers, minor components, and additives on the crystallization behavior of palm oil and its fractions, are well covered by Smith, Bhaggan, Talbot, and Malssen (2011).

Liquid oils when subjected to total catalytic hydrogenation are transformed into a fully saturated product known as hard fats that can be used as alternatives to improve functional characteristics of lipid systems. Hard fats present a homogeneous TAG composition, high melting point (T_M), and can be used as low cost industrial additives. Cocoa butter functional attributes, for instance, were improved with the addition of a small amount of hard fats, that were able to promote considerable changes in the crystallization pattern and in the physical properties of this raw material (Ribeiro, Basso, & Kieckbusch, 2013; Ribeiro, Basso, Santos, et al., 2013).

Hard fats added to palm oil can influence nucleation and crystal growth by acting as inductors in the crystallization events and consequently, enables adjustments in its physical properties. The action mechanism of an additive is related to the high ratio of acyl groups present in the molecule and their solubility in the liquid oil. Therefore, this study evaluated the palm oil and its technological properties by addition of hard fats with distinct chemical compositions, at different concentrations, for future applications in fat-based products. Consideration was given to the chemical characterization of blends, and to ascertain the inter-dependence between solid fat content (SFC), T_M, microstructure and consistency.

2. Materials and methods

2.1. Materials

Deodorized palm oil was provided by Agropalma S/A (Belem, Brazil). Five hard fats obtained by fully hydrogenation of liquid oils were evaluated. The hard fats and their major fatty acids are: hard fat of palm kernel oil (PKO) (45.5 g/100 g C12:0, 15.8 g/100 g C14:0, 9.2 g/100 g C16:0, 23.0 g/100 g C18:0); hard fat of palm oil (PO) (36.2 g/100 g C16:0, 61.2 g/100 g C18:0), hard fat of cottonseed oil (CO) (23.2 g/100 g C16:0, 73.9 g/100 g C18:0), hard fat of soybean oil (SO) (10.5 g/100 g C16:0, 87.3 g/100 g C18:0), and hard fat of crambe oil (CR) (2.8 g/100 g C16:0, 31.6 g/100 g C18:0, 56.3 g/100 g C22:0) where C12:0, C14:0, C16:0, C18:0 and C22:0 correspond to lauric, myristic, palmitic, stearic and behenic acids, respectively. These hard fats were provided by Cargill Agrícola S/A (Itumbiara, Brazil). The hard fats components present exclusively trisaturated TAGs and their main TAGs are: PKO (21.5 g/100 g LaLaLa, 15.4 g/100 g LaLaM, 9.3 g/100 g LaLaP, 8.67 g/100 g LaMP, 6.2 g/100 g LaSM, 6.2 g/100 g LaSP, 6.2 g/100 g LaSS), PO (35.0 g/100 g PPS/PSP, 38.8 g/100 g PSS, 19.2 g/100 g SSS), CO (19.8 g/100 g PPS/PSP, 45.6 g/100 g PSS, 32.4 g/100 g SSS), SO (29.8 g/100 g PSS, 63.8 g/100 g SSS), and CR (28.6 g/100 g SBeBe, 18.1 g/100 g BeBeBe, 17.2 g/100 g SSBe, 9.9 g/100 g PSBe, 9.5 g/100 g SABe) where La, M, P, S, A and Be correspond to lauric, myristic, palmitic, stearic, arachidic and behenic acids, respectively (Ribeiro, Basso, & Kieckbusch, 2013).

2.2. Preparation of the blends

Fifteen different blends with palm oil and the five hard fats were prepared. The hard fats samples were first melted, and then three different concentrations of each hard fat were added to the palm oil: 1 g, 3 g, and 5 g per 100 g of blend. After the addition, blends were kept under stirring for 10 min to ensure complete homogenization. All blends were stored in a refrigerator at 10 °C until use.

2.3. TAG composition

The TAG composition determination was performed by GLC with an Agilent 6850 Series GC System USA. A capillary column DB-17HT Agilent (50% phenyl-methylpolysiloxane, 15 m × 0.25 mm i.d., 0.15 μm film thickness) was used. The operating conditions were: split, ratio of 1:100; column temperature: 250 °C, programmed to 340 °C at the rate of 5 °C/min; carrier gas: helium, at a flow rate of 1.0 mL/min; injector temperature: 375 °C, detector temperature: 375 °C; injected volume: 1.0 μL; sample concentration: 100 mg/5 mL of tetrahydrofuran. The identification of TAGs peaks was performed by comparison of the retention times, according to the procedure of Antoniosi Filho, Mendes, and Lanças (1995). The analysis was performed in duplicate for each blend sample.

2.4. SFC

The samples were melted and homogenized at 100 °C and maintained at this temperature for 1 h to eliminate all crystalline memory. Subsequently, they were placed in a dry thermostatic bath with the temperature controlled by a Peltier system Tcon 2000, (Duratech, USA) and submitted to the tempering procedures for non-stabilizing fats according to the direct method recommended by American Oil Chemists' Society [AOCS] (2009) Method Cd 16b-93. The readings of SFC were performed at temperatures of 0, 10, 20, 25, 30, 35, 40, 45, 50 and 55 °C, using the Nuclear Magnetic Resonance spectrometer Bruker pc120 Minispec (Rheinstetten, Germany).

2.5. Melting point, T_M

T_M was obtained from the SFC data. A polynomial equation was adjusted to the SFC data and the melting temperature was considered as the temperature corresponding to a solids content of 4 g/100 g according to Ribeiro, Basso, Grimaldi, Gioielli, and Gonçalves (2009).

2.6. Microstructure

The crystal morphology was evaluated using polarized light microscopy (Olympus, model BX 51, San Jose, USA) coupled to a digital video camera (Media Cybernetics, model MicroPublisher 5.0 Mpixel, Bethesda, USA). The samples were previously melted at 100 °C in an oven and with the aid of a capillary tube, a drop was placed over a pre-heated glass slide (100 °C) and covered with a coverslip. The slides were kept in an incubator maintained at the temperature of 25 °C for 4 h and then placed on the microscope hot stage (model FP82, Mettler Toledo, Columbus, USA), also held at 25 °C. The images were captured by the applicative Image Pro-Plus version 7.0 (Media Cybernetics, Bethesda, USA), using polarized light under a magnification of 40 times, and previous calibration of the microscope using slide micrometric (1000 ms). Within each slide, three visual fields were arbitrarily chosen and focused. The mean diameter of the crystals was selected as the quantitative parameter and calculated using the software Image Pro-Plus version 7.0 (Media Cybernetics, Bethesda, USA) (Campos, 2005).

2.7. Consistency measurement

The consistency was determined using the texture analyzer TA-XT plus texturometer (Stable Micro Systems, Surrey, UK) controlled by a microcomputer. The samples were initially placed in an oven at 100 °C until complete melting of the crystals, and then stored in 50 mL beakers. The conditioning was performed in an incubator at 5 °C for 24 h to induce the crystallization of the fat and then during 24 h at the reading temperature: 10, 15, 20, 25, 30, and 35 °C. A Plexiglas® cone with a 45° angle and non-truncated tip was used in the consistency determination. The equipment was operated under the following conditions: penetration depth = 10 mm, speed = 2 mm/s, duration = 5 s (Campos, 2005). The force of