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Stability and dynamic rheological characterization of spread developed based on pistachio oil

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ABSTRACT

This study investigated the influence of formulation variables (pistachio oil (PO, 7.5 and 15%, w/w), Cocoa butter (CB, 7.5 and 15%, w/w), xanthan gum (XG, 0 and 0.3%, w/w), and distilled monoglyceride (DMG, 0.5 and 1%, w/w)) on the rheological properties and emulsion stability of spreads. Power law and Herschel–Bulkley models were used for modeling shear-thinning behavior of samples. The power law model was found to describe the flow behavior of spreads better than Herschel–Bulkley model. All the rheological properties were increased by adding XG to the spreads whereas increasing PO content caused to decrease them. The DMG had positive effect on apparent viscosity and elastic behavior but had negative effect on viscose behavior. Apparent viscosity was increased by adding CB while rheological modules were not significantly ($p < 0.05$) affected. The XG and DMG improved stability of emulsion. The best spread formulation with optimum rheological properties was 15% PO, 7.5% CB, 0.3% XG and 1% DMG.

1. Introduction

Spreads are semi-solid foods rich in fat which should flow easily when deformed [1]. They classified as water/oil (W/O) emulsions with different formulation consisting fat (cocoa butter (CB)), water, emulsifiers, stabilizers, salt, antioxidants, and other ingredients [1,2]. Pistachio nut (*Pistacia vera* L.) as a unique nut contains more than 55% oil. The predominant fatty acid of pistachio oil (PO) is oleic acid (56–64%). The oil also contains linoleic and linolenic acids that are essential in human diet [3]. Consumption of semi-solid foods prepared from PO with high concentration of natural antioxidants has been reported as being protective against certain types of cancer and may also decrease the risk of cardiovascular diseases [4]. Crystalline triacylglycerol is added to spreads to obtain the desired structure and texture, however these high saturated fat additives are not desirable because of their negative health implications [1,2]. Extensive researches have been conducted to replace solid fat with some alternatives such as fatty alcohols, waxes, lecithin, sorbitan tristearate, phytosterols, and oryzanol [3,4]. Pernetti et al. [3] review focused on alternatives to vegetable oils/fats and their gelation behavior but did not characterize their crystallization and melting behavior. The use of monopalmitin and monostearin (monoacylglycerols, MGs) in combination with olive oil was investigated by Ojijo et al. [5] and behavior of these blends was compared with the mesomorphic phase behavior of monoglyceride/water systems. When concentrated mixtures of vegetable oils and MGs are cooled from the melt point, they formed stable and semi-solid network structures, so they can be employed in spreads based on vegetable oil [5]. These studies showed that the partial replacement of fat with vegetable oils can ameliorate the spreadability at refrigerator temperature (4 °C) and enhance nutritional values such as desirable fatty acid profile and lower cholesterol level in butter fat-vegetable oil blend spread products [6,7]. Emulsifiers such as proteins or surfactants have also been applied to stabilize emulsions [6,8–11]. Xanthan gum (XG) at certain concentration has also been used as a stabilizer by decreasing the rate of oiling out of spreads [12–14]. Spreads have been reported to show non-Newtonian behavior with apparent yield stress which can be described by a number of mathematical models such as Bingham, Herschel–Bulkley, Power law and Casson [15]. Thixotropic behavior has also been reported for spreads, where apparent viscosity decreases consecutively with time under shear and the latter recovery of viscosity when the flow is discontinued [16,17]. Because of metastable state, texture of foods commonly depends on structural changes that occur during processing. Apparent (plastic) viscosity and rheological modules measurements can be used to quantify the rheological properties of spread and they commonly play a vital role in appealing consumer. Apparent viscosity strongly

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effects on determining of pumping characteristics, filling of rough surfaces, coating, and sensory properties of spread mass. Pasty mouth-feel, after swallowing spread, may be attributed to high viscosity that can significantly be related to particle size distribution, composition, and processing strategy [15,18]. Spread composition and rheological properties relationship measurements can be employed as a powerful tool to investigate the effect of any formulation changes on spread stability and texture. The objective of this study was to prepare low fat spread based on pistachio oil in combination with xanthan gum, cocoa butter and distilled monoglyceride (DMG) and investigates the rheological properties of the formulated low fat spread.

2. Materials and methods

2.1. Materials

Pistachio nuts were obtained from the local market during Nov–Dec, 2011 (Rafsanjan, Iran). They were manually cracked and shelled, and then chopped in a smooth corundum disk mill (Glen Mills, Clifton, NJ, USA). The oil expression was carried out with a screw press (Model NB 90, Kimiagaran Products Co., Kerman, Iran). The fatty acid composition (mol%) of obtained oil was 0.6% C14:0, 11% C16:0, 0.7% C16:1, 1.7% C18:0, 59.5% C18:1, 25% C18:2, 0.2% C18:3, 0.3% C20:0 and 0.6% C20:1 as measured by gas chromatography of their methyl esters derivatization. Other ingredients including sugar, milk powder, and salt powder were supplied by Gorji Biscuit Co. (Tehran, Iran). XG and Locust bean gum (LBG) were purchased from Sigma–Aldrich Co. (St. Louis, MO, USA). Polyglycerol polyricinoleate (PGPR) 4110, PGPR 4175, distilled monoglycerides (DMG) 0291 and DMG 0295 were provided from Emulsion-Holland B.V. (Zierikzee, Holland). DMG0291 and PGPR4110 were included in formulation with more than 20% oil and, DMG0295 and PGPR4175 were used to formulate spreads with less than 20% oil (according to the company recommendation).

2.2. Spread samples preparation

Spreads were prepared according to the method described by Beckett with some modifications [19]. A water-soluble mixture of sugar (45%, w/w), milk powder (13.5%, w/w), pistachio paste (10%, w/w), XG (0 and 0.3%, w/w), LBG (0.09%, w/w) and salt (0.04%, w/w) refined to particle size <30 μm using a combination of two- and five-roll refiners. The fat-soluble ingredients including PO (7.5 and 15%, w/w), surfactants (DMG; 0.5 and 1%, w/w) and PGPR (0.3%, w/w) were separately mixed and then added to the former mixture at 50 °C temperature. The obtained mixture after refining for 2 h was transferred to a laboratory-scale conch. Conching process is a necessary stage for achieving to the suitable viscosity and satisfactory texture and flavor for spreads. This step as an endpoint for manufacture of PO-based spreads was optimized by physico-chemical changes in the final product. Proper control of temperature (50–60 °C) during conching is necessary to produce a high-quality spread. Time of this step depends on the composition of the mass, but it is normally 8–10 h for spread [20]. At the end of the stage of conching, interactions between disperse and continuous phase were promoted, and different formulation were then hot-filled into special containers, cooled and kept at 25 °C for further analyses. Sixteen PO-based spreads (A–P samples) with different formulations were prepared according to the full factorial design (Table 1).

Our preliminary studies showed that the addition of LBG and PGPR at optimal concentrations of 0.09% and 0.3% (w/w) respectively resulted in desirable textural changes of PO-based spreads. In this study, two valid commercial spreads, the internal (sample Q) and external (sample R) producers, were also used as a reference to compare with the formulated spreads and finally the spread which was closer than others to commercial samples was selected as optimized sample.

Table 1
The combination of formulations based on different levels of independent variable.

Sample coding	PO (% w/w)	CB (% w/w)	XG (% w/w)	DMG (% w/w)
A	15	7.5	0	0.5
B	7.5	7.5	0.3	0.5
C	7.5	15	0	1
D	15	15	0.3	0.5
E	7.5	15	0.3	0.5
F	7.5	7.5	0.3	1
G	7.5	15	0.3	1
H	15	7.5	0.3	1
I	15	7.5	0.3	0.5
J	7.5	7.5	0	0.5
K	15	7.5	0	1
L	7.5	15	0	0.5
M	15	15	0.3	1
N	15	15	0	1
O	15	15	0	0.5
P	7.5	7.5	0	1

PO (pistachio oil), CB (cocoa butter), XG (xanthan gum), DMG (distilled monoglyceride).

2.3. Rheological measurements

Oscillatory shear measurements were conducted using a Physical MCR 301 Rheometer (Anton Paar, GmbH, Ostfilden, Germany) and the four-blade vane St14. The vane was introduced into the cup vertically using the dimensions suggested by Steffe [21]. After insemination, 10 g of each of samples was transferred to the rheometer cup. Temperature was controlled at 25 °C. The apparent viscosity of dispersions were measured using of oscillatory rheometer at 1–100 1/s. Couette geometry with a cup (33.93 mm diameter) and a bob system (32.05 mm diameter, 33.29 mm length) was used. Strain sweep tests were performed (strain; 0.01–10% at constant frequency of 1 Hz) to measure the linear viscoelastic range (LVE), where the dynamic parameters (G' and G'') are independent of the magnitude of applied strain, and constant strain of 3% was selected for the frequency sweep test (Fig. 1).

Frequency sweep test is a well-known method for studying the viscoelastic behavior of food, which can be helpful for investigating chemical composition and physical structure [12,21]. Frequency sweep test was carried out at frequency 0.1–30 Hz (at constant strain of 3%) to evaluate the dynamic rheological properties including storage modulus ($G' = a\omega^x$) and loss modulus ($G'' = b\omega^y$). Power

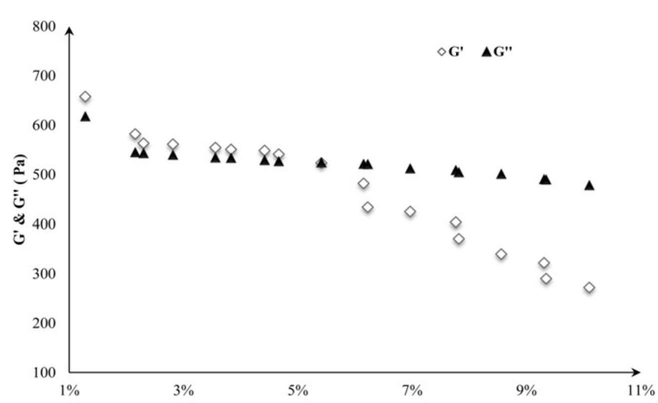

Fig. 1. Strain sweep test of D sample (15% PO (pistachio oil), 15% CB (cocoa butter), 0.3% XG (xanthan gum), and 0.5% DMG (distillated monoglyceride)).