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Influence of bamboo shoot dietary fiber on the rheological and textural properties of milk pudding

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ABSTRACT

Adding dietary fiber in milk pudding is of great significance in improving the nutritional value of a variety of products as well as human health. However, only a few reports on the influence of dietary fiber on the rheological behavior and textural properties of milk pudding are available. Therefore, in this paper, the milk pudding was used as raw material to study the changes in rheological behavior, textural properties, and microstructure of the pudding after adding bamboo shoot diatery fiber (BSDF) at different concentration. Results showed that the BSDF/milk pudding compound system is a typical pseudoplastic fluid with yield stress. With the addition of 2 g BSDF/100 g, the yield stress and consistency coefficient values were the highest, whereas the fluid index showed the smallest value. The hardness, viscosity, and gumminess increased until 2 g/100 g concentration and they decreased with further addition of BSDF, whereas cohesiveness demonstrated the opposite behavior. Meanwhile, the microstructure of the compound system revealed that BSDF increases the aggregation of particles and the cohesiveness between BSDF and the milk pudding and made the microstructure more compact. However, when the concentration was over 2 g/100 g, the gel structure of milk pudding was damaged, resulting in flocculation.

1. Introduction

As a functional food ingredient, dietary fiber has caught the attention of nutritionists throughout the world. Numerous studies and research have shown that dietary fiber has many physiological functions, including adjusting the intestinal flora, preventing coronary heart disease, lowering blood pressure and glucose, preventing cancer, and aiding in weight loss (Li, Lv, & He, 2014; Ma & Mu, 2016; Rodríguez, Jiménez, Fernández-Bolaños, Guillén, & Heredia, 2006). Thus, dietary fiber is indispensable in maintaining human health. Likewise, with its unique functions and refined texture, the dietary fiber, as a main food component, has been widely applied in a variety of foods, such as meatballs (Galanakis, Tornberg, & Gekas, 2010), frankfurter sausage (Choi et al., 2010), biscuits (Verardo et al., 2011), and drinks (Yilmaz, Sert, Karakaya, & Tiske, 2010).

Milk pudding is consumed in an almost daily basis worldwide by several groups of consumers (Ares, Baixauli, Sanz, Varela, & Salvador, 2009). Although milk pudding is rich in nutrients, such as protein, it lacks dietary fiber. Thus, the addition of dietary fiber to the pudding is of great significance in improving the nutritional value and enriching the variety of dairy products, especially those concerning human health. However, given that it is a complicated stable compound, the stability, rheological behavior, and textural properties of milk pudding is changed by the addition of polysaccharides (Pang, Hilton, & Nidhi, 2015). As the fundamental theory for fluid food stability, rheological behavior can provide technological references for product formula, technical design, equipment selection, and quality assessment by virtue of studying the physical properties of food and understanding their composition, inner structure, and molecular forms. With the development of food industry, studies on the physical properties of food are expanding. Currently, a few studies focus on the rheological and textural properties of dairy products (Nursel, Mehmet, Nejat, & Erşan, 2015; Pang, Hilton, Ranjan, & Nidhi, 2015; Schmidt, Mende, Jaros, & Rohm, 2016; Virginia, Federica, Marco, & Santina, 2015); some pay attention to the influence of dietary fiber on the properties reported.

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BSDF, as a rich source of dietary fiber, should be developed because of its superior physicochemical properties, such as good water binding capacity, swelling property, and adsorbing ability together with its bio-active functions, including promoting digestion, lowering cholesterol, and improving intestinal health (Chongtham, Bisht, & Haorongbam, 2011; Singhal, Bal, Satya, Sudhakar, & Naik, 2013). However, the influence of BSDF on the gel formation and rheological behavior of milk pudding is still unknown. Therefore, the aim of this study was to investigate the influence of BSDF on the rheological and textural properties as well as on the microstructure of milk pudding.

2. Materials and methods

2.1. Materials

The BSDF was extracted from bamboo shoots (*Dendrocalamus latiflorus*) through the compound enzyme method (cellulase and papain), and the total dietary fiber obtained reached 85.2 g/100 g. The milk pudding was prepared based on a traditional formula: 8 g water/100 g milk powder (Nestle China co., LTD, Inner Mongolia) (with 24 g protein/100 g, 28.2 g fat/100 g, and 37 g carbohydrate/100 g), 10 g sugar/100 g (Taikoo, Shanghai), 1.0 g gelatin/100 g (Dongguan Haoshi Bakery Technology Co., LTD, Guangdong), 0.1 g k-carrageenan/100 g (Henan Qianzhi Commerce Co., LTD, Henan), 0.05 g sucrose ester/100 g (Shanghai Wuma Food Co., Shanghai), 0.05 g monostearin/100 g (Masson Group, Guangdong), and 0.01 g sodium citrate/100 g (Jiangsu Kolod, Jiangsu). The control group was without BSDF, and the other groups contained BSDF at different levels (1, 1.5, 2 and 2.5 g/100 g).

2.2. Preparation of milk pudding

The preparation was based on the method by Ares et al. (2009). After mixing whole milk powder, colloid, sugar, and other solid raw materials, 75 °C hot water was poured into the mixture to dissolve all the raw material. Then, the solution was placed in a high-speed refiner (T10, IKA, Staufen, Germany) and cropped for 3 min at the speed of 6000 rpm. The cropped sample was heated to 90 °C and kept in a hot water bath for 30 min. The sample was then placed in a 200 mL glass bottle, which was sealed off. After cooling down to room temperature, the bottle was stored in the refrigerator (4 °C) for 24 h for further testing.

2.3. Rheological behavior test

Referring to the method by Anderson, Shoemaker, and Singh (2006), the sample of milk pudding was taken out and placed under room temperature and set in a rheometer (AR550, TA Instruments, New Castle, USA) for the rheological behavior test. Plate–plate measurement system was used in the test. The diameter of the plate is 4 cm with a gap of 0.5 cm. The sample was placed in the system, and the excess was razed off before the covering plate was set down. Silicone oil was used to prevent moisture evaporation. New sample was used in each test.

Static shear rheology test: At the temperature of 25 °C, change in the shear stress was measured within the shear rate (γ) range of 0–300 s^{-1}. Data points were regressed and fitted in the Herschel–Bulkley model. The fitting coefficient (R^2) shows the fitting accuracy of the equation, which is as follows:

$$\sigma = K(\gamma)^n + \sigma_0$$

where σ is the shear stress (Pa), K is the consistency factor (Pa·s^n), γ is the shear rate (s^{-1}), n is the fluid index, and σ_0 is the yield stress (Pa).

Dynamic viscoelasticity test: At the temperature of 25 °C and with a scanning strain of 1%, energy storage modulus (G′), loss modulus (G″), and loss angle tangent (tanδ = G″/G′) changes at different low (0.1 Hz) to high (10 Hz) angular frequencies were observed.

Dynamic time scanning test: At the temperature of 25 °C, frequency of 0.5 Hz, and scanning strain of 1%, changes in the G′ and tanδ within 1 h were measured.

2.4. Textural properties test

Referring to the method by Mohammed, Abdellatif, and Shahzad (2014), the test was carried out. The prepared milk pudding was cooled down to room temperature (25 °C). Afterward, texture profile analysis was conducted with a texture analyzer (CT3, Brookfield, Middleboro, USA). Test conditions: Test probe is TA5; test speed was kept at 0.5 mm/s; trigger force = 5 g; compression degree is 40%. Each group was tested thrice.

2.5. Microstructure observation

The pudding was dispersed in 70 °C hot water by water in the proportion of 1:5 (g:mL). Once the slide was prepared, the pudding was placed under an optical photographic microscope (BX43F, Olympus, Tokyo, Japan) with an ocular of 10× and objective of 40× to capture the micrographs. The microstructure of the compound system was observed according to the images under the scope.

2.6. Data analysis

Test results were presented in the form of mean ± standard error (Mean ± S.E). All the tests were repeated thrice. SPSS 11.5 was used for variance analysis. Origin 8.6 was used for construction of graphs and figures and for data processing.

3. Results and discussion

3.1. Static shear rheological behavior

Changes in the shear stress of milk pudding with the addition of BSDF at different levels and changing shear rate are presented in Fig. 1. The figure reveals that the shear stress in the flowing process

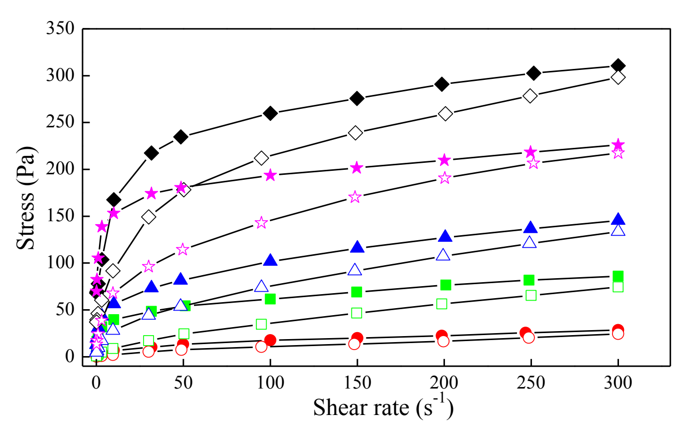

Fig. 1. Effect of BSDF concentration (● 0, ■ 1, ▲ 1.5, ◆ 2, ★ 2.5 g/100 g) on the shear force of milk pudding. Full symbols as the uplink line (the curve of the shear force applied to the sample when the shear rate varies from small to large), empty symbols as the downlink line (the curve of the shear force applied to the sample when the shear rate varies from large to small).