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Evaluating the effects of amylose and Concord grape extract powder substitution on physicochemical properties of wheat flour extrudates produced at different temperatures

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ABSTRACT

In this study, the effects of Concord grape extract powder (CGEP), high-amylose starch, and their combinations on quality parameters of extruded products were investigated by substituting wheat flour with those ingredients in the formulations. Physical quality parameters such as water absorption, bulk density, diametric expansion and hardness of extrudates were evaluated in addition to thermal properties, pasting properties and resistant starch contents. Average values obtained for 90, 120 and 150 °C extrusion temperatures changed respectively as follows: 0.916, 0.987 and 0.467 N for hardness; 2.12, 4.07 and 5.12 ml water/g sample for water absorption; 1.35, 2.09 and 2.51 for diametric expansions and 1286.6, 723.6 and 311.1 kg/m^3 for bulk densities. Extrusion temperature was found to have more distinct effect on physical quality parameters of extrudates than the substitution level of ingredients. Both CGEP and amylose additions negatively affected pasting properties, slightly affected resistant starch content and prevented gelatinization. However retardation of retrogradation was more evident when substitution was with CGEP alone rather than its combination with amylose.

1. Introduction

Extrusion is a common approach for production of various products by the food industry, in which a rotating screw applies shear energy while the extruder barrel is heated, enabling the temperature of the food material to increase. The food becomes "liquefied" as it is conveyed through a die or series of dies under high pressure and changes into a final extrudate which is a different product from the raw material in terms of its novel texture and desirable sensory attributes. Therefore, extrusion is of particular interest as the products may have various different properties when compared to baked products. The nature of extrusion enables the incorporation of functional components into the product formulations and this approach has wide applications for various food commodities.

Although cereal components and particularly starch are assumed to be easily utilisable in extrusion processes, control over the end product characteristics requires much effort. Specifically, starch, which becomes swollen and even gelatinized during extrusion, is subject to many changes with the applied processing conditions while forming the extrudate (Eliasson & Gudmundsson, 2006). Pasting properties of starch are affected by its amylose and lipid contents and by branch chain length distribution of amylopectin. Amylopectin contributes to swelling of starch granules and pasting, whereas amylose and lipids inhibit the swelling because the release of amylose from the interior of starch granules is retarded (Tester & Morrison, 1990). The main change during extrusion is the breakdown of the crystalline structure of starch through gelatinization, but crystallinity can again form during storage. Retrogradation of starch during extrusion is mainly attributed to the B-type starch crystals. On the other hand, formation of amylose–lipid complexes is commonly related to the V-type crystals in starch (Chanvrier et al., 2007; Van Soest & Knooren, 1998).

Most of the colourful and multifunctional phytochemicals (plant chemicals) or nutraceuticals existing in nature are found in fruits. Anthocyanins are among the most powerful phytochemicals in many fruits, being natural colour pigments and one of the most important subclasses of flavonoids. Previous studies on extrusion of fruits have been aimed at detecting effects of extrusion processing conditions, such as die temperature, screw speed and the level of pomace added, on the final product parameters

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while incorporating fruit pomace (Altan, McCarthy, & Maskan, 2009) or fruit by-products (blends of orange peel, grape seed and tomato pomace) (Yağcı & Göğüş, 2008). These studies were primarily interested in the effects of incorporating fibre-rich substances during extrusion. Other researchers (Stojceska, Ainsworth, Plunkett, & İbanoğlu, 2009) evaluated the effects of two different levels of feed moisture and barrel temperature conditions during extrusion of wheat flour and corn starch substituted with brewe's spent grain and red cabbage in four different formulations, and concluded that fibre content, total phenolics and antioxidant activity all increased in samples containing red cabbage.

White, Howard, and Prior (2010) studied the changes in bioactive components and antioxidant activity of cranberry pomace after extrusion when they were mixed with corn starch in different ratios (30:70; 40:60 and 50:50). They reported that extruder barrel temperature and pomace levels were important factors affecting the amount of total anthocyanins remaining in the final extrudate, whereas screw speed had no effect. According to their study, the anthocyanin loss during extrusion was lower when the ratio of corn starch to pomace was higher. Therefore, they suggested that starch may be acting like a barrier to preserve anthocyanins, but the mechanism has not been identified yet (White et al., 2010). However, in those studies, effects of anthocyanins or flavonols on rheological properties were not determined. Moreover, possible interactions related to large molecules in the food system, which might be important for future applications, were not determined. Accordingly, further research on the interactions between regular and functional ingredients during extrusion under different processing parameters and quality changes of the extruded products is necessary. CGEP is high in polyphenols, and particularly anthocyanins. Use of fruit sources in spray-dried powder form is not only beneficial for increasing polyphenol retention during extrusion, but also advantageous due to lower moisture and sugar contents of the powders in comparison to those of fresh and/or concentrated fruit sources.

It is known that the physicochemical aspects of plasticized starch matrix are modified during extrusion depending on the processing conditions (Alvarez-Martinez, Kondury, & Harper, 1988). Some other studies also exist which evaluated the effects of starch or amylose on the physical properties of the extrudates (Blanche & Sun, 2004; Della Valle, Vergnes, Colonna, & Patria, 1997; Zhu et al., 2010). However, in the literature, scarce knowledge is available about the combined effects of anthocyanin-rich fruit-based sources and high amylose starch during extrusion applications. Therefore, the aim of this study was to investigate any effects related to anthocyanins, amylose and their combinations, on the quality parameters of extrudates produced at various extrusion temperatures.

2. Materials and methods

2.1. Materials

Hard wheat bread flour used in this study was provided by Mennel Milling Company (Fostoria, OH, USA). For amylose treatments, high amylose starch (HYLON VII) obtained from National Starch and Chemical Company (Bridgewater, NJ, USA) was used. Concord grape extract powder (CGEP) from Milne Fruit Products (Prosser, WA, USA) was selected as the anthocyanin (A) source. The anthocyanin concentration in CGEP was determined to be 618.8 ± 24.0 mg cyanidin-3-glucoside equivalents/100 g dry matter (determined in a study not yet published).

2.2. Sample preparations

Three different samples were prepared: hard wheat bread flour, which was the control sample (C1), was substituted with 10% (w/w) high amylose starch (C2) or 20% (w/w) high amylose starch (C3). Each sample set was weighed to give a batch of 3.0 kg and mixed using the Hobart mixer (Hobart Corp., OH, USA) for 30 min. The mixing process was done at least 24 h before extrusion to ensure a uniform moisture level (approximately 11%) in the mix. Samples were stored in plastic containers in the cold storage room at 4 °C until analysis. For investigating the effects of anthocyanin and other bioactive components in CGEP, hard wheat flour in C1, C2 and C3 samples was substituted with 7% (w/w) CGEP to obtain batches of A1, A2 and A3, respectively. A detailed scheme of the samples is presented in Table 1. Each treatment was made in duplicate.

2.3. Extrusion

For extrusion, a laboratory scale twin screw extruder (Model MP 19T2-25, APV Baker, Grand Rapids, MI, USA) was used. Constant feed moisture content of 25% and screw speed of 360 rpm were used. The following screw configuration was used, where screw diameter is 19.0 mm (1 D) and one kneading paddle is 1/4 D: 8 D twin lead screws, 7 × 30° forward kneading elements; 8 D twin lead screws; 3 × 60° forward kneading elements; 3 × 30° reverse kneading elements; 2 D single lead screws; 4 × 60° forward kneading elements; 3 × 30° reverse kneading elements; 2 D single lead screws; 7 × 90° kneading elements; 2 D single lead screws.

The exit die used had an opening of 3 mm, barrel diameter was 19 mm, and barrel length to diameter ratio (L/D) was 25:1. Distilled water was injected with an E2 Metripump positive displacement-metering pump (Bran + Luebbe, Northampton, UK) to make the feed moisture 25%. The extruder temperature profile was comprised of 5 different temperature zones, with zone 1 at the feed port and zone 5 at the die. Therefore, using constant screw speed, 2 kg/h^{-1} feed rate and 25% feed moisture, samples were extruded at three different processing temperatures (temperature at zone 5 temperature) 90, 120, or 150 °C. Temperature profiles of the five zones of the extruder barrel, from feed port towards exit die are as following for the 3 conditions: 40–60–60–70–90, 40–60–80–100–120 and 40–60–100–140–150 °C.

For each extrusion condition, the system variables of die pressure (MPa) and motor load (%) were stabilized for at least 5 min between each extrusion run. The product collection continued

Table 1
Sample preparations.

Sample	Ingredients
A1	93% (w/w) Bread flour and 7% (w/w) CGEP
A2	83% (w/w) Bread flour, 10% (w/w) high amylose starch and 7% (w/w) CGEP
A3	73% (w/w) Bread flour, 20% (w/w) high amylose starch and 7% (w/w) CGEP
C1	100% (w/w) Bread flour
C2	90% (w/w) Bread flour and 10% (w/w) high amylose starch
C3	80% (w/w) Bread flour and 20% (w/w) high amylose starch