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Properties of extruded chia–corn meal puffs☆

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ABSTRACT

This study investigated the properties of extruded corn meal puffs containing chia. Mixtures of corn meal and chia seeds (0–20 g/100 g) were processed in a laboratory-scale twin-screw extruder at different moisture contents (18–22 g/100 g) and final heating zone temperatures (120–160 °C). Extrusion processing provides a simple method for grinding the seeds, which is necessary for making the fatty acids available. The expansion of cylindrical extrudates decreased with increasing chia content, increasing moisture and increasing final heating zone temperature. The hardness of the extrudates increased with increasing moisture content and decreased at intermediate chia levels. The specific mechanical energy of the extrusion process decreased with increasing chia content.

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1. Introduction

Chia (*Salvia hispanica* L.) seeds contain the highest level of α-linolenic acid fatty acid from a plant source, at up to 68 g/100 g of the oil (Ayerza, 1995). They also contain high levels of protein (Coates & Ayerza, 1996) and dietary fiber (Reyes-Caudillo, Tecante, & Valdivia-Lopez, 2008). Due to the health benefits of these components, there has been increased interest in developing functional food products containing chia.

A number of recent studies has shown that chia can be successfully incorporated into food products. For example, chia gel was used to replace 25 g/100 g of the oil or eggs in cakes without decreasing sensory properties (Borneo, Aguirre, & León, 2010). Chia flour was used as a shortening in gluten-free chestnut flour doughs by Moreira, Chenlo, and Torres (2012). The chia flour increased water absorption and decreased the development time, and was found to improve the chestnut flour doughs more than olive or sunflower oil. Pizarro, Almeida, Sammána, and Chang (2013) showed that up to 15 g/100 g chia flour could be incorporated into pound cake to improve nutritional properties and maintain sensory acceptance. Chia–barley composites were prepared by Inglett, Chen, Xu, and Lee (2013), who found that replacing up to 20 g/100 g of the barley with chia did not lead to large changes in the pasting or rheological properties of the composites, and improved the water holding capacity. We are not aware of any studies using chia in extruded food products.

Extrusion has been shown to be an effective method for incorporating other functional ingredients into food products. For example, Wu, Huff, and Hsieh (2007) prepared extruded corn meal puffs with flaxseed meal, another good source of α-linolenic acid and fiber. They found that increased flaxseed levels not only led to higher retention of lignan compounds, but also less expanded and harder extrudates. Ramos Diaz et al. (2013) studied the expansion and oxidative stability of extrudates containing corn flour and amaranth, quinoa and kañiwa. Each of the pseudocereals increased the expansion relative to the control, but samples with the highest fiber levels had the least increase in expansion. Whole extrudates exposed to high relative humidity showed very little hexanal formation upon storage. Thachil, Chouksey, and Gudipati (2014) showed that fish oil rich in ω-3 polyunsaturated fatty acids could be used to create oxidatively stable extrudates with corn flour. They found that a higher level of amylose bound higher amounts of oil in the extrudates and decreased oxidation. We are not aware of any studies using chia in extruded food products.

The goal of this work was to study the effects of chia on the properties of a model system of an extruded corn meal puff.

2. Materials and methods

2.1. Materials

Degermed corn meal (Quaker Oats Co., Chicago, IL) was purchased locally. Black chia seeds (*S. hispanica* L.) were purchased

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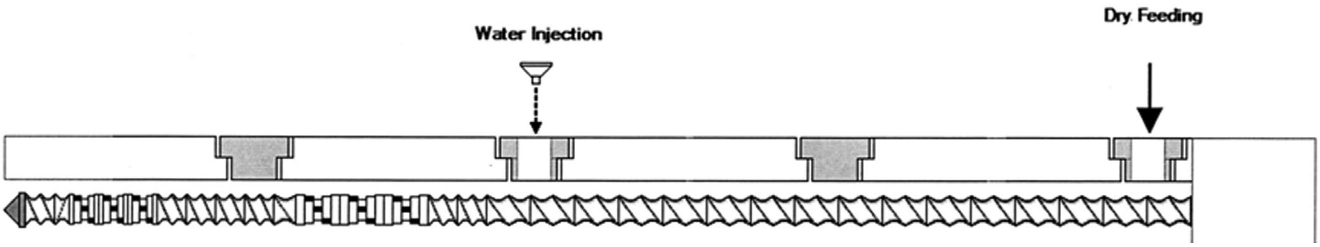

Fig. 1. Schematic of screw configuration.

from Chia Seed Growers (Cuernavaca, Morelos, Mexico). The moisture content of the corn meal was 10.9 g/100 g. The oil content of the materials was 1.9 g/100 g for the corn meal and 29.7 g/100 g for milled chia seeds. 0.7 g/100 g oil was extracted from whole chia seeds. Blends of 5, 10, 15 and 20 g/100 g chia (as is basis) and corn meal were prepared in a planetary mixer (Hobart A200, Troy, OH).

2.2. Extrusion

Corn meal and chia–corn meal blends were extruded in a Brabender TSE-20 (C.W. Brabender Instruments Inc., South Hackensack, NJ) corotating twin-screw extruder. The screw diameter was 20 mm, and the length was 795 mm, and the screw configuration is shown in Fig. 1. The screw speed was 250 rpm. The materials were fed using a volumetric feeder (Brabender DDSR20-5) at a rate of 3.4 kg/h. An annular gear pump and mass flow meter (MZR-7205S and Cori-flow M14, Bronkhorst, Inc, Bethlehem, PA) were used to add water to achieve moisture contents of 18, 20 and 22 g/100 g. The four barrel heating zones were maintained at 25, 55, 75 and 85 °C. The die adapter flange ($L = 45$ mm) was maintained at 110 °C, and the temperature of the die head ($L = 95$ mm) was set at 120, 140 or 160 °C. The diameter of the die was 2.38 mm, and its length was 7.0 mm. Extruded samples were dried in a mechanical convection oven (STM 135, Precision Scientific, Chicago, IL) at 40 °C for 4 h to achieve moisture contents of approximately 8 g/100 g. The moisture content of the cooled products was determined with a moisture analyzer (Mettler-Toledo HR83, Greifensee, Switzerland).

2.3. Expansion ratio

Since the surfaces of many of the samples were irregular due to bubble formation, direct measurements of the diameter were not used. Instead, the volume of the extrudates was measured by displacement of rapeseed. Samples of known length and weight were placed in a 250 mL graduated cylinder, and rapeseed was added to fill the cylinder. The volume of the samples could therefore be determined, and an average diameter was calculated assuming cylindrical extrudates. Five measurements were made for each sample. The expansion ratio was the ratio of the average extrudate diameter to the die diameter.

Table 1
Amount of oil extracted from extrudates.

Chia, g/100 g	Zone 6 T, °C	Moisture, g/100 g	Extracted oil, g/100 g extrudate	Extracted oil, g/100 g chia oil
0	120	22	0.05	n/a
5	120	22	0.93	65.3
5	140	22	0.91	63.1
5	160	22	1.00	68.7
10	120	20	1.51	52.4
10	120	18	1.57	54.0
10	160	20	1.55	53.3
10	160	18	1.62	56.0
15	120	22	2.06	47.7
15	140	22	2.44	56.5
15	160	22	2.75	63.5
20	120	22	3.07	54.7
20	120	20	3.80	67.0
20	120	18	4.24	74.1
20	160	22	3.47	60.9

Table 2
Expansion ratio and hardness of extrudates.

Chia, g/100 g	Zone 6 T, °C	Moisture, g/100 g	Expansion ratio	Hardness, N/mm^2
0	120	22	1.61 ± 0.09	0.658 ± 0.113
0	120	20	2.30 ± 0.06	0.426 ± 0.061
0	120	18	2.80 ± 0.07	0.217 ± 0.021
0	140	22	1.82 ± 0.06	0.473 ± 0.060
0	140	20	2.81 ± 0.05	0.338 ± 0.118
0	140	18	2.74 ± 0.05	0.237 ± 0.046
0	160	22	2.05 ± 0.02	0.358 ± 0.026
0	160	20	2.30 ± 0.05	0.266 ± 0.031
0	160	18	2.39 ± 0.05	0.239 ± 0.041
5	120	22	2.06 ± 0.04	0.304 ± 0.061
5	120	20	2.38 ± 0.07	0.254 ± 0.050
5	120	18	3.03 ± 0.09	0.114 ± 0.042
5	140	22	2.50 ± 0.06	0.274 ± 0.087
5	140	20	2.41 ± 0.01	0.245 ± 0.012
5	140	18	2.71 ± 0.08	0.117 ± 0.003
5	160	22	2.02 ± 0.07	0.241 ± 0.052
5	160	20	2.51 ± 0.03	0.156 ± 0.027
5	160	18	2.45 ± 0.07	0.129 ± 0.021
10	120	22	2.40 ± 0.06	0.217 ± 0.045
10	120	20	2.47 ± 0.04	0.181 ± 0.041
10	120	18	2.96 ± 0.07	0.119 ± 0.031
10	140	22	2.52 ± 0.21	0.183 ± 0.035
10	140	20	2.53 ± 0.12	0.167 ± 0.042
10	140	18	2.75 ± 0.06	0.126 ± 0.030
10	160	22	1.80 ± 0.13	0.318 ± 0.031
10	160	20	2.30 ± 0.11	0.244 ± 0.019
10	160	18	2.53 ± 0.05	0.119 ± 0.016
15	120	22	2.44 ± 0.05	0.301 ± 0.019
15	120	20	2.65 ± 0.09	0.245 ± 0.084
15	120	18	2.83 ± 0.04	0.202 ± 0.025
15	140	22	2.04 ± 0.10	0.388 ± 0.061
15	140	20	2.39 ± 0.09	0.269 ± 0.044
15	140	18	2.98 ± 0.08	0.132 ± 0.033
15	160	22	1.65 ± 0.09	0.393 ± 0.085
15	160	20	2.08 ± 0.17	0.252 ± 0.053
15	160	18	2.06 ± 0.09	0.213 ± 0.037
20	120	22	1.97 ± 0.04	0.458 ± 0.034
20	120	20	2.17 ± 0.08	0.392 ± 0.036
20	120	18	2.37 ± 0.05	0.295 ± 0.060
20	140	22	1.92 ± 0.15	0.403 ± 0.047
20	140	20	2.05 ± 0.05	0.351 ± 0.045
20	140	18	2.23 ± 0.02	0.230 ± 0.055
20	160	22	2.14 ± 0.16	0.210 ± 0.030
20	160	20	2.18 ± 0.04	0.169 ± 0.020
20	160	18	2.40 ± 0.01	0.127 ± 0.029