Food Chemistry 192 (2016) 363–369

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

The effect of extrusion processing on the physiochemical properties of extruded orange pomace

Ya-Ling Huang *, Ya-Sheng Ma

Department of Seafood Science, National Kaohsiung Marine University, 142, Hai-Chuan Road, Nan-Tzu, Kaohsiung 81157, Taiwan

ARTICLE INFO

Article history:
Received 22 January 2015
Received in revised form 15 June 2015
Accepted 8 July 2015
Available online 9 July 2015

Keywords:
Orange pomace
Extrusion
Soluble dietary fibre
Response surface methodology
Physicochemical property

ABSTRACT

Soluble dietary fibre (SDF) is considered the most effective fraction of dietary fibre (DF) for human health. In this study, extrusion technology was applied to enhance the SDF obtained from orange pomace, a byproduct of juice extraction containing a high level of DF. The pomace was processed in a single-screw extruder at various barrel temperatures (X_1; 115–135 °C), feed moistures (X_2; 10–18 g/100 g), and screw speeds (X_3; 230–350 rpm). Based on response surface methodology, the optimum extrusion conditions, which produced a maximum SDF value of 30.36%, were as follows: barrel temperature, 129 °C; feed moisture, 15%; and screw speed, 299 rpm. Compared with unextruded pomace, SDF fraction in extrudate had a higher level of uronic acid. Furthermore, the extrusion process improved the physicochemical properties of extrudate, increasing the water-holding capacity, swelling, water solubility index, and cation-exchange capacity and decreasing the oil-holding capacity.

1. Introduction

Many studies have demonstrated that fruit and vegetables contain large amounts of dietary fibre (DF), which benefits the physiological activities of humans by decreasing cholesterol levels, reducing hyperlipidemia and hypertension, and maintaining gastrointestinal health (Kendall, Esfahani, & Jenkins, 2010; Phillips, 2013). Moreover, DF in vegetables and fruits has a higher insoluble/soluble dietary fibre (IDF/SDF) ratio than that of cereal bran (Grigelmo-Miguel & Martin-Belloso, 1999). In particular, SDF is more effective than IDF in maintaining systemic health. IDF can be converted into SDF by physical method, which unfortunately alters the nutritional and textural properties of the final product (Stojceska, Ainsworth, Plunkett, & Ibanoglu, 2010). Therefore, researchers are seeking ways to increase the SDF contents in total dietary fibre (TDF).

Extrusion is a continuous cooking and shaping process used in the production of numerous snack foods and breakfast cereals. Extrusion technology combines several factors, such as temperature, moisture, shearing, and mixing, to produce fibre-rich foods (Lobato, Anibal, Lazaretti, & Grossmann, 2011). The structure, physicochemical properties and nutrition effects of DF are easily affected by processing (Zhang, Bai, & Zhang, 2011), and the amount of SDF produced during extrusion is highly dependent on the temperature and pressure in the extruder barrel. In brief, high temperatures break down glucosidic bonds in polysaccharide, which can lead to a release of oligosaccharides and eventually increase the quantity of SDF (Wolf, 2010). Thus, extrusion processing can be used to transform IDF into a soluble form. For example, Ng, Lecain, Parker, Smith, and Waldron (1999) extruded the fleshy outer scale leaves of onion to enhance the solubility of the cell-wall pectic polymers and hemicelluloses as well as to enhance the swelling of materials in cell walls. In other words, the extrusion process decreases the quantity of IDF and increased SDF (Jing & Chi, 2013).

Liucheng sweet orange is a tropical fruit that is popular throughout the world. Most of the agricultural output of oranges is used in the preparation of juice and concentrates. After juice extraction, many thousands of tons of pomace are produced as an agricultural byproduct. A recent study demonstrated that orange pomace contains high levels of TDF (71.0 g/100 g dry wt), which is mainly IDF (53.1 g/100 g dry wt). The pomace has distinctive characteristics that can be applied in the food industry (Crizel, Jablonski, Rios, Rech, & Flores, 2013; Ocen & Xu, 2013). As a result of the high fraction of IDF in orange pomace, it is difficult to use in fibre-fortified food products. Any future extruded product with high SDF will need to develop high consumer acceptability in the market, emphasising the mouthfeel and texture. In view of the nutritional and technological relevance of SDF, it can be modified with extrusion technology. Additionally, increasing the SDF fraction from orange pomace would widespread application in

* Corresponding author.
E-mail address: ylhuang@mail.nkmu.edu.tw (Y.-L. Huang).

http://dx.doi.org/10.1016/j.foodchem.2015.07.039
0308-8146/

various food systems, including bakery products, soups, and noodles. Nevertheless, optimum conditions for extruding DF from orange pomace have not been investigated. It is necessary to study further the potential physicochemical properties of rich-fibre orange pomace so that its potential functionality and applications in food and nutrition can be exploited. The objective of the present study was to determine, using response surface methodology (RSM), the most appropriate extrusion conditions for the extraction of SDF from orange pomace and its physicochemical properties.

2. Material and methods

2.1. Materials and chemicals

Liucheng sweet orange (*Citrus sinensis* L. cv. Liucheng) pomace was obtained from a local market (*Nan-Tzu*, Taiwan) on November 2013. All chemicals were purchased locally and were of analytical grade.

2.2. Sample preparation

The initial moisture content of fresh orange pomace was 26.3 ± 0.3 g/100 g. The pomace sample was dried in an air-oven at 50 °C for 48 h to obtain a moisture content of 4.74 ± 0.02 g/100 g. After dried sample was ground to a particle size of 0.5 mm, the resulting orange pomace powder was tightly packaged in a polyethylene bag prior to use.

2.3. Extrusion experiments

A single screw laboratory extruder (RC-003, Tsung Hsing Co. Ltd., Taiwan) was used. The barrel diameter and L/D ratio were 80 mm and 3:1, respectively. A die head with a diameter of 3 mm was used. The feed rate was constant at 24 kg/h. The parameters for extrusion were optimised using response surface methodology (RSM) with Box-Behnken design (BBD). The three independent variables included barrel temperature (X_1; 115, 125, 135 °C), feed moisture (X_2; 10, 14, 18 g/100 g dry basis), and screw speed (X_3; 230, 290, 350 rpm). A total of 15 experiments were designed based on the three replicates of the midpoint and each experiment was performed in triplicate (Table 1). Regression analysis was performed for the experiment data and the following equation was expressed by empirical second order polynomial model:

$$Y = \beta_0 + \sum_{i=1}^{3}\beta_i X_i + \sum_{i=1}^{3}\beta_{ii} X_i^2 + \sum_{i=1}^{2}\sum_{j=i+1}^{3}\beta_{ij} X_i X_j$$

where Y is the predicted response; β_0 is a constant; β_i is the linear coefficient; β_{ii} is the quadratic coefficient; β_{ij} is the interaction coefficient of variables i and j; and X_i and X_j are independent variables.

After extrusion, the extruded sample was kept in an electronic dry cabinet, and was analysed within 3 days.

2.4. Proximate analysis

Protein content was estimated by multiplying the nitrogen content determined by the Kjedahl method ($N \times 6.25$). Ash content was determined according to AOAC method 4.1.10 (AOAC, 1995). Fat content was determined gravimetrically after Soxhlet extraction of dried samples with petroleum ether. The moisture was determined by drying to a constant weight at 105 °C.

2.5. Separation of dietary fibre

Total dietary fibre (TDF), soluble dietary fibre (SDF), and insoluble dietary fibre (IDF) were determined by using an enzymatic–gravimetric method with the fibre assay kit (Megazyme K-TDFR, Wicklow, Ireland). In brief, one gram of sample suspended in Mes-Tris buffer was sequentially digested by heat stable α-amylase for 15 min in a boiling water bath, after which protease and amyloglucosidase were added and mixture held for 30 min at 60 °C. After filtration, the IDF was recovered from enzyme digestate, dried at 105 °C, and then weighed. SDF in the filtrate was precipitated with ethanol and filtered. The precipitate, referred to as SDF, was dried at 105 °C and weighed. IDF and SDF contents were corrected for residual protein and ash content. The TDF content was the sum of IDF and SDF.

2.6. Monosaccharide analysis

According to the method of Englyst, Quigley, and Hudson (1994), the neutral sugars of the dietary fibre were determined using allose as an internal standard. The dietary fibre were first hydrolysed with 12 M H_2SO_4 at 35 °C for 60 min and further boiled in 2 M H_2SO_4 for another 60 min. The released monosaccharides were quantified as alditol acetates using a gas chromatograph (Thermo FOCUS GC series, Milan, Italy) fitted with flame ionisation detector and a capillary column (Quardex 007-225; 15 m × 0.53 mm i.d.). Nitrogen was used as carrier gas with a flow rate of 2.0 mL/min. The temperature program was set as follows: The initial column temperature of 100 °C was held for 3 min, increased at 4 °C/min to 160 °C, and held for 5 min. Thereafter, the temperature was increased again at 3 °C/min to 220 °C and held for 1 min. Detector and injector temperatures were held at 280 °C and 270 °C, respectively.

Table 1
Box-Behnken design (in uncoded level of three variables) and experimental results for three-level-three-factor response surface analysis.

Number	Barrel temperature (X_1, °C)	Feed moisture (X_2, %)	Screw speed (X_3, rpm)	SDF (%)	IDF (%)	TDF (%)
1	135	10	290	26.61 ± 0.18	36.61 ± 0.16	63.23 ± 0.03
2	115	14	350	26.91 ± 0.30	36.47 ± 0.17	63.38 ± 0.12
3	115	10	290	24.11 ± 0.17	39.09 ± 0.23	63.20 ± 0.07
4	125	18	230	27.64 ± 0.25	35.39 ± 0.14	63.03 ± 0.11
5	125	18	350	28.20 ± 0.21	35.21 ± 0.14	63.41 ± 0.08
6	125	14	290	29.69 ± 0.33	33.72 ± 0.20	63.41 ± 0.13
7	125	14	290	29.92 ± 0.20	33.49 ± 0.10	63.41 ± 0.09
8	135	14	230	27.57 ± 0.23	35.69 ± 0.15	63.26 ± 0.08
9	115	14	230	26.05 ± 0.13	37.18 ± 0.24	63.24 ± 0.11
10	125	10	350	25.96 ± 0.30	37.47 ± 0.15	63.43 ± 0.15
11	115	18	290	27.31 ± 0.20	35.95 ± 0.10	63.26 ± 0.10
12	135	14	350	28.51 ± 0.35	34.95 ± 0.15	63.46 ± 0.20
13	125	10	230	23.32 ± 0.18	40.10 ± 0.07	63.42 ± 0.11
14	125	14	290	30.08 ± 0.27	33.52 ± 0.14	63.60 ± 0.13
15	135	18	290	28.91 ± 0.20	34.30 ± 0.11	63.21 ± 0.08

Values are the mean ± SD of triplicates.