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Characterization of Jerusalem artichoke (*Helianthus tuberosus* L.) powder and its application in emulsion-type sausage

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ABSTRACT

Physicochemical and functional properties of two types of Jerusalem artichoke powder (JAP), freeze-dried powder (FDP) and oven-dried powder (ODP), and their potential application in emulsion-type sausages were evaluated in this study. The total phenolic content of FDP was higher than that of ODP. Again, FDP exhibited higher water-holding capacity, emulsion activity, emulsion stability, oil-binding capacity and gel-forming capacity values compared to ODP. TG/DSC analysis of FDP and ODP showed both of them were thermally stable at 150 °C. As a substitute of corn starch, the addition of FDP or ODP could reduce cooking loss and expressible water, increased the moisture content, oxidative stability and enhanced the anti-microbial properties of the emulsion-type sausage. The addition of FDP (9%) and ODP (9%) to the emulsion-type sausage was promising comparable to additions of 3% and 6%. This could be attributed to the inulin contents in the JAP. Scanning electron microscopy also showed that the addition of FDP or ODP in sausage formation led to a difference in the sausages. This study indicated that JAP (FDP and ODP) improved the processing properties of the emulsion-type sausage.

1. Introduction

Jerusalem artichoke (JA), from the Asteraceae family, contains high amounts of inulin and phenolic compounds. As one type of fructooligosaccharide (Rodriguez Furlán, Padilla, & Campderrós, 2014), the inulin in JA is a prebiotic and a good source of low-calorie ingredient. It can increase faecal bulk, enhance bowel regularity and possesses characteristic properties comparable with other fibers. It also has the potential to influence gastrointestinal functions, which could be attributed to its bio-chemical and physiological properties (Roberfroid, 2005). In addition, inulin facilitates calcium, magnesium and potassium assimilation in the gastrointestinal tract (Coudray, Demigné, & Rayssiguier, 2003). The phenolic compounds in JA contain natural antioxidants such as polyacetylenic derivatives, sesquiterpenes and coumarins with antioxidant capacity, which can scavenge free radicals (Yuan, Gao, Xiao, Tan, & Du, 2012).

Jerusalem artichoke tuber has been used in the preparation of pickle, vegetable salads and soup (Kays & Nottingham, 2007). Besides, the tuber was successfully utilized as a folk medicine for the treatment of diabetes and rheumatism (Yuan et al., 2012). Also, Jerusalem artichoke powder (JAP) has a useful function in baking (Praznik, Cieślik, & Filipiak-Florkiewicz, 2002) and dairy products (Penksza et al., 2013). Inulin from JA was also applied to many processed foods including meat and meat products, confectionery products and therapeutic formulations (Rodriguez Furlán et al., 2014). Thus, adding JAP to sausages would supply the requisite quantities of inulin and natural antioxidants, known to prevent tissue damage and "oxidative stress" related diseases (Chen et al., 2013). It may extend the shelf-life of food products (Gedrovica & Karklina, 2013).

In this paper, the physicochemical properties of JAP and its application in emulsion-type sausage (hereinafter referred to as sausage) were studied. The physicochemical properties of the sausages with JAP and corn starch (CS) addition were compared and analyzed. Again, JAP as a substitute for CS in sausages was investigated.

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2. Materials and methods

2.1. Materials

Jerusalem artichoke tubers were purchased from a local market (Zhenjiang, China) during the winter season. The tubers were packaged and stored at 4 °C. CS, salt and purified water were purchased from the supermarket (Zhenjiang, China). The lean meat (pork rump) used for the emulsion-type sausage was trimmed of subcutaneous fat and connective tissues. The meat was stored in a refrigerator at 4 ± 1 °C for about 6–8 h and frozen at −18 °C until used. The rump used was obtained from a healthy adult boar pig slaughtered in accordance with the approved code of ethics for slaughtering animals in China.

2.1.1. JAP preparation

Jerusalem artichoke tubers were washed and sliced with a slicing instrument. One part of the sliced tubers were dried in an oven at 80 °C until they reached a constant weight. Another part of the sliced tubers were immediately freeze dried. The two types of dried samples were ground to a fine powder using laboratory grinder and were sieved through a 0.2 mm sieve to produce JAP (oven–dried powder "ODP" and freeze-dried powder "FDP") (Supplementary-material 1).

2.1.2. Physicochemical analysis of JAP

Moisture, protein and ash contents of the JAP (ODP and FDP) were determined according to the method of Ruiz-Cano et al. (2014). The total carbohydrate analysis was carried out using phenol–sulfuric acid method using glucose as a standard (Albalasmeh, Berhe, & Ghezzehei, 2013). The mineral composition of the powdered samples was determined according to Farıas, Arisnabarreta, Vodopivez, and Smichowski (2002). Inulin was extracted and assayed according to the method of Saengkanuk, Nuchadomrong, Jogloy, Patanothai, and Srijaranai (2011).

Microwave assisted soxhlet extraction (MASE) was employed to extract phenolics from the powdered samples. The extraction parameters such as microwave extraction time (12.31 min), temperature (71.54 °C), microwave power (11.18 W) and extraction solvent (ethanol, 60%) were chosen according to preliminary optimization studies. Briefly, 5 g of powdered-samples were placed in a 50 mL round-bottomed flask containing 25 mL of extraction solvent. After the MASE, the samples were centrifuged at 3500 rpm for 30 min. The supernatants were concentrated by a vacuum rotary-evaporator (35 °C). The total phenol content were determined as described by Lou, Wang, Wang, and Zhang (2009). The results were presented in grams gallic acid equivalent per kilogram dry weight.

2.1.3. Characterization of JAP

Gelation capacity of FDP and ODP was determined using the method of Adebowale, Henle, Schwarzenbolz, and Doert (2009). The least gelation concentration was examined as the concentration at which the sample in the inverted tube did not fall down. The method of Sridaran, Karim, and Bhat (2012) was used to determine the oil-binding capacity, water-holding capacity, emulsifying activity and emulsifying stability of the powders. Thermogravimetry (TG) and differential scanning calorimetry (DSC) analysis of the samples were carried out by Netzsch STA thermo analyzer.

2.1.4. Sausage preparation

Modified method of Feng, Xiong, and Mikel (2003) was used for the formulation of the sausage. Prior to the experiment, the lean meat and fat were stored at −18 °C. 500 g formulation was prepared for each treatment. Control formulation consisted of lean meat 249.5 g, fat 107 g, salt 7.5 g, ice 50 g, and water 86 g. The experimental group (FDP and ODP) and the positive control (CS) were formulated with different amount of FDP (3%, 6% and 9%), ODP (3%, 6% and 9%), and CS (3%, 6% and 9%). Lean meat, salt, ice, and water utilized were similar to the control, but the fat differs in quantity (92 g, 77 g, and 62 g). The powdered samples were added to replace an equal amount (15 g, 30 g, and 45 g) of fat. The mixture was minced at an emulsion temperature of 10 °C for 10 min. The raw emulsion was stuffed into a natural casing using a sausage stuffer. Then the sausages were tied manually into 10–13 cm long, which were weighed and cooked for 30 min.

2.1.5. Characterization of sausage

The moisture content of the sausages carried out with HB43-S halogen moisture-analyzer and the expressible water (EW), and emulsion stability were evaluated by the method of Das, Anjaneyulu, Verma, and Kondaiah (2008).

Cooking loss (CL) was measured by weighing the sausages before (N_O) and after cooking (N_x), then the total CL was calculated as follows:

$$CL = 100(1 - N_x/N_o) \quad (1)$$

The sausage color (CIELAB coordinates) was determined using Color Quest XE, Hunter lab (Reston, USA), with illuminant D65 and a 10° observe angle in the total transmission mode. The total color difference was determined using the formula $\Delta E = [\Delta L^2 + \Delta a^2 + \Delta b^2]^{1/2}$(Bozkurt & Bayram, 2006) where ΔL, Δa, and Δb are the differences between the respective color parameters of the control sample and the treatments with FDP and ODP or CS. The texture profile analysis was performed as described by Das et al. (2008). The texture profile parameters evaluated were hardness, gumminess, adhesiveness, and cohesiveness using TA. XT plus texture analyzer (Beijing, China) with 25 kg-loads and 25 mm-diameter probe.

The antioxidant activity of the sausages was conducted using Rancimat method as described by Viuda-Martos, Ruiz Navajas, Sánchez Zapata, Fernández-López, and Pérez-Álvarez (2010) using Metrohm Rancimat® 892 professional. Antioxidant activity index (AAI) > 1 was an indicator of lipid oxidation inhibition. AAI was calculated as follows:

$$AAI = \text{IT of each sample}/\text{IT of control sample at day 0} \quad (2)$$

Where IT = induction time.

The microbial count of the sausages was determined using the method described by Das et al. (2008) and the microstructure analysis of the samples were evaluated using physical fixation method as described by Stevenson, Liu, and Lanier (2012).

2.2. Statistical analysis

A one-way ANOVA was performed on the characterization of JAP using the OriginPro version 9.0 (Northampton, USA), and the significance was determined using the Tukey test at $P < 0.05$. The results were expressed as mean and standard error. Principal component analysis (PCA) of the textural properties of the sausages was performed using Statistica-version 10.0 (Tulsa, USA). Linear-Mixed-Model analysis was conducted on the physicochemical characteristics of the sausages using SPSS version 13.0 (Chicago, USA).