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Physicochemical assessment of two fruit by-products as functional ingredients: Apple and orange pomace

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ABSTRACT

The purpose of this study was to evaluate the properties of two fruit by-products (apple pomace from the Cv. "Karmijn de Sonnaville" and orange pomace from the Cv. "Valencia") as potential ingredients. The analysis comprised: microstructure, composition, physicochemical properties, pectin quantity and gelling properties of the two materials.

Studying both orange pomace and apple pomace highlighted the different aspects of the two materials orange pomace was mainly fibrous ingredient with applications suited to products requiring improved water/oil holding and binding properties ie. a high water hydration capacity (4.40 ml/g). It had a favourable nutritional composition: high dietary fibre (40.47%), low fat (2.14%) and a high mineral content. In comparison, apple pomace showed visco-elastic properties that could enhance structures within products. Oscillatory rheology illustrated pastes from apple pomace had a high storage modulus (G'). Due to its pectin and starch content, apple pomace flour formed viscous pastes and visco-elastic structures. This study illustrates the importance of comprehending individual components (physicochemical and nutritional) of ingredients to fully utilise their activity in a food system.

1. Introduction

Due to the manner in which fruit and vegetables are processed, a significant amount is traditionally discarded. This discarded material is usually referred to as a "by-product" or "waste". This consists of the core, peel, pips and kernel of the fruit/vegetable being processed. At present, processors may either donate these by-products to farmers for animal food or dispose of them in land fill or by incineration, at a cost to themselves. Apple and orange pomaces (AP, OP) are two examples of by-products remaining after processing (O'Shea et al., 2012).

Post apple juice pressing, the remaining waste can represent up to 25% of the apple fresh weight (Rha et al., 2010). Juices processed from citrus fruits create citrus waste which can constitute up to 45–60% of the fruit (Fernandez-Lopez et al., 2009). Although considered to be waste products, these materials still contain an abundance of unexploited nutrients and bio-actives (Wijngaard et al., 2009).

The by-products usually represent the total fruit or vegetable residue post pressing. These can be described as cell wall materials, which consist of fibrous substances (cellulose, hemicelluloses and water soluble pectin). These fibrous substances have good functional properties e.g. water holding, binding and gelling abilities (Vetter et al., 2001). Therefore, this would suggest that as well as having good nutritional properties they may also have potential in food formulations.

Other than their functionality and nutrition, by-products from fruit and citrus processing also have the advantage of being gluten and lactose free, making them potentially ideal ingredients for a range of products e.g. bakery products, jams, drinks and confectionary. Today, it is a common trend for consumers to seek products which contain natural ingredients.

Previous authors have reported on the quantity and phytochemical properties of fibre found in OP and AP (Figuerola et al., 2005; Gorinstein et al., 2001; Grigelmo-Miguel and Martín-Belloso, 1999; Martí et al., 2010)). Much research has been carried out to study the bioactive (e.g. phytochemical content) and composition (mostly fibre) of AP and OP (Chau and Huang, 2003; Topuz

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et al., 2005; Wolfe and Liu, 2003). The functionality and nutritional properties of these fruit flours can vary depending on their cultivar.

This study builds on the existing knowledge of the nutritional properties of fruit pomace. It highlights the need to comprehend both the nutritional and functional characteristics of a fruit by-product prior to inclusion into a food product.

In the present study, apple (Malus domestica Cv. "Karmijn de Sonnaville") and orange (Citrus sinensis L. Cv. "Valencia") pomaces were obtained from the Irish beverage industry.

The objectives of the study were:

- To determine the composition, functional properties and microstructure of the pomaces.
- To investigate their rheological and gelling characteristics, as potential novel food ingredients.

2. Materials and methods

2.1. Apple & orange pomace preparation

AP (The Apple Farm, Co. Tipperary, Ireland) consisted of the peel, pulp and seeds, which remained after juicing. OP (Wild Orchard Drinks, Co. Limerick, Ireland) consisted of the peel and pulp remaining after juicing. The juicing process involves pressing the entire fruit in a cold press to extract the juice from the fruit; the remaining waste is described as the pomace. Both pomaces were received in a wet condition shortly after juicing. To eliminate fermentation, the pomaces were freeze-dried immediately, milled to a flour of particle size <355 μm and stored at −20 °C until required for analysis.

2.2. Microstructure

2.2.1. Light microscopy of iodine stained samples

Pomace (0.5 grams) was sprinkled onto a microscope slide and one drop (50 μl) of 1% w/v iodine in 2% potassium iodine solution (aq) added with a coverslip placed on top. Starch appears as blue/black particles. To stain polysaccharide/protein, samples were also stained with toluidine blue which is a metachromatic dye staining polysaccharides pink/purple and protein blue (OlgaáFlint, 1990). The slides were examined using an Olympus BX51 light microscope (Mason Technology, Dublin) fitted with 10× or 20× objectives using either bright field or polarised light with slightly uncrossed polars to highlight birefringent material. Digital colour images (8 bit, TIFF format) were acquired.

2.2.2. Scanning electron microscopy

Pomace samples were sprinkled onto a carbon adhesive coated stub and sputter coated with chromium. Samples were examined in a Zeiss Supra 40 VP field emission electron microscope (Carl Zeiss, Cambridge, UK) operating at 2 kV. Digital 8-bit TIF images were acquired at a range of magnifications from 250× to 5000×.

2.3. Chemical composition

Moisture content of the flours was analysed using a Brabender moisture oven as described by Ktenioudaki et al. (2012). Due to the hygroscopic nature of the flours, moisture analysis was carried out at the start of the testing period and at the end of the testing period. Between testing the flours were vacuum-packed (to remove the air) and stored at −20 °C.

Fat was assessed via acid hydrolysis as described by Alvarez-Jubete et al. (2009). Samples (2 g) were mixed with ethanol (2 ml) and hydrocholoric acid (10 ml; 8.3 M), placed in a water bath overnight at 80 °C. The fat in the samples were extracted three times with the addition of three equal amounts of petroleum ether and ethyl ether. Solvents were evaporated over a water bath under a fume hood. Fat was determined gravimetrically.

Protein was determined based on the method described by Alvarez-Jubete et al. (2009). The combustion method based on the Dumas principle using a nitrogen analyser was utilised (FP-328 Leco Instrument; Leco Corporation, St Joseph, Michigan, USA). Blank and the standard compound ethylenediamine tetraacetic acid samples (9.57% N) were run prior to the samples. Combustion of the samples took place in a sealed furnace at 1,150 °C. The nitrogen to protein conversion factor used was 5.70 for the fruit flours.

Ash was measured in accordance with the AOAC method 923.03 (AOAC, 2000).

The content of carbohydrate was calculated based on difference (100 – moisture – fat – protein – ash) (Hager et al., 2012).

Mineral content was measured by atomic absorption spectrometry on previously ashed samples. The method described by Alvarez-Jubete et al. (2009) was used (calcium, potassium, magnesium, zinc and iron results were obtained).

Total starch content was analysed using the Megazyme Assay procedure (K-TSTA; Megazyme, Bray, Ireland) based on the AACC 76.13 and AOAC 996.11 methods.

Total fibre was determined according to the AOAC method 985.29 (AOAC, 1990).

Total sugars were measured by using a diagnostic kit (sucrose/D-Glucose/D-Fructose kit) by Rhône Diagnostic Technologies Ltd, (R-Biopharm AG, An der neuen Bergstraße 17, 64,297 Darmstadt, Germany). The following sugars were tested to give total sugar: fructose, glucose and sucrose.

2.4. Hydration properties

The water hydration characteristics (including water holding capacity, water binding capacity and swelling capacity) and oil absorption capacity were analysed based on the methods developed by Ktenioudaki et al. (2013). Water holding capacity was determined by mixing flour (5 g) with water (50 ml) and allowed to hydrate overnight. 24 h later, excess water was removed. The water holding capacity was determined as the weight of water retained divided by the weight of the flour. Water binding capacity was measured following the AACC 56–30 method (AACC, 1999). Swelling capacity was measured by mixing flour (2.5 g) with water (50 ml) and left overnight. Finally the swelling volume was measured by the volume occupied by the flour. Oil holding capacity was measured as follows; a flour sample (2.5 g) was mixed with vegetable oil (6 ml). The mixture was allowed to rest at room temperature (30 min) before it was centrifuged (15 min at 3000 rpm). The supernatant was carefully decanted and the weight of oil retained by the flour was measured.

2.5. Pectin

2.5.1. Pectin extraction

The pomace flours were extracted with hydrochloric acid (0.1 M) at a ratio of 1:15 w/v. Extraction occurred in an incubator shaker (KS 4000 i control, IKA-Werke GmbH & Co. KG, Germany) (150 rpm). To produce the largest yield while still retaining pectin functionality, extractions were carried out at 3 and 7 h. Following this, the extracts were filtered through a muslin bag to remove insoluble material. The supernatant was neutralised with sodium hydroxide (10 M) and then centrifuged (Sigma 6K10, Sigma Laborzentrifugen GmbH, Germany) at ambient temperature (10 min; 9000 (gravitational acceleration (g))). It was then blast frozen, freeze-dried and stored (−20 °C).

Purification of the pectin (derived from the pomace flours) was carried out by ethanol (98%) precipitation. Briefly, pectin was