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Physicochemical characteristics of sauce model systems: Influence of particle size and extruded flour source

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ABSTRACT

Physically modified extruded flours are suitable ingredients for cold preparation of products such as creams and sauces. The rheological and textural properties and stability of model sauces prepared with wheat and rice extruded flours with three different particle size fractions were assessed. All tested sauces showed non-Newtonian, shear-thinning and thixotropic fluid characteristics. Sauces made with rice extruded flours, with lower protein and amylose contents, presented lower shear-thinning behaviour, consistency index and yield stress than wheat based sauces. Rice sauces also displayed a less compact microstructure and lower viscoelastic character but a higher resistance to freeze-thaw process. Regarding particle size, the finest flours showed lower values of consistency index, yield stress, and G′ and G″ moduli but led to higher syneresis. Overall, results proved that pregelatinised extruded flours can be used in sauces applications without heating, but their properties greatly depend on the cereal type and its particle size.

1. Introduction

Sauces are a product of high added value and represent an important part of the human diet. Essentially, the formulation of sauces includes three main ingredients: water (or milk), starch (or flour) and oil. Among the different ingredients, starch plays a key role in the rheological and textural properties obtained. Therefore, in recent years, different studies have been focused on investigating the influence of the starch type in the microstructure and rheological properties of sauces (Arocas et al., 2009a, c), the sensorial properties (Arocas et al., 2010b), or even, in their interaction with hydrocolloids (Arocas et al., 2009b), proteins (Guardeño et al., 2012; Quiles et al., 2012) and other ingredients (Arocas et al., 2010a). Furthermore, during the last decade, the hectic lifestyle that people in western countries generally has led to a growing interest in convenience foods or foods that are quick and easy to prepare. These prepared products are frequently accompanied by sauces, in which starch plays an important functionality.

In terms of preparation, sauces need to be cooked to develop their viscous properties, based on the gelatinization of starch granules. To ease the preparation and remove or reduce this heating stage, pregelatinised starches and flours can be used. Hydrothermal treatments such as extrusion or drum-drying foster the gelatinization of the starch when this is subjected to enough heat and moisture, enabling the attainment of products with higher water absorption capacity and thickening power in cold temperatures (Chiu and Solarek, 2009; Doublier et al., 1986; Hagenimana et al., 2006; Martínez et al., 2014b). Therefore, pregelatinised flours represent an alternative to starchy products allowing the preparation of sauces with no need for heating. Drum-drying treated flours have higher viscosities and less starch solubilisation than extruded flours (Doublier et al., 1986). However, extrusion is a very versatile and relatively low cost process, with less environmental impact and less space requirements than drum-drying, in such a way that this technique is being widely used in the food industry. Added to starch gelatinization, a denaturation of proteins (Camire et al., 1990) and the formation of amylose-lipid complexes (Hagenimana et al., 2006) is also promoted, which will affect the rheological properties of the pastes. Furthermore, the particle size and the type of cereal used can also influence the properties of the extruded flours (Martínez et al., 2014a, b). In those works it was demonstrated that as extrusion intensity increased (i.e. barrel temperature and moisture content), higher gelatinization of starch was produced, but a minimum barrel temperature and feed moisture content were necessary to break the starch structure and induce gelatinization phenomena. When those processing

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requirements were met, an important increase in cold water absorption capacity and swelling power of the flours was found, being those values generally higher when using coarser flours (132–200 μm). In fact, due to this ability to absorb water at low temperatures, pregelatinised extruded flours have been used to improve the hydration in bread doughs (Martínez et al., 2013), as well as fat replacements in mayonnaises (Román et al., 2015a) and cakes (Román et al., 2015b).

The rheological behaviour of emulsions, such as sauces, is a critical characteristic that must be studied as it is closely related to the sensory attributes, quality, and processing properties of a food product (McClements, 2005). Most importantly, it provides fundamental insights into the structural organization and interaction between the components within the emulsion (McClements, 2005). Moreover, the stability towards freezing is also an important aspect to consider since many convenience foods containing sauces are preserved this way so as to extend their shelf life. In general, these sauce properties have been studied on different native or modified starches. Nevertheless, to the best of our knowledge, there are no studies based on the use of pregelatinised extruded flours for sauce development.

The objective of this study was to assess the effect of extruded flours of different particle sizes on the rheological characteristics and stability towards freezing of model sauces with no need for heating. To achieve this aim, two types of extruded flours were selected, wheat flour, as it is the most commonly used cereal in developed countries, and rice flour, the most commonly used gluten-free flour.

2. Materials and methods

2.1. Materials

The extruded rice and wheat flours used in this study commercially available as Ooc 190 and Toc 190, respectively, were provided by Molendum Ingredients (Zamora, Spain). The extrusion conditions were chosen according to the manufacturer expertise in order to ensure starch gelatinization, and DSC analyses of the flours were carried out to confirm that gelatinization was complete. In this way, when flour samples were analysed, a flat DSC curve with no endothermic peak in the range of starch gelatinization was observed, indicating that gelatinization was complete. The extrusion treatment was carried out in a single screw extruder Bühler Basf (Bühler S.A., Uzwil, Switzerland). The diameter of the extruder was 140 mm, the length to diameter (L/D) ratio of the extruder was 20:1 and the screw speed was 340 rpm. The diameter of the die hole and the number of holes used was 8 mm and 18 holes, respectively. The flours were extruded at a maximum barrel temperature of 160 °C, a feed rate of 500 kg/h and a feed moisture content of 25%. The extruded products were dried by convection air until reaching 10% moisture and then ground with a compression roller (Bühler S.A., Uzwil, Switzerland) to a particle size below 200 μm. Each of the flours were sieved and separated into three fractions according to the amount of particles remaining on each sieve. The different particle sizes obtained were as follows: fine (less than 80 μm), intermediate (80–130 μm) and coarse (130–200 μm). The sieving process was performed with an Automatic Bühler MLI300B Sieve (Braunschweig, Germany) for 15 min. Each of the fractions was stored separately in sealed plastic bags until their analysis and use. Particle size of the flours was measured in duplicate with a laser diffraction particle size analyser (Mastersizer 3000, Malvern Instruments, Ltd., Worcestershire, UK) equipped with an Aero S unit. The mean diameter of equivalent volume D (4,3), which indicates the central point of the volume distribution of the particles, was recorded. For wheat extruded flours, D (4,3) values were 72.4 μm, 146.0 μm and 279.5 μm for fine, intermediate and coarse fractions, respectively. D (4,3) values of rice flours were 78.5 μm, 151.0 μm and 213.5 μm for fine, intermediate and coarse fractions, respectively.

2.2. Methods

2.2.1. Flour characterisation

The characterisation of the extruded flours was carried out before the preparation of the sauces. Flours were analysed following AACC Methods (AACC, 2012) for moisture, method 44–16.01 and protein method 46–30.01 with a Leco TruSpec device (Leco, St. Joseph, MI, USA). Amylose-amylopectin content was measured using Concanavalin A precipitation method (K-AMYL, Megazyme International, Wicklow, Ireland). Determinations were carried out in duplicate.

Water binding capacity (WBC) defined as the amount of water retained by the flour after it has been subjected to centrifugation was measured as described by method 56.30 (AACC, 2012). After centrifugation, the supernatant was decanted into an evaporating dish and the residue of the eppendorf tube was weighed (Wr). The weight of dry solids in the supernatant was recovered by evaporating the supernatant at 105 °C till constant weight. Water solubility index (WSI) was calculated as the amount of dry solids recovered in the supernatants divided by the initial sample weight in percentage (g/100 g). Determinations were carried out in triplicate.

Pasting properties of flours were analysed using the standard method (AACC, 2012), (AACC 61–02.01) with a Rapid Visco Analyser (RVA-4) (Newport Scientific Pty Ltd., Warriewood, Australia) controlled by Thermocline software (Newport Scientific Pty. Limited, Warriewood, Australia) for Windows. All flours were run in duplicate.

2.2.2. Sauces preparation

Model sauces were prepared using flour (16.78%), sunflower oil (2.68%) and water up to 100%. It is noteworthy than extruded flours have less thickening power than the native ones after cooking (Martínez et al., 2014a, b), so it has been necessary to increase the flour content of the sauces to obtain a texture similar to conventional sauces. All the ingredients were placed in a food processor (Thermomix TM31, Wuppertal, Germany), and mixed at 1100 rpm and 30 °C for 10 min. The resulting sauces were placed in glass beakers, covered with plastic film. Two sauces were prepared for each of the particle sizes of the two flours studied. In order to be able to study freshly prepared sauces, measurements were performed within the same day.

2.2.3. Sauces characterisation

2.2.3.1. Optical microscope observation. Sauces were examined with a DM750 microscope (Leica Microsystems, Wetzlar, Germany) with 20× times magnification, fitted with an EC3 video camera. Images were captured with LAS-EZ software (Leica Microsystems, Wetzlar, Germany). First of all, the sample was placed on a glass microscope slide and covered with a cover slip. The slides were compressed under a 1 kg weight for 2 min to create a sample layer of uniform thickness. Micrographs were performed on the freshly prepared sauces at least twice in two random points of each sample.

2.2.3.2. Rheological analysis. Rheological properties of sauces were determined with a Thermo Scientific Haake RheoStress1 rheometer (Thermo Fisher Scientific, Schwerte, Germany) and a Phoenix II P1-C25P unit to control the temperature, which was fixed at 30 °C for all analyses. All tests were monitored with RheoWin 4 Job Manager