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Effect of bioprocessing and fractionation on the structural, textural and sensory properties of gluten-free faba bean pasta

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ABSTRACT

This work evaluated the effects of processing faba bean flour on textural, structural and sensory properties of gluten-free pasta. Pasta was prepared using faba bean flour, starch-rich fraction of faba bean flour or faba bean flour fermented with lactic acid bacteria. The impact of cross-linking enzyme transglutaminase (TG) on the quality of faba pasta was also studied. The structure, cooking quality, starch digestibility, textural and sensory characteristics of faba pasta samples were evaluated and compared to semolina pasta. Pasta prepared with faba bean and fermented faba bean flours had higher cooking loss (10.8–11.5%) and lower water absorption (130–160%) than semolina pasta (6 and 193%), but pasta prepared from fractionated faba flour had similar water absorption to semolina pasta. The texture of pasta made with faba bean flour was comparable to that of semolina pasta. Fermentation adversely affected the texture by increasing hardness, chewiness, sourness and flavour intensity. Starch hydrolysis index of pasta prepared with the three faba bean flours was similar to semolina pasta (46–50). TG reduced the *in vitro* starch hydrolysis index and increased some textural parameters of pasta made with faba bean flour, but no influence was observed on pasta made with fractionated or fermented faba.

1. Introduction

Pulses such as peas, chickpeas and faba beans are good sources of proteins, dietary fibre and bioactive compounds. There is evidence that the consumption of pulses is linked to many health benefits, including reduced risk of diabetes, cardiovascular disease and certain cancers (Campos-Vega, Loarca-Piña, & Oomah, 2010). Pulses have high protein content (20–36%) that is about twice of the content of cereals, making pulses a good substitute for meat and a potential protein-rich ingredient. Faba bean is rich in favourable proteins (about 30% of lysine-rich proteins), vitamins, minerals and dietary fibre but also bioactive compounds, such as phenols and γ-aminobutyric acid (Jezierny, Mosenthin, & Bauer, 2010). Currently faba bean is mainly used for feed. During the past decades there have been a few studies where faba bean was used for fortification of protein content in food products such as bread, biscuit and pasta (Abdel-Kader, 2000; Giménez et al., 2012; Petitot, Barron, Morel, & Micard, 2010; Rababah, 2006).

One of the main limiting factors for using faba bean in food is its anti-nutritional compounds, such as condensed tannins and pyrimidine glycosides called vicine and convicine (Jamalian, 1999). In order to reduce the content of anti-nutritional factors, several methods have been applied in faba beans such as dehulling, soaking, cooking, microwave and autoclaving (Luo & Xie, 2013). Recently, the potential of air classification and lactic acid bacteria fermentation to produce valuable faba bean ingredients has been reported (Coda et al., 2015). Fermentation decreased anti-nutritional compounds, increased the amount of free essential amino acids, improved the *in vitro* protein digestibility and lowered the starch hydrolysis index (Coda et al., 2015). Air classification was successfully applied to faba bean flour for efficient separation of protein and starch rich fractions (Gunawardena, Zijlstra, & Beltranena, 2010). Moreover, starch rich fraction presented lower amount of anti-nutritional compounds, such as vicine, convicine, phytic acid and condensed tannins (Coda et al., 2015).

Besides its excellent nutritional profile, faba bean is gluten-free and could thus be utilized for both gluten sensitive and celiac

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patients. In the manufacture of gluten-free pasta, faba bean has been used for fortification (10–30% w/w) of gluten-free flours (corn and amaranthus) (Chillo, Laverse, Falcone, & Del Nobile, 2008; Giménez et al., 2013). Pasta prepared only from non-gluten flours is generally considered to have an inferior quality than semolina pasta due to the lack of gluten functionality, which is responsible for structure formation, elasticity and *al dente* texture. Some suggested strategies to mimic gluten network in pasta are use of crosslinking enzymes, additives and texturing agents (hydrocolloids and emulsifiers) as well as pre-gelatinization of starch (Marti & Pagani, 2013). Transglutaminase (TG: glutaminylpeptide:amine γ-glutamyltransferase) catalyses an acyl transfer reaction between the γ-carboxyamide group of a protein-bound glutamine residue and a primary amine or the amino group of a protein-bound lysine side chain to form covalent cross-links of ε-(γ-Gln)-Lys bonds (Folk & Finlayson, 1977). The intermolecular crosslinks introduced by TG change the protein structure and could improve the textural properties of gluten-free pasta by entrapping starch in the protein network induced by TG. The effect of TG has been studied only for gluten-free noodles (rice or corn) (Kim, Kee, Lee, & Yoo, 2014; Yalcin & Basman, 2008).

The objective of this work was to evaluate the effects of processed faba bean flour on the mechanical, structural and sensory properties of gluten-free pasta. Faba bean flour was either fractionated by air classification or fermented by lactic acid bacteria. The faba bean fractions obtained were used as the sole ingredient for manufacturing gluten-free pasta. Due to the lack of gluten network, a cross-linking enzyme transglutaminase was also added to the faba bean fractions in order to evaluate its effect on the structure and texture of gluten-free faba bean pasta. To the best of our knowledge, this is the first study reporting the use of faba bean ingredients as the sole ingredient for gluten-free pasta.

2. Material and methods

2.1. Fractionation and fermentation of faba bean flours

Faba beans (cv. Kontu, cultivated in Finland in 2011, provided by University of Helsinki, Department of Agricultural Sciences) were stone milled, dehulled and ground into flour (Faba) for further air classification or fermentation as described in Coda et al. (2015). For air classification, ground faba bean flour was separated into protein and starch rich fractions (Starch-Faba). Fermentation of ground faba bean flour (Ferm-Faba) was carried out with the selected lactic acid bacteria (30 °C, 48 h) mixed with water in a ratio of 50:50 (wt:vol) and then freeze dried and milled (Coda et al., 2015). Three materials were used in this study for manufacturing pasta: faba bean flour (Faba), starch-rich fraction (Starch-Faba) and fermented faba bean flour (Ferm-Faba). The mean particle size (D_{50}) of Faba, Starch-Faba and Ferm-Faba flours was 17.6 ± 1, 23.8 ± 0.2 and 63.7 ± 2.8 μm, respectively (Coda et al., 2015). The chemical composition of raw materials was reported in Coda et al. (2015).

2.2. Pasta production

All pasta samples were manufactured in the National Technological Platform of JRU IATE (Montpellier, France) on a lab-scale pasta discontinuous extruder (Sercom, Montpellier, France) according to Petitot, Boyer, Minier, and Micard (2010). Durum wheat semolina was hydrated with distilled water to 470 g/kg (db) moisture content and mixed for 5 min at 120 rpm then 15 min at 60 rpm. The product was extruded (20 rpm, 40 °C) and dried (55 °C) in a pilot-scale drier (AFREM, Lyon, France). During the drying, the relative humidity gradually reduced from 88 to 70% RH for 15 h in order to reach 12% of moisture in the final product. The three faba bean materials (Faba, Starch-Faba and Ferm-Faba) were processed as described for semolina with some modifications. Hydration was reduced to 400, 380 and 310 g/kg (db), respectively, mixing time was reduced to 10 min and mixing speed increased to 120 rpm. The hydration level was modified based on preliminary evaluation of hydration properties of the flours in a farinograph (Petitot and Boyer et al., 2010) and the mixing speed was increased to 120 rpm for pasta made with faba bean flours in order to limit the formation of particle aggregates. Transglutaminase (TG) enzyme Activa WM (Ajinomoto, Mesnil-Saint-Nicaise, France) was also added in faba flours for preparing pasta. In this case, the enzyme powder was mixed to the faba flours (20 nkat/g flour dm) during 10 min (120 rpm) before the hydration step. The pasta samples with TG were named as Faba-TG, Starch-Faba-TG and Ferm-Faba-TG and produced as described above for faba bean flours without TG. The dosage of TG was chosen based on preliminary screening trials with faba bean flour and evaluated by the intensity of protein cross-linking on SDS-page (data not shown).

2.3. Chemical characterization

Moisture and total protein concentration were analysed according to the methods 44-15.02 (AACC-International, 2013) and 46-11A (AACC, 2003), respectively. Total and resistant starches were analysed using Megazyme kits (K-TSTA 09/14 and K-RSTAR 09/14) according to the AACC methods 76-13.01 and 32-40.01, respectively. Ash content was determined with gravimetric method using Naber N11 ash oven (Nabertherm, Lilienthal, Germany). Fat was determined using Soxhlet extractor Büchi B-811 (Labortechnik AG, Flawil, Switzerland). Total dietary fibre was analysed with the enzymatic-gravimetric method 985.29 (AOAC, 1990). Chemical composition was performed in uncooked pasta. Protein and starches analysis were also performed in pasta samples after cooking.

2.4. Colour

Colour of dry spaghetti was determined by a Minolta Chroma Meter CR-200 (Konica Minolta Inc., Tokyo, Japan) using the Hunter L*, a*, b*. Three measurements were taken for each replicate (n = 9).

2.5. Cooking properties

2.5.1. Optimal cooking time (OCT)

Dried spaghetti (10 cm long) was cooked in distilled water (10 g/250 ml) and OCT was indicated when the white core of the pasta disappeared when squeezed between two glass plates.

2.5.2. Cooking loss

Cooking loss was determined by weighing the residue (cooking water) after drying in an oven at 105 °C for 2 h (Sozer, Dalgiç, & Kaya, 2007).

2.5.3. Water absorption

Cooked samples were weighed soon after removing the excess water and dried in an oven at 105 °C for 2 h (Sozer et al., 2007).

2.6. Starch hydrolysis index

Pasta samples were cooked until their OCT, rinsed and minced (Kenwood, Havant, United Kingdom). *In vitro* starch digestibility was performed as described by Germaine et al. (2008). Portions of the minced pasta containing 1 g of starch were weighted in 0.05 mol/L sodium potassium phosphate buffer (pH 6.9), placed in water bath (37 °C) and pancreatic amylase (110 U) was added to the