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Technological, nutritional and functional properties of wheat bread enriched with lentil or carob flours

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Blending wheat flour with carob seed or green lentil flour at 5–6%, 10–12% or 24% level modified the dough's technological properties and bread characteristics. Carob seed flours increased dough tenacity while reducing extensibility, whereas lentil flour reduced dough tenacity, extensibility and strength. Carob seed flours increased water absorption up to about 40%. Flours from all legumes increased dough development time (carob flours more than lentils flour). Lentil flour strongly decreased the stability due to weakening of the gluten network. In a baking test, however, all blends gave acceptable loaves. Blending the wheat flour with 5–6% legume flour generally did not alter the loaf volume. However, increasing the legume flour to 10–12% or 24% reduced the loaf volume, except when supplemented with refined carob seed flour at 10%, which increased it. Carob flour and especially lentil flour enriched bread with lysine-rich proteins, dietary fibre, phenolic compounds and lignans and in general increased its antioxidant power.

The nutritional value of lentils and the technological properties of carob are useful in increasing nutritional and functional value of wheat bread.

1. Introduction

Wheat bread is a popular food worldwide. It is a source of calories and of complex carbohydrates (Gomez, Oliete, Rosell, Pando, & Fernandez, 2008). However, its proteins contain low levels of essential amino acids such as lysine and threonine. In addition, the use of refined white flour reduces the nutritional density and fibre content of white bread, compared to wholemeal bread (Dewettinck et al., 2008).

The enrichment of wheat flour with legume flours is an effective means to improve the nutritional quality of cereal-based foods: it is well known that the legumes' amino acidic composition is complementary to the one of cereals (Boye, Zare, & Pletch, 2010), and they are also rich in bioactive compounds such as fibres and phytochemicals (Asif, Rooney, Ali, & Riaz, 2013).

This study focused on two legumes grown in Italy, i.e. lentils and carob, which were chosen for their low level of antinutritional factors and for their mild taste. Lentils (*Lens culinaris* Medik.) are commonly consumed worldwide, particularly in the Mediterranean area. They are known to induce short-term satiety and a low glycaemic response and to be of help in body weight maintenance, due to the presence of β-glucans (Kim, Behall, Vinyard, & Conway, 2006). Lentils also contain phytochemicals such phenolic acids, flavanols, flavonols, saponins, phytic acid and condensed tannins (Faris, Takruri, & Issa, 2012) and present antioxidant properties (Durazzo, Turfani, Azzini, Maiani, & Carcea, 2013). Carob is the fruit of the carob tree (*Ceratonia siliqua* L.), an evergreen tree which grows both spontaneously and cultivated throughout the Mediterranean region. It is consumed as it is or in various foods, beverages and confectionery. Different flours can be prepared from the different parts of the carob pod (pulp and seeds). Carob seeds are rich in polyphenols, fibre, and they show antioxidant action (Durazzo et al., 2014).

The objectives of this study were to formulate, develop and characterize functional bread from wheat flour enriched with lentil or carob flours. The addition of legume flour changes the technological properties of wheat flour, therefore the baking properties of a number of blends of wheat flour with lentil or carob flour were studied and the product characteristics were evaluated, together with their nutritional quality, with particular regard to the polyphenol and lignan content and antioxidant power. We are not aware of such a nutritional characterization of lentil-wheat and

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lentil-carob flours bread being published before.

2. Materials and methods

2.1. Samples

Commercial wheat flour ("0" type according to the Italian flour classification, Horeca brand) and commercial green lentils (Agricola Orve brand) were purchased from the market. Lentils were ground in a refrigerated laboratory mill (Janke and Kunkec Ika Labortechnik, Germany) to produce a wholegrain flour. Three different carob flours were purchased from an Italian producer (Barbagallo s.r.l., Catania, Italy): a raw carob seed flour (RCF) obtained by grinding degermed, non decorticated carob seeds; a refined carob seed flour (CF) obtained from the decortication and calibrated grinding of degermed carob seeds (rich in galactomannans); a flour obtained by grinding carob seed germs (GCF). The commercial wheat flour had moisture content 12.8%, ash 0.63% d.m., total protein 10.5% d.m., fat 0,8% d.m., total dietary fibre 3,2% of which 1,1% soluble and 2,1% insoluble.

2.2. Chemicals and standards

The solvents used (diethyl ether, ethyl acetate, n-hexane, acetone, methanol) were of HPLC or analytical grade and were purchased from Carlo Erba (Milan, Italy). Reagents were of the highest available purity.Hydrochloric acid 35%, glacial acetic acid, sulphuric acid 96%, tartaric acid, boric acid, sodium hydroxide, sodium hydroxide 32% solution, tris(hydroxymethyl)amminomethane (TRIS), Folin-Ciocalteu reagent, sodium carbonate 20% solution, Iron (II) sulphate $FeSO_4 \cdot 7H_2O$ (99%) and Iron Chloride (97–102%) were purchased from Carlo Erba. Kjieltabs ($CuSO_4$/K_2SO_4), sulphuric acid solution 0.1 N and hydrogen peroxide 30% from VWR International PBI (Milan, Italy). Sodium Acetate trihydrate (99%), MES (2(N-morpholino)-ethanesulpohonic acid), Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), TPTZ (2,4,6-Tris(2-pyridyl)-s-triazine) and Helix Pomatia μ-glucuronidase/sulphatase S9626–10KU Type H-1, 0.7 G solid, 14200 units/G solid were purchased from Sigma-Aldrich (Milan, Italy). Standards were of the highest available grade: gallic acid monohydrate was purchased from Sigma-Aldrich, whereas isolariciresinol, secoisolariciresinol, lariciresinol and pinoresinol were from Chemical Research (Rome, Italy). Ultra-pure water was produced by using in sequence a Millipore Elix 5 system and a Millipore Synergy 185 system (Millipore, France).

2.3. Proximate composition

Moisture, proteins (conversion factor 6.25 for legume flours and 5.70 for wheat flour), lipids and ash were determined by standard methods 110/1, 105/2, 136, 104/1 respectively (ICC, 2003). Soluble (SDF), insoluble (IDF) and total (TDF) dietary fibres were determined according to Lee, Prosky, and DeVries (1992), using a reagent kit (K-TDFR, Megazyme Int., Wicklow, Ireland).

2.4. Baking test

Nine blends were prepared by mixing wheat flour with lentil or carob flours as shown in Table 1. Preliminary tests were carried out to determine the proportions needed, in particular the maximum amount of legume flour that could be added to avoid technical problems such as the dough sticking. The wheat flour on its own was used as control.

The bread formulation was intentionally kept simple to study the flour's behaviour without additives. Loaves of bread were produced by adapting the standard method No. 131 (ICC, 2003) as follows: solution 1 was not used (thus reducing sugar and eliminating ascorbic acid from the ingredients); the dough was mixed for 10 min in a planetary bread mixer (mod. Quick 20 by Sottoriva, Marano, Italy). The bread volume was determined by the rapeseed displacement method (AACC Method 10–05.01; AACC International, 2009). Blends containing a same flour at different percentages were baked in the same day, together with a wheat control. A panel of five laboratory technicians evaluated colour, crumb texture and taste on a qualitative basis, by comparing samples with the control and with each other. Each loaf was tasted pairwise with the control, providing the panellists with small slices of bread containing both crust and crumb. Perception of legume flavour was evaluated on a three-level scale (not perceivable, perceivable, strong). Crust crunchiness and crumb chewiness were evaluated as similar or inferior with respect to the control. The overall acceptance was evaluated on a simple like/dislike basis.

The loaves were sliced immediately after baking and were freeze-dried for subsequent analyses.

2.5. Dough technological properties

The water absorption of the flour blends and the dough mixing properties were studied by means of a Farinograph (Brabender, Duisburg, Germany), according to standard method No. 115/1 (ICC, 2003).

Viscoelastic properties were analysed by a Chopin MA 82 Alveograph according to standard method No. 121, whereas pasting properties were determined by means of a Rapid Visco Analyzer (Newport Scientific, Warriewood, NSW Australia) according to standard method No. 162 (ICC, 2003).

2.6. Determination of total polyphenol content, lignans content and antioxidant properties

Total polyphenols (TPC) were extracted from samples as described by Durazzo et al. (2013) in two separate fractions. Free polyphenols were extracted in methanol/water 1:1 and acetone/water 3:7. The residues were treated with hot sulphuric acid in methanol to free the hydrolysable polyphenols. The phenol content was determined by means of the Folin-Ciocalteau reagent (Singleton, Orthofer, & Lamuela-Raventos, 1999). Absorbance was measured at 760 nm and gallic acid was used as a standard.

For the analysis of lignans, samples were preliminary defatted with hexane and diethyl ether for 8 h in a Soxhlet apparatus. The lignans were extracted and analysed by HPLC as in Durazzo et al. (2013). HPLC analyses were performed on 50 μL extract using an ESA–HPLC system (ESA, Chelmsford, Ma, USA), consisting of an ESA Model 540 autoinjector, an ESA Model 580 solvent delivery module with two pumps, an ESA 5600 eight channels coulometric electrode array detector and the ESA coularray operating software which controlled all the equipment and carried out data processing. A Supelcosil LC-18 column (25 cm × 4.6 mm, 5 μm) with a Perisorb Supelguard LC-18 (Supelco, Milan, Italy) was used. Isolariciresinol, lariciresinol, secoisolariciresinol, pinoresinol and matairesinol were detected and quantified. The sum of identifiable lignans was indicated as total lignans.

The antioxidant properties were determined by the Ferric Reducing Antioxidant Power (FRAP) assay according to Durazzo et al. (2013).

2.7. Presentation of results

All analyses except amino acids, Alveograph and Farinograph tests were performed at least in duplicate. Mean values are