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A comparison of the nutritional value and food safety of organically and conventionally produced wheat flours

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ABSTRACT

Growing interest in organic agriculture has prompted this study aiming to evaluate nutritional content of wheat flours originating from organic and conventional production systems. Obtained results showed that organic samples had significantly lower protein content and lower levels of Ca, Mn and Fe compared to conventional samples. Protein digestibility and levels of K, Zn and Mo were significantly higher in organic than in conventional wheat flours. Regarding undesirable metals, significantly higher levels of As and Cd were found in conventional compared to organic wheat flours. Although the mean concentrations of zearalenone and ochratoxin A were higher in conventional than in organic flours, this difference was not significant. This study revealed that organic agriculture has the potential to yield products with some relevant improvements in terms of high quality proteins and microelements contents, while the reduction in contamination with toxic elements and mycotoxins may be accomplished.

1. Introduction

Worldwide, emphasis is increasingly being put on the relationship between food, nutrition and health (Lairon, 2010). Such combined awareness raises public concern over the quality and safety of foods, which, in turn, continuously increases demand for organically produced food (Dangour et al., 2009; Lairon, 2010). The latest survey on certified organic agriculture world-wide shows that 37 million hectares of agricultural land are managed organically by 1.6 million producers at the end of 2010 (FiBL (Forschunginstitut für biologischen Landbau)., 2012). The certified organic production area in Europe has increased by more than 40% in the period form 2004 to 2010 (FiBL (Forschunginstitut für biologischen Landbau)., 2012). In 2006, permanent grassland represents 47.1% of the whole organic area and arable crops (excluding green fodder) 23.2% according to statistics published by FiBL (2012). Among arable crops, cereals represent the most important category with 1.2 million hectares in 2007, i.e. 18.3% of all EU organic land and about 80% of the total organic arable crop area (FiBL, 2012). Today, wheat is a dominant cereal crop used for human consumption in many areas worldwide. In 2010, world production of wheat was 653 million tons, making it the third most-produced cereal after maize and rice (FAO, 2012). The biggest wheat producer in 2010 was European Union where organic wheat production represents roughly 204 million tons (FAO, 2012).

Organic farming is the practice of growing crops without the use of chemical pesticides, herbicides and fertilizers, relying mainly on crop rotation, organic fertilizers and plant-based pesticides to maintain soil productivity. Food sold as 'organic' in European Union must be produced according to European laws on organic food production (EC 1881/2006. European Commission, 2006). These laws stipulate that organic food must come from growers, processors or importers who are registered and approved by organic certification bodies (Williamson, 2007). A certification body is responsible for verifying that the product sold or labelled as organic is produced or prepared according to these guidelines.

The nutritional and toxicological value of organically produced food has long been a matter of interest and debate (Lairon, 2010; Dangour et al., 2009; Kirchmann, Mattson, & Eriksson 2009). Despite many limitations in the quality of the published data, overall a trend for higher nutrient levels was observed in organic

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product, including vitamins, phenolic compounds and some micronutrients, although a much more good-quality research is needed to confirm these findings (Lairon, 2010; Dangour et al., 2009; Mäder et al., 2007). The nutritional value of wheat is extremely important as it presents an important source of nutrients such as protein, carbohydrate, minerals, vitamins, fibre and phytocompounds in the daily food of humans (Mäder et al., 2007). There have only been a small number of comparative studies of organically and conventionally produced cereals and conclusions reached by them are still inconsistent (Kirchmann et al., 2009; Lairon, 2010; Mäder et al., 2007; Williamson, 2007). De Magistris and Gracia (2008) showed that consumers who perceive that organically produced food is healthier, safer and of higher quality than conventional ones will have a higher intention to purchase organic food products.

Therefore, this research aimed to compare nutritional quality and food safety of organic wheat flours (OWFs) and conventional wheat flours (CWFs) at the retail level, as representative of consumer purchases. We examined multielement profile, protein content and protein digestibility in whole wheat flours produced by organic and conventional management systems in two consecutive years, 2008 and 2009. In addition, we examined possible co-occurrence of two mycotoxins, zearalenone (ZEA) and ochratoxin A (OTA), in flour samples. To our knowledge, this is the first comparative study on the nutritional value of organic and conventional wheat flours produced in Croatia.

2. Materials and methods

2.1. Wheat flour samples

Whole wheat flour samples were purchased from different local supermarkets in Zagreb city representing the food as normally obtained by the customer. Whole wheat flour is a course-textured flour ground from the entire wheat kernel. Organic and conventional flour samples were originated from winter wheat (*Triticum aestivum* L.) planted during two consecutive years, mid October 2007 and 2008, and harvested in July 2008 and 2009, respectively, by different organic and conventional growers located in northern part of Croatia. In December 2008 and 2009, we purchased six organic flours produced by six different producers certified for organic production and six conventional flours produced by six different conventional producers. Conventional samples were selected from the localities which were comparable to organic wheat production sites. Organic labelled samples denoted products that were produced in accordance with organic standards throughout production, handling, processing and marketing (EC 1881/2006, 2006). The moisture content analysis (Table S1 of Supplementary Materials) showed no significant differences among tested samples. Observed moisture content was suitable for storage stability and longer shelf life of all wheat flours.

2.2. Determination of protein content and digestibility

Proteins were determined according to Kjeldahl procedure (AOAC, 2000) using semiautomatic Büchi system. Investigations were carried out in triplicates and conversion factor 5.7 was used for recalculating the content of organically bound nitrogen to protein content. Verification of the method was performed by using amino acid tryptophan as reference standard while obtained recovery was 94.7%.

The *in vitro* digestibility of proteins from whole wheat flours was determined by the pepsin-pancreatic method described by Saunders, Connor, Booth, Bickoff, and Kohler (1973). Briefly, for simulation of stomach digestion, 1 g of wheat flour sample was suspended in 15 mL of 0.1 mol L^{-1} HC1 containing 0.1 mg of pepsin, and gently shaken at 37 °C for 3 h. The solution was neutralized with 0.5 mol dm^{-3} NaOH and treated with 7.5 mL of 0.53 g L^{-1} pancreatin dissolved in 0.2 mol L^{-1} phosphate buffer (pH 8.0), containing 0.005 mol L^{-1} sodium azide. The mixture was gently shaken at 37 °C for 24 h to simulate intestinal digestion. Afterwards, the solids were separated by centrifugation at 4000*g* for 20 min. Undigested residue was washed 5 times with 30 mL of double distilled water and burned after addition of 10 g K_2SO_4, 0.31 g $CuSO_4$ and 20 mL concentrated H_2SO_4. Portion of undigested proteins in burned residue was determined according to Kjehldal procedure (AOAC, 2000).

2.3. Multielement analysis

An Agilent Technologies 7500cx ICP-MS system (Agilent, Waldbronn, Germany), which utilises an octopole ion guide enclosed in a collision/reaction cell, was used for multielement analysis in wheat flours. The instrument was equipped with an integrated auto-sampler, a Scott Quartz spray chamber and a MicroMist nebulizer (Glass expansion, Australia). The interface cones were the standard items, made of Ni. Operating conditions were normal for general, high matrix analysis, recommended by Agilent Technologies. The instrument was operated in an air-conditioned laboratory (20–22 °C) equipped with a filter to remove dust particles. The instrument was tuned daily with an ICP-MS tuning solution (Agilent Technologies, Japan) containing 10 μg L^{-1} of lithium, magnesium, yttrium, cerium, thallium and cobalt in 2% HNO_3 (w/v) to achieve higher or compromised intensities and lower yields for both oxide ions and doubly charged ones. High purity He (99.9999% He, SOL Spa, Italy) and H_2 (99.9995% H_2, SOL Spa, Italy) were used, in order to minimise the potential problems caused by unidentified reactive contaminant species in the cell.

All chemicals were of the highest purity grade that is commercially available. "Suprapur" nitric acid (Merck, Darmstadt, Germany) was used for sample digestion. All dilutions were made with ultrapure water (18.2 MΩcm), obtained from a GenPure UltraPure water system (GenPure UV, TKA Wasseraufbereitungssysteme GmbH, Niederelbert, Germany). The dilutions were carried out in a screw-capped 5 ml polypropylene test tubes (Sarstedt, Nümbrecht, Germany) rinsed with ultrapure water. Non-metallic devices were always used to collect and transport the samples. Before use all glassware and plastic containers were cleaned by washing with 10% HNO_3 for at least 24 h, then rinsed copiously with ultrapure water before use and left to dry under cover. All glassware, plastic containers, pipettes and reagents coming into contact with the samples or standards were randomly checked for contamination. The samples were prepared taking into account the rigors of the analysis of ultra traces.

Calibration standards were prepared daily from stock elemental standard solutions of 1000 mg L^{-1} from Merck (Darmstadt, Germany). The ICP-MS system was calibrated by the method of external standards with Rh and Lu as the internal standards. Both samples and standards were spiked with the 'internal standard stock solution' to a final concentration of 30 μg L^{-1}. Calibration curves were obtained by using at least five multi-elemental calibration solutions containing Mg, Al, K, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Sr, Mo, Cd, and Pb. For the purpose of contamination control each series of measurements included a reagent blank. Each calibration curve was constructed linearly through zero after subtraction of the reagent blank. Standards and blanks were subjected to the same treatment as the wheat samples.

Verification of the accuracy and precision of the proposed method was performed using the following Standard Reference Materials (SRMs): SRM 1567a (Wheat flour) from the National Institute of Standards and Technology (NIST) and IAEA H-9 (Mixed human diet) from the International Atomic Energy Agency (IAEA).