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Effect of high temperature drying on gluten-free pasta properties

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ABSTRACT

High temperature drying is commonly used for the production of durum wheat pasta because it induces superior product quality and reduces process costs. In respect to gluten-free noodles no information about high temperature drying is available. Aim of this study was to investigate the influence of high temperature drying on gluten-free pasta properties. Two types of gluten-free pasta (one amaranth/quinoa/buckwheat and second millet/white bean) were produced und dried under different conditions. Durum wheat pasta was used as a reference. Drying temperatures of 60, 80 and 100 °C with optional pre-drying at 40 °C for 0, 2 and 4 h were applied. The influence of drying parameters on cooking quality (cooking loss, cooking weight), texture properties (firmness, elasticity and tensile strength), and protein solubility were determined.

Higher drying temperature increased pasta properties significantly, especially texture. Pre-drying had a significant effect on most pasta properties. Compared to the millet/white bean pasta, the pasta from amaranth/quinoa/buckwheat exposed a higher degree of quality improvement after high temperature drying. The differences can be explained predominately by differences in the chemical composition, especially their amino acid composition. Texture properties reached values comparable to the wheat reference, but elasticity of the gluten-free pasta still needs further optimisation.

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1. Introduction

Dried pasta is one of the most important staple foods used around the world (Marchylo & Dexter, 2004). Pasta contains predominantly starch and protein. One primary target is to establish a firm but also elastic protein-starch network, which resists cooking (Sissons, 2004). On a macroscopic scale this leads to desirable sensory and texture properties (Bruneel, Pareyt, Brijs, & Delcour, 2010). Desirable pasta has 'al dente' characteristics (moderate firmness and high elasticity), no sticky surface, good integrity, bright, yellow colour and appealing taste and flavour. In overall assessment of pasta quality, the texture properties are most important because they are dominating consumer acceptance (Marchylo & Dexter, 2004). High cooking quality can be defined as low cooking loss and existing but not too excessive increase in volume during cooking. Considering nutritional value, the availability of lysine and the digestibility of starch and protein are relevant and are mainly influenced by drying conditions (Dexter, Tkachuk, & Matsuo, 1984).

Celiac disease is a permanent intolerance to gluten. Its only possible treatment is a life-long gf diet. Currently available gf food is often based on starch, mainly from rice and maize, which results in products with a low nutritive value (Marti & Pagani, 2013; Schoenlechner, Siebenhandl, & Berghofer, 2008). According to Saturni, Ferretti, and Bacchetti (2010) especially deficits in intake of proteins, fibres, minerals (calcium, magnesium, iron and zinc) and vitamins (folate and niacin) occur. This malnutrition needs to be balanced with food of high nutritional value. Therefore, pasta from pseudocereals are a possible alternative, because they are highly nutritious (e.g. high in minerals, vitamins and essential amino acids) (Marti & Pagani, 2013; Schoenlechner, Drausinger,

Abbreviations: gf, gluten-free; ABQ, amaranth, buckwheat, quinoa; MW, millet, white bean; WR, wheat reference pasta; HT, high temperature; SDF, soluble dietary fibre; IDF, insoluble dietary fibre.

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Ottenschlaeger, Jurackova, & Berghofer, 2010). Another possibility to increase the nutritive value is the combination of (gf) cereals and legumes.

Gluten-free pasta are still relatively poor in terms of texture and cooking quality compared to wheat semolina noodles (Marti & Pagani, 2013; Schoenlechner et al., 2010), in particular in terms of elasticity. The application of high temperature (HT) drying (>60 °C) has been shown to induce a positive effect on cooking quality of wheat pasta, especially in weak gluten pasta (Cubadda, Carcea, Marconi, & Trivisonno, 2007). By applying low temperatures drying (LT), cooking quality is mainly a function of gluten quality rather than its content (Marti, Fongaro, Rossi, Lucisano, & Ambrogina Pagani, 2012), while in the case of HT drying only the content (amount) of protein is responsible for pasta quality, protein quality plays a less important role. The coagulation of gluten in pasta before cooking induced by drying temperatures higher than 60 °C reduced the need for a strong gluten network in semolina pasta (D'Egidio, Mariani, Nardi, Novaro, & Cubadda, 1990), while in strong gluten pasta the increase in texture through HT drying was less significant (Cubadda et al., 2007). Since high protein contents improve cooking quality, an addition of proteins from other sources was suggested to increase the texture properties. Egg albumen was shown to have the best impact on cooking quality, resulting in firm and elastic pasta with low cooking loss (Matsuo, Bradley, & Irvine, 1972). Also in gf pasta higher addition of albumen was helpful to enhance texture properties (Schoenlechner et al. 2010). Another approach to enhance gf pasta quality is to modify starch macromolecular structure and functionality. High temperature drying could also work in this direction. In wheat pasta (high and low gluten content) HT drying increased pasting temperature of starch and thus cooking resistance of the resulting pasta (Marti et al., 2011). Zhang, Nishizu, Hayakawa, Nakashima, and Goto (2013) found that water absorption of starch decreased with increasing drying temperature; also the formation of lipid-amylose-complexes probably contributed to an increased texture firmness and decreased cooking loss.

The objective of this study was to investigate the effect of HT drying on the quality of two types of gf pasta (AQB and MW pasta). Gluten-free pasta were produced and dried at 60, 80 or 100 °C. Additionally, the effect of a pre-drying step (40 °C for 0, 2 and 4 h) was investigated. Pasta quality was determined by evaluating cooking loss, cooking weight, texture properties (firmness, elasticity and tensile strength), and protein solubility.

2. Material and methods

2.1. Materials

Buckwheat flour was derived from Strobl Naturmühle GesmbH (Linz-Ebelsberg, Austria). Quinoa, amaranth (Strobl Naturmühle GesmbH, Linz-Ebelsberg, Austria) and white beans (Linus HandelsgesmbH, Herzogenburg, Austria) were purchased as wholegrain and milled using a Universal Mill (Pallman PXL 18, Pallmann Maschinenfabrik GmbH & Co.KG, Zweibrücken, Germany). A pin disc set was used as grinding component. Durum wheat semolina was obtained from Vonwiller GmbH (Schwechat, Austria), emulsifier (distilled monoglyceride, Dimodan PH100, NS/B) from DuPont™ Danisco (DuPont Nutrition & Health, Grindsted, Denmark), pasteurized egg white powder from Enthoven-Bouwhuis Eiproducten B.V. (Raalte, the Netherlands).

2.2. Chemical composition

Determination of dry matter was performed according to ICC standard method No. 110/1. Crude protein was determined according to ICC standard method No. 105/2 (Kjeldahl). For calculation of the protein content a combined conversion factor of 5.81 for AQB and 6.42 for MW pasta was applied. The amount of total dietary fibre was analysed according to ICC standard method 156, which was given as SDF and IDF. All analyses were performed in triplicate.

2.3. Pasta production

Detailed pasta recipes are shown in Table 1. Two different types of gf pasta recipes were selected, in order to follow if HT drying has effects in general, and if yes, how is it influenced by different pasta types. Millet is often suggested for gf pasta making, but pasta from pseudocereals would be the better nutritional option. Throughout the study, these two recipes were kept constant, as change in recipe parameters would influence the texture properties like firmness or elasticity (elongation). Mixing of dough was performed using a Bear Varimixer™ (RN10 VL-2, Wodschow & Co., Broendby, Denmark). First, the mixture of all dry raw materials was blended for 1 min at lowest speed, then water was added slowly within 1 min. By increasing the speed to approximately 190 rpm (level one, four stripes) mixing was continued for 15 min. The dough obtained was extruded using a laboratory-scale noodle press (Model P3; La Monferrina Co., Castell'Alfero, Italy). Two different dies were used: one band noodle (*tagliatelle*, width 10 mm) die and one *lasagne* sheet die (width 10 cm). The reason for producing two different types of pasta was due to the determination of pasta texture parameters. Firmness was always determined from the *tagliatelle* shaped pasta, while elasticity properties were determined from rings cut from the *lasagne* sheet (see chapter 2.6). The fresh pasta (about 30 cm in length) were put on racks and dried at the defined conditions (Table 2).

2.4. Experimental design for pasta drying

For evaluating the effect of HT drying and pre-drying a response surface 2^2 experimental design (face centred with two centre points) was applied. Drying parameters were 60, 80 or 100 °C, pre-drying parameter was performed at 40 °C for 0, 2 and 4 h. After drying all pasta were cooled to 30 °C before removing them from the oven, in order to prevent cracking of the pasta. In pre-trials duration of drying at defined temperatures was set in a way that the overall energy that entered the pasta was comparable (5 h at 60 °C, 1.6 h at 80 °C, and 1 h at 100 °C). The cooling period from the maximum temperature to 30 °C was 2 h from 60 °C, 4.5 h from 80 °C, and about 5 h from 100 °C. The detailed drying programmes and energy intake for each point are shown in Fig. 1 and Table 2. The time to reach the targeted temperature was different for 40, 60 or 80 °C after the pre-drying step, and was considered in the calculation of overall energy intake (In Fig. 1 this is shown by vertical lines). Wheat pasta was produced as a reference from durum wheat semolina. The recipe corresponds to a commercial pasta from an Austrian company, which is available on the market in Austria. In order to avoid any disturbing influences from varying machinery it was produced with the same equipment as the two gf pasta during this study. Drying of the wheat pasta was done at 80 °C for 3 h, then cooled to 30 °C (defined in pre-trials not presented here).

2.5. Electrophoresis (SDS-page)

Sodium dodecyl sulphate-polyacrylamid Gelelectrophoresis (SDS-PAGE) was used to separate and detect proteins according to their molecular mass.

Samples were extracted using a phosphate buffer and mixed with SDS sample buffer (2 ml/100 ml SDS, 10 ml/100 ml glycerine, 0.004 ml/100 ml bromphenol blue, phosphate buffered 0.0625 mol/

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