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Investigation of physicochemical, sensory characteristics, cooking and texture properties of whole grain pasta

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The consumption of whole-grain products, such as pasta, has been linked to the reduced risks of some illnesses. Nutritional benefits include dietary fibre, minerals, and phytochemicals. Traditionally, whole-grain products tend to be darker in colour, fiber can interfere with the drying process affecting production processes. The purpose of the current research was to investigate the colour, cooking properties and texture of the whole-grain pasta. For pasta production, flour blends were made from wheat flour type 405 in combination with whole-grain flours as whole-grain wheat, triticale, rye and hull-less barley flour in previously determined proportions. In experiments, the whole-grain Italpasta (Italy) was used as a control sample. The colour, cooking properties and texture of the obtained pasta were tested using standard methods. The results of the present experiments demonstrate that the cooking time of control, whole-grain triticale and wheat pasta was longer than the cooking time of whole-grain rye and hull-less barley pasta. The colour of control, whole-triticale and whole-wheat pasta samples was darker as compared with whole-rye and hull-less barley pasta samples. However, more firmness had pasta samples made from whole-rye and hull-less barley whole-grain flour.

Key words: whole grain, pasta, colour

Introduction

Cereals and their products constitute an important part of the human diet, providing a high proportion of carbohydrates, proteins, fats, dietary fibres, B-group vitamins and minerals. More and more foods are made from whole grain [1]. In that regard, pasta is a staple food product that can be fortified with non-traditional ingredients, being especially important those that contribute to improve the essential amino acids and essential fatty acids profile or that increase the fiber, vitamins, and mineral content [2]. It has been observed that when pasta dough is fortified with non-traditional ingredients, it behaves differently than when only semolina is present [3].

Pasta cooking is an important step in pasta processing. During cooking, a weak or discontinuous protein matrix results in a protein network that is too loose and permits a greater amount of exudate to escape during starch granule gelatinization [4]. The exudate forms a surface starch, and the pasta becomes sticky [5], giving strands the tendency to clump. The variation in pasta cooking quality is due in part to the amount of protein present in semolina samples and in part to the intrinsic characteristics of these proteins. There is a general agreement that protein content is the primary factor influencing pasta quality and that gluten strength is an important secondary factor [6].

The inclusion of dietary fiber in pasta can negatively alter the tenacity of protein-starch product, affecting the integrity of the protein-starch network and hence pasta quality in terms of water absorption, swelling index, optimum cooking time, cooking loss, texture, appearance and taste [9].

Pasta is traditionally cooked in an excess of water (the recommended pasta : water ratio is 1 : 10) at 100 °C for different immersion times depending on the desired texture of the final product. Hydration of the product occurs by a diffusion-controlled process, and the temperature-moisture conditions induce the gelatinization of starch. Gelatinization is accompanied by an increase in viscoelasticity and starch solubilisation. Regarding changes at the macroscopic level, starch gelatinization proceeds toward the centre of the pasta strand as the cooking time increases [7]. Thus, starch morphological changes range from a strong swelling and partial disintegration in the outer layer of the strand to a slight swelling in the centre. Additionally, water uptake by the matrix promotes a significant softening of the pasta [10]. During cooking, the pasta structure changes from elastic to a more plastic state. Textural attributes are usually correlated to rheological parameters obtained by mechanical measurements, which are very important in understanding the structure of food and biological materials [11]. At the macromolecular level, pasta is essentially a large protein network formed by irreversible protein–protein crosslinks through thermal dehydration, which encapsulates starch granules [12]. Bran from whole-grain flour can interfere with water migration during this step, increasing water retention within the pasta [13]. Bran and germ particles also disrupt the continuity of the protein network, resulting in a weaker, less firm pasta [14]. It has been shown that wheat bran or whole-wheat flour incorporation leads to crucial changes: increased cooking loss [14–17], decreased water uptake [15], decreased pasta firmness [2, 14, 15, 18, 19], and reduced extensibility [17] were reported. Pasta processing, and especially the temperature at which it is dried and the subsequent cooking process, gives the end product its rheological characteristics due to starch gelatinization and protein coagulation (mainly gluten proteins). Industrial production (drying and extrusion in particular) can modify the pasta's structure, influencing starch digestibility and protein hydrolysis [20]. The protein network depends strictly on the drying temperature and influences the action of the proteolytic enzymes due to the formation of highly-aggregated proteins linked by covalent bonds [20]. Multiple studies have shown that the selection of adequate drying conditions is critical for the production of high-quality pasta [14, 21]. However, the selection of adequate drying conditions is generally not a straightforward task. Temperature and relative humidity profiles should be selected carefully, such that drying is fast enough to minimize the operating time, but sufficiently slow to promote adequate microstructural changes of the starch and proteins [20, 22].

The purpose of the current research was to investigate the colour, cooking properties and texture of whole-grain pasta production.

Materials and methods

The study was carried out at the scientific laboratories of the Faculty of Food Technology at Latvia University of Agriculture (LLU) and at the laboratory of the JSC "Jelgavas dzirnavas" (Latvia).

Conventional rye (′Kaupo′), hull-less barley (line ′PR 5099′) and triticale (line ′9405-23′), grains of 2014 cultivated at State Priekuli Plant Breeding Institute (Latvia), wheat (′Zentos′) grain cultivated at LLU Research Centre "Peterlauki" (Latvia) were used in the experiments. For obtaining the flour blend wheat flour type 405 from JSC "Dobeles dzirnavnieks" (Latvia) was used. Wheat, rye, hull-less barley and triticale grain were ground in a laboratory mill PLM3100/B (Perten, Sweden) obtaining fine whole-grain flour. In the previous experiments [23], it has been determined that for pasta production flour proportions will be used: 50 % whole-wheat flour and 50 % wheat flour type 405 (W/W); 20 % whole-rye flour and 80 % wheat flour type 405 (W/R); 20 % whole-hull-less barley flour and 80 % wheat flour type 405 (W/H); 30 % whole-triticale flour and 70 % wheat flour type 405 (W/T).

Whole-grain pasta in the shape of spaghetti (diameter 3 mm) was produced using a L-20 series single-screw extruder Göttfert (Germany). The barrel was divided into three zones. Each temperature zone was heated by means of electric heating, cooled with water and air. The electric control cabinet provided the control, recording and monitoring of temperature of each zone. Screw speed and feeder speed of 60 rpm were used for the extrusion of the whole-grain pasta. In the previous experiments, it was determined that the effects of the barrel temperatures of zones 2 and 3 on the whole pasta properties were studied, using temperature zones 1 : 2 : 3 as follows: whole-wheat 106 : 108 : 111 °C, whole-rye 102 : 104 : 105 °C, whole hull-less barley 104 : 106 : 109 °C, and whole-triticale 101 : 103 : 105 °C. Extruded whole spaghetti was air-dried for about 12 h at ambient temperature (50 ± 3 °C) in a rotary-convection oven "Sveba dahlin" (Sweden), and then kept in sealed polyethylene bags for further experiments. Pasta making was carried out in five replications.

The value of the surface colour of pasta was measured in triplicates using the Colour Tec-PCM colour measurement (USA). Colour readings were expressed by CIE values for L*, a* and b*. L* values measure black to white (0–100), a* values measure redness when positive, and b* values measure yellowness when positive.

The optimal cooking time (OCT, min) was determined as the time when the inner white core of the pasta disappeared according to the Approved Method 16-50 [24].Water holding capacity (WHC) was tested in five replications according to AACC 56-40 with modification. 10 g of a pasta-like product was hydrated in 500 ml of hot water (98 °C) for 10 min in a covered container; subsequently, the samples were drained for 10 min and weighted. The water-holding capacity was calculated as the increase of a product weight before and after reconstitution. Boiling water turbidity contents of the volumetric flask were thoroughly mixed, and 10 ml was filtered through a GF/A filter paper, using suction to 1 ml of the filtered cooking water in a 25 ml volumetric flask, 20 ml of distilled water and 1 ml of iodine solution (2.0 g of KI plus 0.2 g of I_2 made up to 100 ml) were added, this was made up to volume and allowed to stand for 10 min. Absorbance at 650 nm was measured with a spectrophotometer using 1 ml of iodine solution diluted to 25 ml as a blank. Actual cooking loss % was determined on the remainder (90 ml) of the cooking water in the volumetric flask. The solution was poured into a plastic freezing tray, combined with water used for rinsing the volumetric flask and freeze-dried. The freeze-dried material was weighed and corrected for moisture, for the amount of salt residue present in the prepared water and for the volume loss (10 ml) used for the iodine test. The cooking loss was expressed as a percentage of the weight of the spaghetti before cooking.

The firmness of cooked pasta samples was measured using Texture analyser (TA-XT2, Stable Micro systems, UK) equipped with a 5 kg load cell. Samples were rested for 10 min after cooking before testing. The following settings were used for measuring firmness: 50 kg load cell, pre-test speed 0.5 mm/s, post-test speed 10.0 mm/s, test speed 2.5 mm/s, distance 1 mm in compression mode (return to start). The maximum force in the force–time graph was taken as firmness. Four measurements were taken for each sample, and their average value was reported. The Microsoft Excel software was used for the research purpose to calculate the mean arithmetical values and standard deviations of the obtained data. The SPSS 20.0 software was used to determine the significance of research results, which were analysed using the two-factor ANOVA to explore the impact of factors and their interaction at the significance effect (*p-value, factors estimated as significant if the p-value* < $\alpha_{0.05}$). In the interpretation of results, it is assumed that $\alpha = 0.05$ with the credibility of 95 %, if not stated otherwise.

Results and discussion

Pasta cooking is an important step in pasta processing. The cooking quality of pasta is the characteristic of greatest importance to consumers and, therefore, of greatest importance to durum wheat producers, breeders and processors. During cooking, a weak or discontinuous protein matrix results in a protein network that is too loose and permits a greater amount of exudate to escape during starch granule gelatinization [4]. In the present experiment, it was found that (Fig. 1) the longer cooking time was for control, whole-wheat and whole-triticale pasta samples (9 min), however, significantly shorter (p = 0.012) it was for whole-rye and whole-hull-less barley (5 min). This behaviour could be associated with the formation of a weaker gluten network as the result of a dilution effect on gluten. Observed was a minor impact on the cooking time for fiber fortification [14].

The cooking losses of enriched pasta testify the quality of pasta and components bounding inside products during cooking for traditional pasta or during hot water hydration for precooked products. The values of this parameter below 10 % of pasta mass indicate a good quality of the instant or precooked products [25].

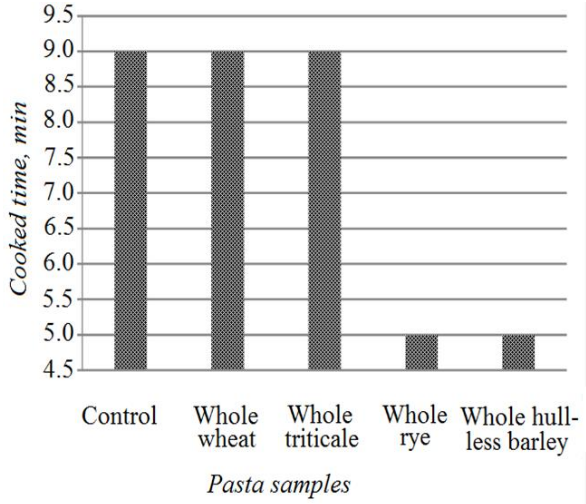

Fig. 1. Cooking time of whole-grain pasta samples

In the present experiment it was obtained that the cooking loss of an analysed pasta sample increases by increasing the amount of whole-grain flour (Table 1), what mainly could be explained with bran and germ particles also disrupt the continuity of the protein network, resulting in a weaker, less firm pasta [14].

Table 1. Cooking properties of pasta

Pasta samples	Cooking loss, %	Water holding capacity, %	Boiling water turbidity
Control	9.140 ± 0.030	11.860 ± 0.020	0.041 ± 0.001
Whole-wheat	6.760 ± 0.040	8.030 ± 0.040	0.083 ± 0.002
Whole-triticale	6.610 ± 0.020	7.570 ± 0.020	0.037 ± 0.003
Whole-rye	6.790 ± 0.060	7.560 ± 0.010	0.045 ± 0.002
Whole-hull-less barley	6.960 ± 0.040	7.980 ± 0.020	0.065 ± 0.001

The higher cooking loss was obtained for control sample (9.140 ± 0.030); however, significantly smaller (p = 0.014) it was for whole triticale (6.610 ± 0.040). Similar effects on increasing cooking losses have been reported for pasta products incorporating non-durum ingredients – dietary fibre [26].

The colour of dry pasta depended on the amount and type of whole-flour added (Table 2).

Table 2. Color profile of pasta

Pasta samples	L*	a*	b*
Control	58.27	1.28	20.23
Whole wheat	55.71	2.01	17.13
Whole triticale	58.91	1.42	18.01
Whole rye	61.03	2.30	15.82
Whole hull-less barley	65.11	1.16	16.02

L – lightness, a* (+)red, (−)green, b* (+)yellow, (−)blue, means of 20 replications.*

Lightness L * decreased slightly (p = 0.016) with increasing the amounts of whole-rye (61.03 ± 0.23) and whole-hull-less barley (65.11 ± 0.42) flour. In general, a more intense yellow colour b* was observed depending on the control sample. Protein content is the primary factor influencing pasta quality, and gluten strength is an important secondary factor [6].

The textural characteristics of cooked pasta play an essential role in determining the global acceptability of the food by consumers [27]. A good quality pasta product should present certain degrees of firmness and elasticity, absence of stickiness, appearance uniformity and structural integrity [10]. The firmness of dry (Fig. 3) and cooked pasta (Fig. 4) was analysed. The higher firmness was obtained for dry whole-wheat (6.670 ± 0.150) and triticale (5.399 ± 0.017) pasta samples. However, a higher firmness of cooked pasta was obtained for whole-wheat (0.358 ± 0.003), control (0.323 ± 0.004) and hull-less barley (0.342 ± 0.004) samples, what mainly could be explained by bran in the whole-grain pasta.

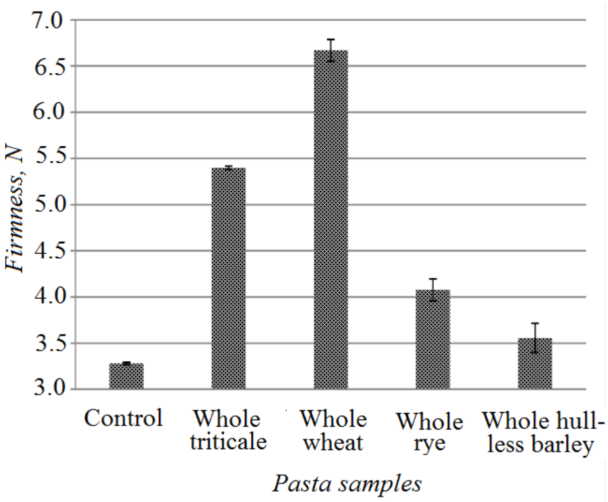

Fig. 3. Firmness for dry whole pasta samples

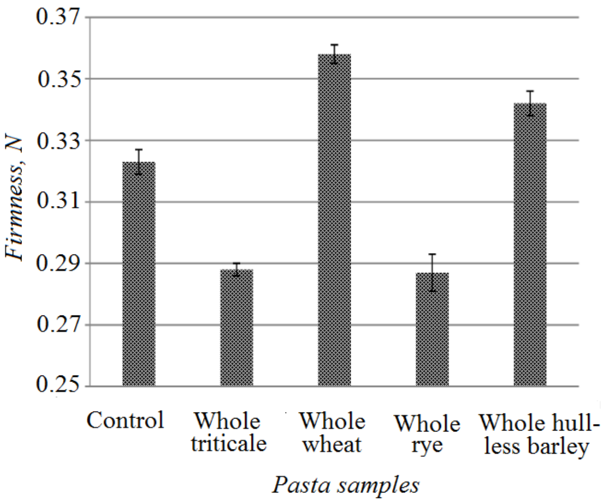

Fig. 4. Firmness for cooked whole pasta samples

Pasta cooking quality and textural characteristics, such as firmness, are determined by the physical competition between protein coagulation in a continuous network and starch swelling with exudate losses during cooking. If the former prevails, starch particles are trapped in the network alveoli promoting firmness of cooked pasta; whereas if the latter prevails, the protein coagulates in discrete masses lacking a continuous framework, and consequently pasta will show softness and usually stickiness [7, 8].

Conclusions

The higher cooking loss was obtained for the control pasta sample (9.14 ± 0.30 %).

The shorter cooking time was observed for whole-rye and whole-hull-less barley pasta samples, but the longer cooking time – for control, whole-wheat and whole-triticale samples.

The higher firmness was obtained for dry whole-wheat (6.670 ± 0.150 N) and whole-triticale (5.399 ± 0.017 N) pasta samples. However, higher firmness of cooked pasta was obtained for whole-wheat (0.358 ± 0.003 N), control (0.323 ± 0.004 N) and whole-hull-less barley (0.342 ± 0.004 N) pasta samples.

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NESMULKINTŲ GRŪDŲ MAKARONŲ SPALVOS, VIRIMO SĄLYGŲ IR TEKSTŪROS TYRIMAS

S a n t r a u k a

Viso grūdo dalių produktų, tokių kaip makaronai, vartojimas siejamas su kai kurių ligų prevencija. Mitybinius tokių produktų pranašumus lemia didesnis juose esančių maistinių skaidulų, mineralinių medžiagų ir fitochemikalų kiekis. Tradiciškai viso grūdo dalių produktai turi tendenciją būti tamsesnės spalvos, skaidulinės medžiagos gali turėti įtakos džiovinimo procesui ir trikdyti gamybos procesus. Šio tyrimo tikslas buvo ištirti viso grūdo dalių makaronų spalvą, virimo savybes ir tekstūrą. Makaronų gamybai miltų mišiniai gaminti iš 405 tipo kvietinių miltų, įmaišant į juos kviečių, kvietrugių, rugių ir miežių viso grūdo dalių miltų pagal ankstesniuose tyrimuose nustatytas proporcijas. Makaronams ruošti naudotas L serijos vieno sraigto tipo „Göttfert" ekstruderis (Vokietija). Paskui makaronai džiovinti 50 ± 3 °C temperatūroje „Sveba Dahlin" tipo rotacinėje-konvekcinėje krosnyje (Švedija) iki pastovaus drėgnumo 10 ± 3 %. Eksperimentuose kontrolei naudoti viso grūdo miltai „Italpasta" (Italija). Pagamintų makaronų spalva, virimo ir tekstūros savybės tirtos standartiniais metodais. Šių eksperimentų rezultatai rodo, kad virimo trukmė kontrolinių, viso grūdo dalių kvietrugių ir kviečių makaronų buvo ilgesnė nei gaminių, ruoštų iš viso grūdo dalių rugių ir belukščių miežių miltų. Kontrolinių makaronų ir tiriamųjų mėginių, ruoštų su viso grūdo dalių kvietrugių ir kviečių miltų priedais, spalva buvo tamsesnė nei makaronų mėginių, pagamintų iš viso grūdo dalių rugių ir belukščių miežių miltų. Tačiau makaronų mėginiai, pagaminti iš viso grūdo dalių rugių ir belukščių miežių miltų, buvo linkę daugiau lūžinėti.

Reikšminiai žodžiai: viso grūdo miltai, makaronai, spalva, tekstūra.