Heat–moisture treatment of wheat flour and its application in noodle production

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Key findings

- Heat–moisture treatment can be successfully applied to wheat flour to change its functional properties.
- Treatment time and flour moisture content significantly affected the functional properties of the treated wheat flours.
- Lower flour moisture content and shorter treatment times are more appropriate to produce heat–moisture-treated wheat flour suitable for noodle production.

Introduction

Starch is a main component of cereal grains and the foods produced from them. It supports nutritional value, texture, sensory properties and the food's shelf-life. Efforts have been made to modify the native structure of starch in order to broaden applications; different modified starches (e.g. instant starch and cross-linked starch) have been developed and used widely in food processing.

Generally, starch is extracted from its source and then modified. However, there is a lack of information on the *in situ* starch modification, i.e. as in the grains or flour. The advantages of flour modification are related to the wider application of flour than starch in many foods, and saving time and cost of starch extraction. Although flour modification such as heat–moisture treatment (HMT) has been tried already on millet, sorghum and wheat flours (Sun et al. 2014; Majzoobi et al. 2015; Verdu et al. 2017), many aspects such as the possible effects on proteins, health effects and the quality of foods produced from modified flours have not been fully investigated.

HMT is a physical method for starch modification. In this method, starch with low moisture content (~35%) is heated at above gelatinisation temperature (84–120 °C) for about 1–16 hours. HMT can change the gelatinisation temperature and water interaction and increase resistant starch content. Resistant starch is a type of dietary fibre as well as a prebiotic. It resists acidic and enzymatic hydrolysis and hence can be used to develop low glycaemic index (GI) foods and exhibit health benefits (Gunaratne & Hoover 2002). It is well documented that the HMT, type of starch and moisture content have great impacts on the physicochemical properties of the modified starch. HMT starch has previously been used in noodle, bread and edible packaging development (Majzoobi et al. 2015; Marston et al. 2016).

The main purpose of this study was to produce HMT wheat flour under different treatment conditions in terms of flour moisture content and treatment time, and then to investigate the effects that the HMT had on the flours' pasting properties, water solubility and water absorption. The HMT flours were replaced with 20% of ordinary wheat flour in noodle production (as a common food around the world) and some quality aspects of the resulting noodles were studied.

Material and methods

Commercial wheat flour with a moisture content of 14.06% was purchased from a local market.

HMT of the wheat flour

HMT wheat flour was produced according to the method described by Chen et al. (2015) with some modifications. First, the moisture content of the flour was adjusted to 14%, 20% and 30%. Then flours in sealed glass jars were placed in an electrical oven set at 100 °C for two, six and 10 hours. Then they were removed, poured evenly over a tray, and dried further for 8 hours at 40 °C. The treated flours were then ground slightly to break any clumps, sieved to achieve a consistent particle size, and stored in sealed glass jars at room temperature for further tests. Abbreviated names were given to all samples such as 2HMT14 (code in tables) meaning 2 hours of treatment at 14% moisture content. The control sample was the untreated wheat flour.

HMT flour testing

The pasting properties of the flours were studied by a rapid visco analyser (RVA S4) using the standard method of the instrument according to Ragaee and Abdel-Aal (2006) with slight modification. Water absorption and water solubility of the treated flours were measured as per Rafiq et al.'s (2016) description.

Noodle sheet preparation

Briefly, 20% of wheat flour was substituted with HMT flour and mixed well. Then other ingredients including 1% NaCl, 0.6% Na_2CO_3, 0.4% K_2CO_3 and about 34% water were added and mixed to form a dough. The dough was then sheeted using a laboratory noodle machine (Imperia RME 220: IPS-Santambrogio-Torino, Italy) to a thickness of 1.45–1.5 mm and incubated in sealed plastic bags overnight at 25 °C.

Colour of the sheets

The brightness (L-value), yellowness (b-value) and redness (a-value) of the noodle sheets were measured using a Minolta Chromameter 410 fitted with a 50 mm head. The colour parameters were tested on the fresh sheets and on the stored sheets (incubated sheets at 25 °C for 24 hours after production).

Cooking time and water absorption during cooking

The sheets were shredded to form noodles with thickness of 1.5 ± 0.05 mm. Cooking time and water uptake of the noodles were evaluated using the Ritthiruangdej et al. (2011) method.

Results

Flour properties

Heating in excess water is a common process when preparing starch-based foods. During heating, viscosity increases initially and then reduces upon further heating and mixing. These changes are mainly due to starch gelatinisation followed by the pasting process. During cooling, viscosity increases, mostly because of starch gelation and retrogradation. All the described changes are influenced by starch type, molecular structure of amylose and amylopectin, amylose content and the presence of other components such as proteins and lipids.

Table 1 shows the pasting properties of the control compared with the HMT flour. HMT increased the pasting temperature of all samples, meaning that the gelatinisation process was delayed for these samples. Within the HMT samples, both increased moisture content of the flour and increased treatment time enhanced the pasting temperature.

The treatment time and flour moisture content affected both peak and final viscosities of the HMT samples. With increasing flour moisture content, peak and final viscosities of the HMT samples reduced dramatically. Therefore, within each group, samples prepared with 30% moisture content (i.e. 2HMT30, 6HMT30 and 10HMT30) had the lowest peak and final viscosities. Similar results have been reported for HMT wheat flour and arrowroot starch produced under different conditions. HMT enhances the amylose-lipid complex formation and a more ordered double helical amylopectin clusters compared to the structure of native starch. This rigid structure could prohibit starch water uptake and swelling and reduce starch solubility. This may be the reason for the marked reduction in pasting and final viscosities for the HMT samples (Gunaratne & Hoover 2002). In addition, protein denaturation due to HMT might cooperate with the increased hydrophobicity, and could further delay the HMT starch granules in wheat flour swelling, resulting in reduced viscosity (Chen et al. 2015).

Compared with the control samples, HMT flours treated for two and 6 hours and at 14% and 20% moisture content showed higher peak and final viscosities than the control, while further increasing the treatment time and flour moisture content resulted in reduced viscosity. It is possible that the strengthened structure of the HMT granules allowed them to remain intact for longer, continuing to take up water and thus contributing to increased viscosity. However, increasing the treatment severity (10 hours heating at different moisture contents) caused other changes, which decreased the viscosity.

Table 1. Pasting properties, water absorption and water solubility of the control and wheat flours modified by heat–moisture treatment (HMT).

Sample	Pasting temperature (˚C)	Peak viscosity (cP)	Final viscosity (cP)	Water absorption (%)	Water solubility (%)
Control	64.25 ± 0.28	174.34 ± 1.53	200.13 ± 1.59	69.0 ± 0.5	15.0 ± 0.9
2HMT14*	65.45 ± 0.78	301.54 ± 4.30	341.71 ± 1.36	113.2 ± 1.3	14.6 ± 1.1
2HMT20	68.43 ± 0.04	272.13 ± 4.07	320.30 ± 1.24	114.7 ± 5.9	12.6 ± 0.7
2HMT30	77.73 ± 0.32	134.96 ± 2.89	213.25 ± 7.19	131.6 ± 3.3	11.4 ± 0.3
6HMT14	66.25 ± 0.28	222.54 ± 2.89	311.00 ± 4.01	131.3 ± 2.6	10.4 ± 1.0
6HMT20	70.63 ± 1.38	195.71 ± 1.59	264.58 ± 3.77	124.4 ± 5.6	10.9 ± 0.2
6HMT30	82.23 ± 1.24	63.33 ± 1.65	97.88 ± 4.89	144.4 ± 10.2	10.2 ± 0.2
10HMT14	67.83 ± 0.81	174.71 ± 1.47	266.00 ± 5.42	139.0 ± 4.3	10.4 ± 0.1
10HMT20	72.13 ± 0.88	152.13 ± 2.42	223.79 ± 1.94	129.2 ± 14.4	14.4 ± 1.4
10HMT30	80.20 ± 0.07	55.46 ± 0.41	87.00 ± 0.35	115.9 ± 9.3	12.6 ± 0.3

Values are the average of at least duplicates ± standard deviation.
*Numbers before and after HMT are the treatment time (hours) and flour moisture content (%), respectively.

Similarly, Chen et al. (2015) reported that the HMT wheat flour produced by heating at 120 ˚C for 24 hours with a moisture content of 15–35%, had lower peak and final viscosities than the control. The different values can be related to the differences in the conditions used for preparing HMT flour, partial gelatinisation of the starch granules (as reported by Chen et al. 2015) and the extent of protein denaturation, which require further investigation.

Table 1 shows that the HMT reduced the water solubility while increasing the water absorption of the flour. For the 2HMT and 6HMT samples, increasing the moisture content and treatment time had a positive effect on starch water absorption while the opposite result was observed for the 10HMT flour. The water solubility of the 2HMT flours reduced slightly with increasing the flour moisture content, but remained unchanged for the 6HMT flours and increased for the 10HMT samples.

Noodle properties

Colour has a very strong influence on customer choice when purchasing a product. For yellow alkaline noodles, a bright yellow colour is preferred. L-value indicates product lightness with higher values representing greater brightness. The a-value indicates redness (positive values) or greenness (negative values) of the product. The b-value is related to blueness–yellowness, and higher positive values represent increased yellowness of the sample. In general, including HMT flour reduced the brightness and increased the redness of the noodle sheets, particularly for the 10 hour treatments. The yellowness of the sheets prepared with the 2HMT and 6HMT was very similar to the control, while the sheets produced with 10HMT had slightly greater yellowness. Storage for 24 hours resulted in decreased brightness, increased redness and no change to yellowness for all samples. Changes in the colour can be attributed to some interactions between flour components (i.e. proteins and carbohydrates) and water. Changes in surface integrity and uniformity as well as possible enzymatic browning can also affect light reflection.

Table 2 shows the cooking properties and firmness of the cooked noodles. Generally, the cooking time of all samples was in the range of 5.30 min to 5.42 min. Therefore, it can be concluded that the HMT had no effect on the cooking time of the samples. Cooking weight gain is attributed to the amount of water absorbed by the noodles during cooking, which can affect the texture and sensory attributes of the cooked product. The cooking weight gain of all samples was in the range of 94.43% to 113.45%. Overall, HMT samples had a lower cooking weight gain than the control. Treatment time and flour moisture content had no considerable effects on the cooking weight gain.

Table 2. Cooking properties and firmness of the noodles produced by replacing 20% HMT flour with wheat flour.

Sample	Cooking time (min)	Cooking weight gain (%)
Control	5.33 ± 0.02	113.45 ± 8.05
2HMT14*	5.31 ± 0.02	99.85 ± 2.85
2HMT20	5.31 ± 0.01	97.24 ± 3.35
2HMT30	5.31 ± 0.01	103.03 ± 3.22
6HMT14	5.42 ± 0.01	105.81 ± 5.22
6HMT20	5.38 ± 0.03	94.43 ± 4.66
6HMT30	5.33 ± 1.24	101.87 ± 6.44
10HMT14	5.30 ± 0.01	98.83 ± 5.38
10HMT20	5.31 ± 0.01	98.66 ± 5.38
10HMT30	5.31 ± 0.01	102.82 ± 6.02

Values are the average of at least duplicates ± standard deviation.
*Numbers before and after HMT are the treatment time (hours) and flour moisture content (%), respectively.

Summary

Starch modification has been a successful method to change the functional properties of starch for many years, while it is less common for flour. In this study, HMT was applied to modify wheat flour. HMT affected pasting properties, water solubility and water absorption of the flour. These properties were highly affected by the treatment time and flour moisture content. Noodles produced using 20% wheat flour instead of HMT flour exhibited a similar cooking time, lower cooking weight gains and duller colour compared with the control. To produce HMT flour suitable for noodle production treatments at lower moisture content and shorter time seems to be more appropriate compared to other conditions. Further studies are required to determine the amount of resistant starch content of the treated samples and the organoleptic properties of the noodles.

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