Effect of psyllium husk and wheat mill bran fractions on the microstructure and mixograph characteristics of Arabic bread

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ABSTRACT

When psyllium husk, wheat bran and germ was added, incorporation of psyllium and wheat bran may affect the dough structure, dough rheology as well as the final quality of baked Arabic flat bread, which, thus, became important for this study. Scanning Electron Micrographs (SEM) taken on Arabic bread, depicted both intact small and the large starch granules on the outer crust area. This was mainly due to the rapid loss of moisture from the Arabic bread surface during intense baking operation leaving less moisture for gelatinization to take place. With psyllium added to WWF at 0, 3, and 5 % level, the peak time was increased from 3 to 4.5 min. The ascending and descending angle values were more or less identical in all the samples except with wheat germ addition, whereas much lower values (51 to 58 °) for these parameters were observed, indicating a faster rate of dough breakdown. With psyllium, fine- and coarse bran addition to WWF, a corresponding increase in peak time was observed. Ascending and descending angles showed similar trends to that of the WWF and psyllium combinations. Use of falling number apparatus is an indirect method of measuring the diastatic enzyme activity in cereal flours. WGF showed lower falling-number values (502 s) than the WWF (607 s). Addition of fine bran to WWF lowered the falling number (607 to 563 s) whereas with coarse wheat bran and germ, these values were increased.

Keywords: Psyllium husk, Wheat bran, Wheat germ, SEM, Arabic bread, Mixograph

1. Introduction

Mainly the pan bread and Arabic breads produced from white wheat flour as well as the highly polished white rice are eaten by the Kuwaitis. Evidently, a number of noncommunicable diseases (NCDs) are being attributed to the lower intake of dietary fiber ((Masrul and Nindrea, 2019; Nazario-Franco et al., 2020). Consumption of inadequate amounts of dietary fiber has also been attributed to higher incidences of metabolic syndrome both in children as well as in adults (Jane et al., 2019). Whole wheat grains being rich in many antioxidant compounds are reported to protect against many NCDs, such as, diabetes, certain types of cancers and cardiovascular diseases (Yu et al., 2020). Interestingly, the psyllium mucilage has been reported to possess health-promoting effects (Belorio et al., 2020). During baking process, a desirable gel structure is produced when psyllium heteroxylans combine with cellulose present in wheat bran particles, thus affecting the bread crumb structure favorably (Ren et al., 2020a, b). Phytic acid content in baked bread decreases lipolysis, but produces higher lipid storing capacity (Kim et al., 2014). But the binding of trace minerals (zinc, copper, iron etc.) with phytic acid lowers their absorption, thus toxicology induced by carbon tetrachloride (Wahid et al., 2020). The wheat bran being rich in myo-inositol and phytic acid has been shown to possess antioxidant and hepatoprotective properties to reduce the hepatotoxicity induced by carbon tetrachloride (Benitez et al., 2018). Moreover, psyllium acid content in baked bread and its health-promoting effects (Belorio et al., 2020) have shown that rheological characteristics of dough were adversely affected with the addition of psyllium husk. Statins when consumed are known to have side effects, whereas psyllium fiber when consumed has been reported to have synergistic effect with statins (Brum et al., 2018). Psyllium husk being a natural ingredient, when used in bakery products imparts a number of health-promoting effects (Belorio et al., 2020). During baking process, a desirable gel structure is produced when psyllium heteroxylans combine with cellulose present in wheat bran particles, thus affecting the bread crumb structure favorably (Ren et al., 2020a, b). Phytic acid content in baked bread decreases lipolysis, but produces higher lipid storing capacity (Kim et al., 2014). But the binding of trace minerals (zinc, copper, iron etc.) with phytic acid lowers their absorption, thus toxicology induced by carbon tetrachloride (Wahid et al., 2020). The wheat bran being rich in myo-inositol and phytic acid has been shown to possess antioxidant and hepatoprotective properties to reduce the hepatotoxicity induced by carbon tetrachloride (Benitez et al., 2018). Moreover, psyllium acid content in baked

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products can easily be reduced significantly through the yeast fermentation (Chhabra and Sidhu, 1988; Spaggiari et al., 2020; Alkandari et al., 2021a).

The above review of literature, thus, support the use of psyllium fiber and wheat bran as one of the most useful materials for the production of functional foods (pan bread and Arabic bread) having higher dietary fiber contents. But these fiber sources may affect the microstructure, and rheology of dough which would have strong influence on the texture and sensory qualities of finally finished baked product. Considering the importance of psyllium fiber and the wheat bran rich in phytic acid, both with tremendous nutritional benefits as well as having significant effects on the structure of dough and its rheological properties, the main objective here was, therefore, to investigate the effect of psyllium fiber and flour mill fractions on dough mixing behavior, wheat flour pasting properties and the microstructure of dough as well as the quality of Arabic flat bread.

2. Materials and methods

2.1. Raw materials

Wholegrain wheat flour (WGF), white wheat flour (WWF), coarse wheat bran (CB), fine wheat bran (FB), wheat germ (WG), required for this work, were obtained from the Kuwait Flour Mills & Bakeries Co., Shuwaikh. A local company supplied us with the psyllium husk (PS) that was of Indian origin. Using standard AACC methods (AACC, 2000), flour, mill fractions and psyllium were tested for moisture (method 44–19), crude fat (method 30–25), crude protein (Nx5.70) (method 46–12), total ash (method 08–01), and crude fiber (method 32–10) contents, and the average values have been reported in another publication earlier (Aldughpassi et al., 2021a).

2.2. Baking studies

Various baking supplies, such as, bakery shortening (Wesson brand, USA), common salt, fine granulated sugar, and instant dry yeast were procured locally. With the control sample made from WGF, different levels of FB and CB, were added to the WWF, to produce Arabic bread according to the method of Aldughpassi et al., 2021a. The bread dough after sheeting to 2 mm thickness (Pastry dough sheeter, Swiss make), was manually cut into 6 in. dia discs, proofed for 15 min at 105 °C and 86 ± R.H., baked at 190 °C for 90 s on the shelves type oven (Salwa brand, Italy made), having live steam injection facilities. The injection of steam is important as the Arabic bread being flat in surface is likely to an extensive loss of moisture during baking, thus, adversely affecting its texture. The Arabic bread samples were freeze-dried (Virtis make, Model: Unitop 800L, USA) to conduct scanning electron micrograph studies. The incorporation of psyllium fiber, CB, FB, and WG affecting the chemical composition and quality of Arabic bread (Aldughpassi et al., 2021a); the chemical composition as well as instrumental texture of pan bread and hamburger buns (Alkandari et al., 2021b; Abdullah et al., 2021); CIE tristimulus L* a* b* values (Aldughpassi et al., 2021b); phytic acid in various baked products (Alkandari et al., 2021a), the rheology of Arabic bread dough (Aldughpassi et al., 2020), have recently been reported and can be referred to for more detailed information.

2.3. Scanning electron microscope (SEM) studies

For SEM studies, WGF, WWF, psyllium husk powder, the crust and crumb of freeze-dried pan bread and Arabic bread were fractured manually, these pieces then mounted on a carbon double-sided conductive tape and were sputter coated with gold (Structure Probe, West Chester, PA). SEM studies were performed in a JEOL 8600MX electron probe micro-analyzer that was operated at an accelerating voltage of ≥ 9.0 kV (Sidhu et al 1997). The purpose of depositing a thin film of gold on the sample surfaces was to minimize the electron charging while observing the sample surface under high vacuum conditions. Scanning electron micrographs of WWF, psyllium husk, and these Arabic bread samples made in a laboratory bakery were viewed and photographs were recorded at different magnifications ranging from 50X to 2500X. From these Arabic bread, WWF and psyllium husk photographs, a few representative scanning electron micrographs have been presented here.

2.4. Mixograph studies

Using white wheat flour and various blends containing flour mill fractions and psyllium husk, mixograms were developed with a 10 g mixograph (National Manufacturing Co., Inc., Nebraska, US) as per the AACC Method 54–40A (AACC, 2000). Corresponding farinograph water absorption (FWA) values obtained using a 50-g bowl were used in these flour, wheat bran and psyllium husk samples for conducting mixograph studies. The mixograms were evaluated for peak time, ascending angle and descending angle.

2.5. Falling number values

Falling number determinations were made using 7 g of flour or flour-bran-psyllium combinations (14 % moisture basis) in Hagenberg Falling Number apparatus (Model 1400, Sweden) as per AACC method 56-81B (AACC, 2000). All of the rheological runs were made in duplicate, and average values are reported.

2.6. Statistical analysis

One-way analysis of variance using Duncan’s New Multiple Range Test (SAS Program Windows Version 6.08) was used for carrying out the statistical analysis of research data. P = 0.05 was taken to statistically evaluate the significance of research data. Mean ± standard deviations are presented here (Aldughpassi et al., 2021a).

3. Results

3.1. Scanning electron micrograph studies

Scanning electron microscopy is very beneficial tool to examine the physical changes during gelatinization of the starch granules while heating with a limited amount of water that is usually available in a bread dough. Keeping this in mind, SEM was employed to examine the WWF and psyllium husk particles as well as to record the physical changes occurring in the starch granules in the Arabic bread during baking process, and the results are shown in Figs. 1A-1C, and 2A-2C, (and in Fig. S6 in Supplementary file, Appendix-I). The white wheat flour particles showed clearly the protein bodies (P), intact small starch granules (S), and large starch granules (L) as presented in Fig. S6 (Appendix-I). The white wheat flour particles showed clearly the protein bodies (P), intact small starch granules (S), and large starch granules (L) as presented in Fig. S6 (Appendix-I). On the other hand, the psyllium husk particle surface seemed to have rough ridges and did not show any cell boundaries (Fig. S6). The increased surface area of psyllium husk arising out of these ridges may also be one of the factors responsible for its increased water holding capacity. 

In case of WGF Arabic bread, the starch granules were found to be intact on the outer crust surface, but in the crumb, a matrix of completely gelatinized starch was visible (Fig. 2A-C, a, b). A series
of small holes were also observed in the crumb area indicating the routes through which the gases and water vapors might have escaped during the baking process (Fig. 2 A, b). In case of Arabic bread made from WGF with 3 and 5% psyllium, still much higher water absorption was used than the Arabic bread made with WWF. For the gelatinization of starch during baking process, much more water will be available in the WGF samples. As expected, a continuous matrix of gelatinized starch granules was noticed in the crumb (Figs. 2B-C, b). The Arabic bread making conditions were sufficiently distinct than those employed for pan bread and hamburgers. Firstly, a lot more water was incorporated into flour to produce a dough of 850 BU farinograph consistency required for producing Arabic bread. Secondly, the dough for Arabic bread was sheeted thin (3 mm) and was baked at high temperature (400 °C), short time (only 90 s) compared to that of the pan bread (220 °C for 22 min) or hamburger buns (200 °C for 9 min). Thirdly, a lot of dusting flour is used to prevent sticking of slack dough to the sheeting equipment. These differences in the pasting behavior of starch granules in Arabic bread and pan bread can, therefore, be explained on the basis of variations in processing conditions. Such observations about the intact starch granules on the outer crust surface but completely gelatinized matrix of starch granules in the crumb area in Arabic bread have also been made earlier (Sidhu et al., 1997).

Fig. 1A. Scanning Electron Micrograph of WWF Arabic bread (control).

Fig. 1B. Scanning electron micrograph of WWF Arabic bread containing 3% psyllium.

Fig. 1C. Scanning electron micrograph of WWF Arabic bread containing 5% psyllium.
3.2. Mixograph studies

The mixograph is an instrument which measures dough rheological parameters, this quite similar to a Brabender Farinograph, but uses only 10-g flour samples instead of the 50 g required for the farinograph. When psyllium was incorporated into WWF at different levels (0, 3, 5 %), it had increased the peak time from 3 to 4.5 min (Table 1A-B). The higher peak times meant that due to competition between gluten proteins and the psyllium fiber, it took longer time for the gluten proteins to develop into a viscoelastic mass. The ascending and descending angle values were more or less identical in all of the samples, except when wheat germ was added, which produced much lower values (51° to 58°), indicating a faster rate of dough breakdown (Table 1A). Ascending and descending angle values showed trends similar to that of the WWF and psyllium combinations. Similar effects with coarse-bran and psyllium addition to WGF were also observed for these mixograph characteristics (Sidhu et al., 1988). Typical pictures of a few of the mixograms have also been presented in Figs. S1-5 in a Supplementary file (Appendix-I).

Fig. 2A. Scanning electron micrograph of WGF Arabic bread (control).

Fig. 2B. Scanning electron micrograph of WGF Arabic bread containing 3% psyllium.

Fig. 2C. Scanning electron micrograph of WGF Arabic bread containing 5% psyllium.
values only insignificantly.

607 to 563 s), whereas addition of both CB and WG increased these falling-number values than that of WWF (607 s). Addition of FB WGF having higher diastase activity showed lower (502 s) values for falling number (in seconds), indicate a lower diastase activity in a wheat flour samples (Table 4A). Obviously, the higher values for falling number (in seconds), indicate a lower 

| Sample Code | Peak Time (min) | Ascending Angle | Descending Angle |
|-------------|-----------------|-----------------|-----------------|
| Wholegrain Wheat Flour (WGF) | 3.0^a | 71^a | 83^a |
| White Wheat Flour (WWF) | 2.5^a | 50^a | 78^a |
| WWF + 10 % Fine Bran | 3.0^a | 60^a | 83^a |
| WWF + 20 % Fine Bran | 3.5^a | 67^a | 82^a |
| WWF + 10 % Coarse Bran | 2.5^a | 63^a | 83^a |
| WWF + 20 % Coarse Bran | 3.0^a | 65^a | 83^a |
| WWF + 10 % Wheat Germ | 3.0^a | 51^a | 76^b |
| WWF + 20 % Wheat Germ | 3.0^a | 58^b | 73^b |

Mean values having same superscripts do not differ significantly in a column (P = 0.05).

| Sample Code | Peak Time (min) | Ascending Angle | Descending Angle |
|-------------|-----------------|-----------------|-----------------|
| White Wheat Flour (WWF) | 2.5^a | 50^a | 78^a |
| WWF + 1 % Psyllium | 2.5^a | 58^ab | 82^ab |
| WWF + 2 % Psyllium | 3.0^ab | 56^ab | 82^ab |
| WWF + 3 % Psyllium | 4.0^bc | 58^ab | 83^ab |
| WWF + 4 % Psyllium | 4.0^b | 64^b | 83^ab |
| WWF + 5 % Psyllium | 4.5^a | 67^b | 85^a |

Mean values having same superscripts do not differ significantly in a column (P = 0.05).

3.3. Falling number values

The Falling Number apparatus is useful for indirectly measuring the level of diastase enzymes (mainly α-amylase) in cereal flours. The higher values for falling number (in seconds), indicate a lower diastase activity in a wheat flour samples (Table 4A). Obviously, WGF having higher diastase activity showed lower (502 s) falling-number values than that of WWF (607 s). Addition of FB to WWF decreased the falling-number values significantly (from 607 to 563 s), whereas addition of both CB and WG increased these values only insignificantly.

4. Discussion

The outer crust surface of WWF Arabic bread showed intact small and large starch granules which did not undergo any noticeable changes in their morphology during the baking process (Fig. 1A, a). Generally, sufficient amounts of flour is dusted during sheeting, molding and cutting of the Arabic bread dough to prevent sticking of pieces to the dough handling equipment. Arabic bread has quite a thinner structure with extensive surface area compared with pan bread and thus a lot of moisture is lost at a much rapid rate from the surface leaving only a small amount of water available for the gelatinization of starch granules. Consequently during the short baking time (only 90 s), obviously these starch granules do not get fully gelatinized. In contrast, the SEM of crumb portion of WWF Arabic bread (Fig. 1A, b) showed a continuous layer of gelatinized starch with very defused outlines for starch granules, along with some gas holes, through which the gas and water vapors had escaped during the baking process. Because of the availability of enough water for the generation of steam during the baking/puffing of Arabic bread in the oven, a continuous layer of gelatinized starch was developed. Psyllium fibers absorb a lot of water during dough making which may aid in the gelatinization of

Table 2A

Mixograph characteristics of dough made from flour, fine bran and psyllium blends.

| Sample Code | Peak Time (min) | Ascending Angle | Descending Angle |
|-------------|-----------------|-----------------|-----------------|
| White Wheat Flour (WWF) | 2.5^a | 50^a | 78^a |
| WWF + 10 % Fine Bran + 1 % Psyllium | 3.0^ab | 59^ab | 83^b |
| WWF + 10 % Fine Bran + 2 % Psyllium | 3.5^ab | 61^ab | 83^a |
| WWF + 10 % Fine Bran + 3 % Psyllium | 4.0^bc | 66^b | 85^bc |
| WWF + 10 % Fine Bran + 4 % Psyllium | 4.5^a | 68^b | 86^a |
| WWF + 10 % Fine Bran + 5 % Psyllium | 4.5^a | 68^b | 85^bc |

Mean values having same superscripts do not differ significantly in a column (P = 0.05).
Mixograph characteristics of dough made from flour, coarse bran and psyllium blends.

| Sample Code | Peak Time (min) | Ascending Angle | Descending Angle |
|-------------|----------------|----------------|-----------------|
| White Wheat Flour (WWF) 2.5 a 50 a 78 a | 3.0 ab | 65 b 84 bc |
| WWF + 20 % Fine Bran + 1 % Psyllium 3.0 ab | 58 ab | 82 ab 84 ab |
| WWF + 20 % Fine Bran + 2 % Psyllium 4.0 bc | 65 b | 84 bc |
| WWF + 20 % Fine Bran + 3 % Psyllium 4.0 bc | 65 b | 84 bc |
| WWF + 20 % Fine Bran + 4 % Psyllium 4.0 bc | 65 b | 84 bc |
| WWF + 20 % Fine Bran + 5 % Psyllium 4.5 c | 72 b 86 d |

Mean values having same superscripts do not differ significantly in a column (P = 0.05).

Mixograph characteristics of dough made from flour, fine bran and psyllium blends.

| Sample Code | Peak Time (min) | Ascending Angle | Descending Angle |
|-------------|----------------|----------------|-----------------|
| White Wheat Flour (WWF) 2.5 a 50 a 78 a | 2.5 a | 50 a 78 a |
| WWF + 10 % Coarse Bran + 1 % Psyllium 3.0 ab | 58 ab | 82 ab |
| WWF + 10 % Coarse Bran + 2 % Psyllium 4.0 bc | 65 b | 84 bc |
| WWF + 10 % Coarse Bran + 3 % Psyllium 4.0 bc | 65 b | 84 bc |
| WWF + 10 % Coarse Bran + 4 % Psyllium 4.0 bc | 65 b | 84 bc |
| WWF + 10 % Coarse Bran + 5 % Psyllium 4.5 c | 72 b 86 d |
| WWF + 20 % Coarse Bran + 1 % Psyllium 3.5 b | 66 b 85 b |
| WWF + 20 % Coarse Bran + 2 % Psyllium 4.0 bc | 70 b 87 b |
| WWF + 20 % Coarse Bran + 3 % Psyllium 4.0 bc | 71 b 86 b |
| WWF + 20 % Coarse Bran + 4 % Psyllium 4.5 c | 71 b 86 b |
| WWF + 20 % Coarse Bran + 5 % Psyllium 3.5 bc | 72 b 85 b |

Mean values having same superscripts do not differ significantly in a column (P = 0.05).

Mixograph characteristics of dough made from flour, fine bran and psyllium husk.

| Sample Code | Peak Time (min) | Ascending Angle | Descending Angle |
|-------------|----------------|----------------|-----------------|
| White Wheat Flour (WWF) 2.5 a 50 a 78 a | 3.5 ab | 66 ab 85 ab |
| WWF + 10 % Coarse Bran + 1 % Psyllium 4.0 b | 66 b 84 b |
| WWF + 10 % Coarse Bran + 2 % Psyllium 4.0 bc | 70 b 87 b |
| WWF + 10 % Coarse Bran + 3 % Psyllium 4.0 bc | 71 b 86 b |
| WWF + 10 % Coarse Bran + 4 % Psyllium 4.5 c | 71 b 86 b |
| WWF + 10 % Coarse Bran + 5 % Psyllium 3.5 bc | 72 b 85 b |

Mean values having same superscripts do not differ significantly in a column (P = 0.05).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Dr. Sidhu conceived the research idea and guided the research team, Mr. Al-Foudari did the mixograph and falling number studies. Dr. Alhazza carried out the SEM studies. All authors have approved the final manuscript for submission to this journal.
Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sjbs.2022.103479.

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