Food Research 5 (4) : 80 - 85 (August 2021)
Journal homepage: http://www.myfoodresearch.com

FULL PAPER

Large scale industry mill: effect of extraction rate of flour on the dough rheological properties

[1,*]Alhendi, A.S., [2]Ahmed, Z.A., [2]Hussein, M.S. and [2]Abed, S.A.

[1]*Quality Control Department, Grain Board of Iraq, Ministry of Trade, Al Taji, Baghdad, Iraq*
[2]*General Company of Grain Processing, Ministry of trade, Baghdad – Iraq*

Article history:
Received: 8 January 2021
Received in revised form: 12 February 2021
Accepted: 20 March 2021
Available Online: 11 July 2021

Keywords:
Wheat,
Extraction rate,
Flour,
Rheological properties,
Fine bran

DOI:
https://doi.org/10.26656/fr.2017.5(4).026

Abstract

Consumption of whole wheat flour is increasing worldwide because of its nutritional value. However, the flour rheological properties are affected by a high extraction rate (ER), that have been mentioned for many studies done on a laboratory scale. In the present study, a high ER flour produced by using a large-scale industrial mill was used to determine the effect of high ER on the dough rheological properties. The three studied extraction rates (80%, 85%, and 92%) were achieved by changing the roll adjustments and adding fine bran. The rheological properties (farinogram, extensiogram, and amylogram parameters) of the produced flour were determined in addition to some chemical and physical attributes. The result showed that there were no significant differences between farinogram parameters except for water absorption, which was increased with increasing ER. Also, there were no significant differences for extensiogram parameters and amylogram parameters, as well as for wet gluten and gluten index, protein, and moisture content. Conversely, for ash content, there were significant differences between the three flours. For PSD, there were no significant differences between produced flour related to the large particle size (above 720 and 354 µm). In conclusion, increasing ER of produced flour up to 92% with adding fine particle size bran had no significant effect on the rheological properties of the produced flour compared to 80% ER.

1. Introduction

Wheat is one of the most important crops in the world, and it is used for human consumption and livestock feed (Shewry *et al.,* 2002; Shewry, 2009). Wheat grains consist of 80- 85% endosperm, 13-17% bran, 2-3% germ at dry matter basis (Belderok *et al.,* 2000). Fibre (the main component of bran) is about 53% of bran, and it contains cellulose, pentosans, and polymers of xylose and arabinose. Also, bran contains 16% protein, 16% carbohydrates, and 7.2% minerals (Šramková *et al.,* 2009). The germ contains 25% protein, 8-13% lipids, and 4.5% minerals (Cornell, 2012). Shewry and Hey (2015) mentioned that there is a high relationship between the consumption of cereal fibre and reducing the risk of cardiovascular diseases, some cancers, and type two diabetes.

Gluten is a unique protein that gives viscoelastic properties to the dough, which is necessary for bread production. The chemical and rheological properties of dough are an important issue. Therefore, several instruments have been developed to determine these properties (Kaur *et al.,* 2011). The quality and quantity of gluten play a key role in determining baking quality because of its function (Wieser, 2007). Farinograph is an important device for dough rheological properties such as development time, water absorption, stability, and degree of softening, which are useful parameters to optimize baking quality (Yazar *et al.,* 2016). Measuring the extensibility and resistance to deformation of dough can be determined by extensograph device (Di Cagno *et al.,* 2002). Flour starch gelatinization, degradation of starch pastes by α-amylase, can be determined by amylograph and falling number techniques (Perten, 1964).

The Grain Board of Iraq (GBI) on behalf of the Iraqi government imported 152, 775, 1549 thousand tons of, in addition to domestic cultivated crops, which were 3000, 2400, 2306 thousand tons of wheat for 2016, 2017 and 2018 year respectively. The previous huge numbers indicate the importance of the wheat crop in the daily diet of Iraqi people (Data from GBI). The extraction rate (ER) of flour produced in Iraqi mills is 80% (Alhendi *et al.,* 2019), which is higher than the common ER flour (71-73%), (Posner and Deyoe, 1986; Hassan *et al.,*

*Corresponding author.
Email: *aalhendi@ufl.edu; rdqc@grainb.iq*

eISSN: 2550-2166 /

2015). Increasing bran fractions are known to reduce bread quality due to the lowering of specific volume and increasing the density of crumb texture. However, for health reasons, some consumers prefer whole grain products (Noort *et al.,* 2010). Although many studies determined the deleterious effects of bran on bread quality in terms of its functionality, most studies were done on laboratory scales (Azizi, *et al.,* 2006; Noort *et al.,* 2010). Therefore, this study aims to determine the effect of increasing ER on the rheological properties of flour produced by a large-scale industrial mill. Besides, this study concerns the effects of adding fine bran particles produced by an industry mill on the rheological properties of the produced flour.

2. Materials and methods

2.1 Produced flour

The mill used in the study was Altaji mill (OCRIM SPA 600 ton/day Cremona-Italy), located 5 km to the north of Baghdad centre and the real milling capacity used in this study was 11 ton/h. The wheat used for this study was mixed with 35% American Red wheat, 35% Australian wheat, and 30% domestic (Iraqi) wheat. The grain has been moisturized overnight before milling, and the desired level of wheat moisture content set up before by the automatic dampening machine in the mill to obtain 16.5±0.2%. The mill was adjusted to produce 80% ER flour routinely. Increasing the percentage rate to 85% was made by adjusting the mill rolls (decreasing the space between the opposite rolls). An extraction rate of 92% was achieved by changing the direction of the fine bran pipe to the flour production line and re-adjusting the gap between the rolls (decreasing more). The extraction rate was calculated by dividing produced flour of each treatment by the total output (flour + bran) multiplying by 100.

2.2 Chemical, and rheological analyses

The moisture content of flour was determined depending on (44-10, AACC, 2000). Ash content was achieved by following (08-01, AACC, 2000). Wet gluten and gluten index were determined based on (38-12, AACC, 2000). Farinograph, Extensograph, and Amylograph parameters were attained by following (115/1, ICC, 1996), (54-10, AACC, 2000), and (126/1, ICC, 1996) respectively.

2.3 Particle size distribution (PSD) of flour

The produced flours with different ER were analysed for PSD by using Buhler Laboratory Siftermin 300 (Buhler Group Company, Uzwil, Switzerland) for 5 mins. Sieves with mesh diameter 710, 354, 183, and 129 µm were used to determine the flour particle size distribution.

2.4 Particle size of bran

Increasing ER is mostly made by adding bran to flour, bran produced by different mills has different PSD. Therefore, in order to determine the PSD by different mills, 10 kg of the moisturized wheat in the industry mill which was ready to be milled in the milling section have been taken and subjected (at the same time) to be milled by two laboratory mills, which were Buhler (Buhler MCKA 202, Buhler Group Company, Uzwil, Switzerland) and Quadrmat (Brabender® OHG, Brabender GmbH Co. KG, Duisburg, Germany). The produced flour by the laboratory mills was raised to 80% (by adding some of the sieved fine bran for Buhler and some of the sieved bran for Quadrmat) to mimic the 80% ER of the industrial mill. The remaining fine bran of Buhler mill and remaining bran of Quadrmat mill in addition to fine bran of the industrial mill were analysed for PSD by using 1120, 710, 500, and 354 µm sieves.

2.5 Statistical analysis

Statistical analysis was performed by using one-way analysis of variance (ANOVA) with SAS version 9.0 (Cary, NC, USA). The least significant difference (LSD) comparison of means procedure was used. Differences were considered statistically different at $\alpha = 0.05$. All the analyses were duplicated.

3. Results

The chemical composition of flour at different ER (80%, 85%, and 92%) is shown in Table 1. There were no significant differences between all the produced flour for moisture, protein, wet gluten, and gluten index. However, gluten and gluten index values for 85% and 92% ER flour were lower than 80% ER flour. For ash content, there is a significant difference between all the treatments. The more ER, the higher the ash content. For rheological properties, there was a significant difference between produced flour for water absorption value. Flour at 92% ER had a higher water absorption value than others (Table 2). Otherwise, there were no significant differences between flours at different ERs for stability, development time, degree of softening (DoS), and quality number (Q number) (Table 2).

There were no significant differences between all the treatments for all extensiogram characteristics (Table 3). For α-amylase activity, there were no significant differences between amylogram parameters of the produced flours (Table 4). There were no significant differences between produced flour for big particle size

(> 710 µm and > 354 µm) (Figure 1). The percentage was between 0.2 to 0.3% and between 0.4% to 0.8% for particle size > 710 µm and > 354 µm respectfully for the three produced flours. Whereas the flour at 80% ER had a significant increment compared to other flours for particle size > 183 µm (Figure 1). For particle size < 129 µm, flour at 85% ER had a significant increment compared to flour at 80% ER (Figure 1).

Table 1. Chemical properties of flour produced at different extraction rates

Attributes	Extraction rate		
	80%	85%	92%
Moisture (%)	13.5±0.07[a]	13.6±0.00[a]	13.5±0.00[a]
Protein (%) at 14% mb	11.3±0.24[a]	11.2±0.24[a]	11.4±0.06[a]
Ash (%) at db	1.04±0.02[c]	1.11±0.03[b]	1.24±0.02[a]
Wet gluten% at 14% mb	25.8±0.05[a]	23.8±0.14[a]	23.8±0.91[a]
Gluten index (%)	96.1±0.55[a]	94.8±1.51[a]	93.1±0.56[a]

Values are expressed as a mean±SD from two independent experiments. Values with different superscripts within the same row are significantly different (p<0.05). db: dry basis, mb: moisture basis.

Table 2. Farinogram characteristics of flour produced at different extraction rates

Attributes	Extraction rate		
	80%	85%	92%
Water absorption (%)	58.4±0.28[c]	60.1±0.21[b]	61.4±0.1[a]
Stability (min)	5.0±0.35[a]	4.8±0.21[a]	4.8±0.28[a]
Development time (min)	4.3±0.0[a]	4.3±0.88[a]	4.6±0.38[a]
DoS (BU) 10 (min)	91±8.5[a]	103±9.9[a]	88±9.9[a]
Q number	57±2.1[a]	56±2.83[a]	58±2.8[a]

Values are expressed as a mean±SD from two independent experiments. Values with different superscripts within the same row are significantly different (p<0.05). DoS: Degree of softening.

Table 4. Amylogram characteristics of flour produced with different extraction rates

Amylogram characteristics	Extraction rate		
	80%	85%	92%
Begin of Gelatinization (°C)	61.5±0.14[a]	61.3±0.28[a]	61.7±0.14[a]
Gelatinization temperature (°C)	86.4±1.77[a]	85.8±0.21[a]	85.5±0.01[a]
Gelatinization maximum (AU)	915±44.55[a]	953±21.92[a]	897±10.61[a]

Values are expressed as a mean±SD from two independent experiments. Values with different superscripts within the same row are significantly different (p<0.05).

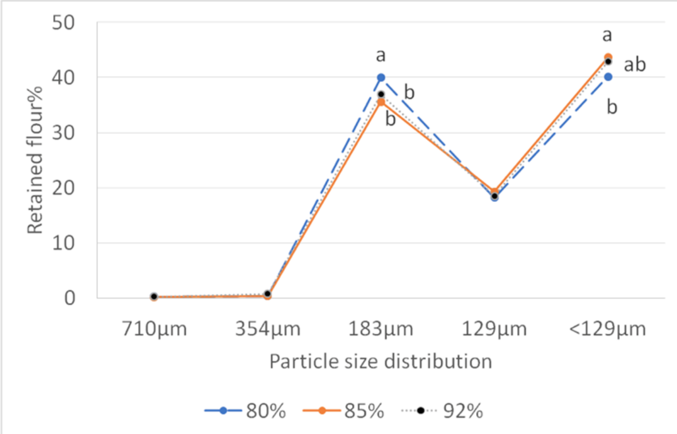

Figure 1. Particle size distribution of produced flour at different extraction rate. The mentioned particles were above the sieves except for <129, which was under the sieve. Different letter notations indicate significant difference (p<0.05).

There were considerable differences between bran obtained by different mills. The fine bran obtained by the industry mill generally had a smaller particle size compared to other produced bran (Figure 2), whereas

Table 3. Extensiogram characteristics of flour produced at different extraction rates

Attributes	Extraction rate		
	80%	85%	92%
45 min			
Energy (cm^2)	64.5±2.12[a]	61.5±3.54[a]	59.0±4.24[a]
Extensibility (mm)	183±16.26[a]	185±10.61[a]	170±19.09[a]
Resistance$_{50}$ (BU)	230±14.14[a]	232.5±13.44[a]	248.0±1.41[a]
Max Resistance (BU)	268.5±10.61[a]	259±15.56[a]	264±0.0[a]
Ratio (max)	1.5±0.21[a]	1.4±0.14[a]	1.6±0.21[a]
90 min			
Energy (cm^2)	73.5±0.71[a]	70.5±0.71[a]	71.0±8.49[a]
Extensibility (mm)	178±20.51[a]	161±24.04[a]	166±5.66[a]
Resistance$_{50}$ (BU)	274±25.56[a]	304±7.07[a]	315±38.18[a]
Max Resistance (BU)	326±21.92[a]	344±3.54[a]	340±38.9[a]
Ratio (max)	1.9±0.35[a]	2.2±0.35[a]	2.1±0.35[a]
135 min			
Energy (cm^2)	79±3.54[a]	73.5±3.54[a]	72.5±12.02[a]
Extensibility (mm)	173±14.85[a]	148±5.66[a]	152±8.49[a]
Resistance$_{50}$ (BU)	286±65.05[a]	327±12.73[a]	353.5±55.86[a]
Max Resistance (BU)	344±62.93[a]	369±12.73[a]	376±58.69[a]
Ratio (max)	2.0±0.57[a]	2.5±0.14[a]	2.5±0.49[a]

Values are expressed as a mean±SD from two independent experiments. Values with different superscripts within the same row are significantly different (p<0.05).

bran produced by Quadrumat mill had a bigger particle size compared to other produced bran.

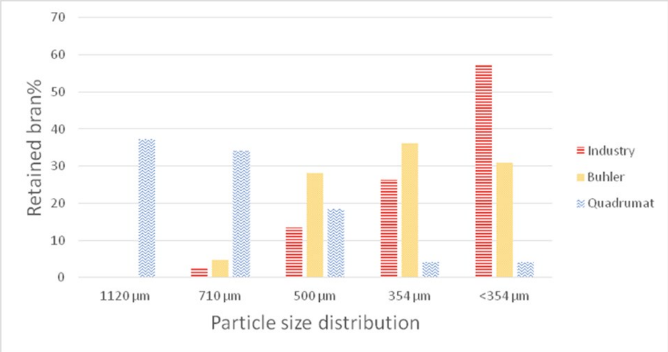

Figure 2. Particle size distribution of fine bran produced by an industry mill, Buhler, and Quadrmat mill. The mentioned particles were above the sieves except for <355, which was under the sieve.

4. Discussion

The chemical composition of flour is an important issue in terms of its nutritional value and its quality. High ER flour is known to have more vitamins, minerals, fibres, and antioxidants compared to refined wheat flour because outer layers of grains have more of these compounds (Boita *et al.,* 2016). Furthermore, increasing ER led to a rise in the protein content of the produced flour. Azizi *et al.* (2006) mentioned that protein content was increased from 10.9% to 11.8% for flour with 80% ER and 93% ER respectfully at a 14% moisture basis. In the current study, unexpectedly, there was insignificant and a slight increment of protein on behalf flour at 92% ER (Table 1). Ramírez-Wong *et al.* (2007) reported that there was a significant difference between flour at ER 74% and 80% of white wheat flour, but no significant difference of the same ERs with red wheat flour. Azizi *et al.* (2006) mentioned that ash content was increased with high ER flour, it was increased from 0.54% to 1.51% for flour at 70% and 93% ER respectfully, which agrees with the result of this study. Ash content of 80%, 86%, and 93% ER flour were 0.79%, 1.06%, and 1.51% respectfully (Azizi *et al.,* 2006), which were different from the ash content of this study for the approximately similar ER (Table 1). However, these differences are probably belonging to the wheat variety and milling process. The moisture content of the produced flour was within the limit of the Iraqi Standardization 14.0±0.1% (IQS, 1988). Alhendi *et al.* (2021) reported that the moisture content of flour produced by three different industry mills was between 12.4 to 14%, which is within the moisture content of this study. The gluten concentration was reduced insignificantly with increasing ER, and this result disagrees with the Ramírez -Wong *et al.* (2007). They mentioned that the amount of gluten-reduced significantly with the increase of ER from 80% to 100% for red and white wheat. Bressiani *et al.* (2019) observed that with a bigger particle size whole wheat flour, the amount of wet gluten was decreased significantly, and they claimed that the reason is the aggregation of gluten will be difficult with large particle size. The fine bran added in this study made no significant differences related to the big PSD (710 and 350 µm) (Figure 1) as it will be discussed in the particle size section. Therefore, the small bran added in this study might be the reason behind the insignificant change of the gluten aggregation. On the other hand, there was no definite pattern for wet gluten amount at different ERs (70% to 93%) (Azizi *et al.*, 2006). High gluten amount and high gluten index are good indicter of high-quality flour (Meerts *et al.,* 2017).

Farinogram and extensiogram are very popular techniques to measure the dough strength by their different parameters provides. Water absorption is one of these parameters, and it increased at high ER flour compared to others (Table 2), and this result agrees with the Mueen-ud-Din *et al.* (2010) and Ramírez-Wong *et al.* (2007). Dough stability was changed insignificantly at different ER, as well as for dough development time (DDT). Azizi *et al.* (2006) mentioned that dough stability was decreased with high ER, while Ramírez-Wong *et al.* (2007) reported that dough stability was decreased with increasing ER from 70% to 80% then it was increased at 100% ER. Development time was reduced at high ER for white wheat flour, while it has fluctuated with red wheat flour (Ramírez-Wong *et al.*, 2007). Energy and extensibility of flours at high ER were lower than the counterparts of flour at 80% ER for the three resting times (Table 3), however the decrease was insignificant. Ramírez-Wong *et al.* (2007) mentioned that dough strength is known to be reduced with increasing ER, probably because of gluten dilution with increasing bran content and because of impaired network formation. Also, Hemdane *et al.* (2016) mentioned that loaf specific volume was decreased when replacing 15% of bran instead of flour. Mostly, there were no significant changes related to the rheological parameters (Tables 2 and 3), and this might be due to the particle size effect of the produce, and it will be discussed later. However, such an unexpected result should be confirmed by different industry mills. In addition to studying the effect of adjusting the rolls on the efficiency of the mill with long time processing.

Alpha-amylase is located mostly in the pericarp and slightly in the aleurone layer and seed coat (Rani *et al.,* 2001), which refers to increasing Alpha-amylase with high ER. However, in this study increasing ER up to 92% compared to 80% had no significant effect on Alpha-amylase activity. This result is probably due to the lower Alpha-amylase activity in the grain. Alhendi *et al.*

(2019) reported that four Iraqi wheat varieties had low Alpha-amylase activity, also Alhendi *et al.* (2021) mentioned that flour produced from a wheat mixture, which used in different mills in Iraq had low enzyme activity too.

While Azizi *et al.* (2006) reported that the coarser particle size of bran influences the flour quality more than the finer particle size, which can affect the gluten network, texture, and general quality of bread. Zhang and Moore (1999) reported that fine bran reduced the specific bread volume and darker crumb compared to medium and coarser particle size bran, however, fine bran produced smoother crust than others. Concurrently, there were mostly no significant differences between flour at different ER levels in terms of dough strength and that might be referring to the insignificant differences between the big particle size (710 and 354 µm) of the produced flour (Figure 1). The particle size above 180 µm of 80% ER flour was significantly higher than other flours, and this is an expected result because the opposite rolls of the mill were the nearest to each other at the 85% and 92% ER treatments, which led to producing smaller particle size. The significantly lower amount of flour passes through 129 µm at 80% ER treatment can be because of the same reason. The effect of ER on flour quality was studied extensively (Azizi *et al.,* 2006; Ramírez-Wong *et al.,* 2007; Mueen-ud-Din *et al.,* 2010). However, all these studies were done on a laboratory scale and there was a significant difference between flour particle size, mostly because of adding bran to increase the flour ER, which affected the flour quality. The comparison of PSD of bran produced by an industry mill and two laboratory mills revealed that there were clear differences between them (Figure 2).

4. Conclusion

In conclusion, increasing flour ER from 80% up to 92% without a significant effect on the flour rheological properties is considered a promising achievement in terms of high ER (high nutrition value) without affecting the dough quality. This extraordinary result is probably because of producing flour at different ER with no significant differences in their particle size, which was obtained because of using an industrial mill instead of a laboratory mill.

Acknowledgements

The authors are grateful to the State Company for Grain Processing for allowing us to use a governmental mill and made all the required adjustments.

References

AACC Methods. (2000). Approved methods of the American Association of Cereal Chemists. 10th ed. St. Paul, USA: American Association of Cereal Chemists.

Alhendi, A.S., Ahmed, T.H., Albayati, W.S., Almukhtar, B.Q., Ali. Z.K. and Al-Hayani, N.K. (2021). Comparisons between flour quality produced from three different mills: buhler, quadrumat and industry mills. *International Journal of Food Studies*. [In Press].

Alhendi, A.S., Almukhtar, B.Q. and Al-haddad, F.M. (2019). Changes in flour quality of four Iraqi wheat varieties during storage. *Pertanika Journal of Tropical Agricultural Science*, 42(1), 15-25.

Azizi, M.H., Seyedin, S. and Peyghambardoust, S.H. (2006). Effect of flour extraction rate on flour composition, dough rheological characteristics and quality of flatbread. *Journal of Agricultural Science and Technology*, 8(4), 323-330

Belderok, B., Mesdag, J., Mesdag, H. and Donner, D.A. (2000). Bread-making quality of wheat: a century of breeding in Europe. Springer Science and Business Media. https://doi.org/10.1007/978-94-017-0950-7

Boita, E.R., Oro, T., Bressiani, J., Santetti, G.S., Bertolin, T.E. and Gutkoski, L.C. (2016). Rheological properties of wheat flour dough and pan bread with wheat bran. *Journal of Cereal Science*, 71, 177-182. https://doi.org/10.1016/j.jcs.2016.08.015

Bressiani, J., Oro, T., Da Silva, P., Montenegro, F., Bertolin, T., Gutkoski, L. and Gularte, M. (2019). Influence of milling whole wheat grains and particle size on thermo-mechanical properties of flour using Mixolab. *Czech Journal of Food Sciences*, 37(4), 276-284. https://doi.org/10.17221/239/2018-CJFS

Cornell, H.J. (2012). The chemistry and biochemistry of wheat. In Breadmaking, p. 35-76. Woodhead Publishing. https://doi.org/10.1533/9780857095695.1.35

Di Cagno, R., De Angelis, M., Lavermicocca, P., De Vincenzi, M., Giovannini, C., Faccia, M. and Gobbetti, M. (2002). Proteolysis by sourdough lactic acid bacteria: effects on wheat flour protein fractions and gliadin peptides involved in human cereal intolerance. *Applied and Environmental Microbiology*, 68(2), 623-633. https://doi.org/10.1128/AEM.68.2.623-633.2002

Hassan, E.G., Mustafa, A.M.I. and Elfaki, A.A. (2015). Effect of different starches on dough rheological properties of wheat flour. *Journal of Agri-Food and Applied Sciences*, 3(4), 110-117

Hemdane, S., Jacobs, P.J., Dornez, E., Verspreet, J., Delcour, J.A. and Courtin, C.M. (2016). Wheat (*Triticum aestivum* L.) bran in bread making: a critical review. *Comprehensive Reviews in Food Science and Food Safety*, 15(1), 28-42. https://doi.org/10.1111/1541-4337.12176

ICC Standards. (1996). Standard Methods of the International Association for Cereal Science and Technology. Vienna, Austria: International Association for Cereal Science and Technology,

IQS, Quality Standard of Iraq 37. (1988). Wheat products: wheat flour for bread industry. Central Organization for Standardization and Quality Control. Iraq: Ministry of Planning.

Kaur, A., Bala, R., Singh, B. and Rehal, J. (2011). Effect of replacement of sodium chloride with mineral salts on rheological characteristics of wheat flour. *American Journal of Food Technology*, 6(8), 674-684. https://doi.org/10.3923/ajft.2011.674.684

Meerts, M., Van Ammel, H., Meeus, Y., Van Engeland, S., Cardinaels, R., Oosterlinck, F., Courtin, C.M. and Moldenaers, P. (2017). Enhancing the rheological performance of wheat flour dough with glucose oxidase, transglutaminase or supplementary gluten. *Food and Bioprocess Technology*, 10(12), 2188-2198. https://doi.org/10.1007/s11947-017-1986-0

Mueen-ud-Din, G., Rehman, S., Anjum, F.M., Nawaz, H. and Murtaza, M.A. (2010). Effect of wheat flour extraction rates on flour composition, farinographic characteristics and sensory perception of sourdough naans. *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*, 4(8), 668-674.

Noort, M.W., van Haaster, D., Hemery, Y., Schols, H.A. and Hamer, R.J. (2010). The effect of particle size of wheat bran fractions on bread quality–Evidence for fibre–protein interactions. *Journal of Cereal Science*, 52(1), 59-64. https://doi.org/10.1016/j.jcs.2010.03.003

Perten, H. (1964). Application of the falling number method for evaluating alpha-amylase activity. *Cereal Chemistry*, 41(3), 127-140.

Posner, E.S. and Deyoe, C.W. (1986). Changes in milling properties of newly harvested hard wheat during storage. *Cereal Chemistry*, 63(5), 451-456.

Ramírez-Wong, B., Walker, C.E., Ledesma-Osuna, A.I., Torres, P.I., Medina-Rodríguez, C.L., López-Ahumada, G.A., Salazar-Garcia, M.G., Ortega-Ramirez, R., Jonson, A.M. and Flores, R.A. (2007). Effect of flour extraction rate on white and red winter wheat flour compositions and tortilla texture. *Cereal chemistry*, 84(3), 207-213. https://doi.org/10.1094/CCHEM-84-3-0207

Rani, K.U., Rao, U.P., Leelavathi, K. and Rao, P.H. (2001). Distribution of enzymes in wheat flour mill streams. *Journal of Cereal Science*, 34(3), 233-242. https://doi.org/10.1006/jcrs.2000.0393

Shewry, P.R. (2009). Wheat. *Journal of experimental botany*, 60(6), 1537-1553. https://doi.org/10.1093/jxb/erp058

Shewry, P.R. and Hey, S.J. (2015). The contribution of wheat to human diet and health. *Food and Energy Security*, 4(3), 178-202. https://doi.org/10.1002/fes3.64

Shewry, P.R., Halford, N.G., Belton, P.S. and Tatham, A.S. (2002). The structure and properties of gluten: an elastic protein from wheat grain. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 357(1418), 133-142. https://doi.org/10.1098/rstb.2001.1024

Šramková, Z., Gregová, E. and Šturdík, E. (2009). Chemical composition and nutritional quality of wheat grain. *Acta Chimica Slovaca*, 2(1), 115-138.

Wieser, H. (2007). Chemistry of gluten proteins. *Food Microbiology*, 24(2), 115-119. https://doi.org/10.1016/j.fm.2006.07.004

Yazar, G., Duvarci, O., Tavman, S. and Kokini, J.L. (2016). Non-linear rheological properties of soft wheat flour dough at different stages of Farinograph mixing. *Applied Rheology*, 26(5), 52508.

Zhang, D. and Moore, W.R. (1999). Wheat bran particle size effects on bread baking performance and quality. *Journal of the Science of Food and Agriculture*, 79(6), 805-809. https://doi.org/10.1002/(SICI)1097-0010(19990501)79:6<805::AID-JSFA285>3.0.CO;2-E

eISSN: 2550-2166