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Comparisons between Flour Qualities Produced by Three Different Mills: Buhler, Quadrumat, and Industry Mills

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Abstract

Three types of mills (Buhler, Quadrumat, and industry mill) have been used to determine the effect of mill type on the quality of the produced flour. Quadrumat and Buhler mills are usually used to produce flour at a laboratory level. Flour quality has been determined physically, chemically, and rheologically. Results showed that the particle size of flour produced by Buhler mill (FPB) was finer (mostly less than 132μm) than other produced flour, while flour produced by Quadrumat mill (FPQ) had 8% particle size bigger than 50gg, which is more than Iraqi accepted limit (5%). The moisture content of FPQ exceeded the moisture content limit (14%). While, all flour produced by industry mills (FPI) was within the Iraqi standard in term of particle sizes and moisture content. Gluten content of FPB was higher than other produced flours; however, most increments were not significantly different. The results also showed that using different mills has no clear effect on the gluten index and alpha-amylase activity. Farinogram and extensogram results showed that FPQ was stronger than other produced flour followed by FPI. In conclusion, the quality of FPQ was closer to the quality of FPI, however, Quadrumat mill needs to be adjusted to produce flour with finer particle sizes and lower moisture content. The Buhler mill, on the other hand, needs to be adjusted to produce flour with bigger particle size. Both laboratory mills (Quadrumat and Buhler) need to be adjusted to produce flour that expresses FPI correctly.

Keywords: Flour quality; Mills; Rheological properties

1 Introduction

Wheat is a unique cereal, which contains gluten protein that gives viscoelastic properties to dough, which is necessary for bread production. Several instruments have been developed to study chemical and rheological properties of dough (Kaur et al., 2011). Quality and quantity of gluten proteins play a key role in determining baking quality because it is responsible for determining water absorption capacity, viscosity, elasticity, and cohesively (Wieser, 2007). A Farinograph is an important device used to determine dough rheological properties such as development time, water absorption, stability, and degree of softening, which are useful parameters for the optimization of baking quality (Yazar et al., 2016). Measuring extensibility and resistance to deformation of dough can be determined with the use of an extensograph device (Di Cagno et al., 2002). Starch gelatinization, degradation of starch pastes by α-amylase, of flour can be

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determined by amylograph and falling number devices (Perten, 1964).
Iraqi domestic wheat varieties were classified as weak wheats that need to be mixed with strong imported wheat to produce a suitable flour for Iraqi bread (Tanorry) (Alhendi et al., 2019). The Grain Board of Iraq (GBI) determines the percentage mix of domestic and imported wheat at laboratory level by using the Quadrumat mill. The State Company for Grain Processing (SCGP) monitors flour quality at industry level either by testing the flour produced by industry mills or by monitoring wheat mixture by using a laboratory Buhler mill. Therefore, the aim of this study is to define the flour quality produced by different mills, namely, the Quadrumat mill, Buhler mill, and several industry mills. The physical, chemical, and rheological properties of the produced flour will be determined. The aim of this study is to compare the flour quality produced by Quadrumat mill, which is used to regulate the wheat mixtures, and flour produced by Buhler mill, which is used to monitor produced flour express the flour quality produced at industry level.

2 Materials and Methods

Wheat samples used in this study were taken from two different silos in Baghdad, which were Khan Bani Saad silo and Altaji silo. A wheat mixture of Altaji silo (one truck) was about 60% Iraqi domestic wheat (different varieties) + 40% Australian wheat, while a wheat mixture of Khan Bani Saad silo (two trucks) was about 90% domestic wheat (different grades) + 10% Australian wheat. In Baghdad silos, all domestic wheat varieties are stored together, and all imported wheat varieties stored together depending on the origin country. Three different, 20 to 25 tonne loads, two from Khan Bani Saad silo and one from Altaji silo, were used in this study. Although similar wheat mixtures were used in the two trucks of Khan Bani Saad silo, some differences between wheat mixtures were expected because of some technical issues. From each truck, two identical samples were taken to produce flour by using the Quadrumat mill and the Buhler mill, while the whole truck was monitored from a silo to an industry mill to produce flour (Fig. 1).

2.1 Produced Flour

A truck loaded with wheat was followed by the research team to an industry mill; the wheat was placed in an empty storage place (Fig. 1) and moisturized overnight (≈20-24h) before milling. The moisturization rate was based on an industry mill, which accounted for the long bath process, heat produced from machines, etc. to produce flour with moisture content about 14% wet basis (wb) or less. The impurities of wheat after cleaning were between 0.1 to 0.2%. The extraction rate of the produced flour was 80%, which is the percent of the produced flour in Iraq. Three different industry mills were used, which were named 1, 2, and 3 industry mills throughout the paper. The three mills were Buhler mills (Buhler mill, Buhler Group Company, Switzerland), and they were in Baghdad/ Iraq.
The first wheat samples (three samples from three different trucks), about 5 kg, were cleaned manu-ally to ensure that all the impurities and stones were removed (approximately zero% impurities). The samples were moisturized to 16% (wb) overnight (about 20-24h) by determining wheat moisture con-tent and calculating the required water amount to reach 16% wet weight (ww) by following The Pear-son square of balancing rations. Milling was done by using the laboratory Quadrumat mill (Braben-der® OHG, Brabender GmbH Co. KG, Duisburg, Germany) at Quality Control Department (QCD)/ GBI. The extraction rate of the produced flour increased to 80% by addition of some of the sieved bran.
The second wheat samples (three samples from three different trucks), about 5kg, were cleaned using a mechanical sifter (Tripette & Renaud Chopin, Marcellin Berthelot, France) (approximately zero% impurities) and moisturized to 16% overnight (20-24h) (similar to the method mentioned above) before milling using laboratory Buhler mill (Buhler MCKA 202, Buhler Group Company, Uzwil, Switzerland) at QCD/SCGP. Moisturizing wheat to 16% (ww) is the percentage used to follow in both laboratories to give

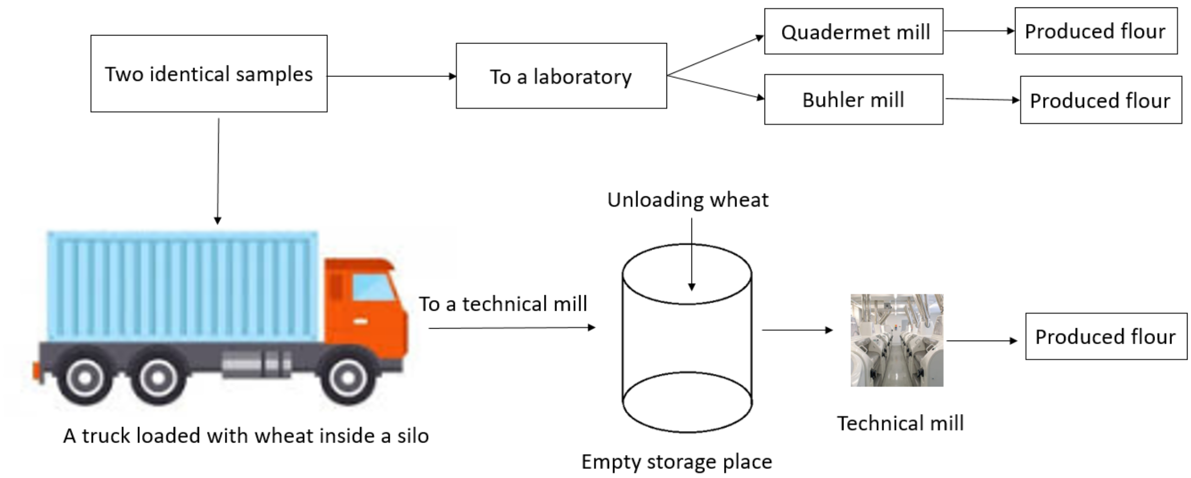

Figure 1: Diagram of wheat samples and mills used to produce flour.

flour within 14% (ww) moisture content flour. Sieves of Buhler mill consisted of three roll break (B) sieves with the following mesh sizes: B1 (710 and 150μm), B2 (600 and 132μm), B3 (530 and 132μm) and three smooth roll reduction (C):C1 (530, 150, 150μm), C2 (400, 132, and 132μm), and C3 (132 and 132μm). The extraction rate of the produced flour was raised to 80% through addition of some sieved bran produced by a bran finisher (Chopin BS, Tripette & Renaud Chopin, Marcellin Berthelot, France).

2.2 Physical, Chemical, and Rheological Analyses

Flour produced from different mills was analysed for particle size by using the Buhler Laboratory Siftermin 300 (Buhler Group Company, Uzwil, Switzerland) for five minutes. Also, they were analysed for moisture content (AACC 44-10), ash (AACC 08-01), wet gluten and gluten index (AACC 38-12), falling number AACC (56-81B), Farinograph (ICC 115/1), Amylograph (ICC 126/1), and Extensograph (AACC 54-10). All the analyses were made in the QCD/ SCGP.

2.3 Statistical Analysis

One-way analysis of variance (ANOVA) performed for statistical analysis of data. Least Significant Difference (LSD) of means implemented by using SAS version 9.0 (Cary, NC, USA). Significant differences considered at $\alpha = 0.05$ level. All analysed data accomplished in duplicates.

3 Results and Discussion

3.1 Physical and Chemical Analyses

Table 1 shows some chemical and physical properties of produced flour from different mills. Moisture content values of FPQ were the highest (14.8 to 15.6%) compared to other produced flour, and this result was expected because of the way that flour was produced by Quadrumat mill, which is a one-step produced flour (one flour product and one bran product), short bath, and one sieve. In the laboratory Buhler mill, there were several flour products and several bran products, several sieves, and a relatively longer bath process; all these factors led to reduce the moisture content of the produced flour. for the industry mill, heat produced by big machines and a long bath process were the main reasons to reduce moisture content, therefore, wheat usually moisturized to higher moisture (more than 16%) content to produce flour at 12-14% moisture. Moisture content values of FPB were between 11.6 and 12.9% and moisture content values of FPI were between 12.4 and 14.0%, which were within the Iraqi Standard 14.0 ± 0.1% (Quality Standard of Iraq 37, 1988). The difference of moisture content of FPIs was probably due to the moisture level used in each mill. FPQ was the only one that exceeded the limit and should be moisturized to less than 16% mc to produce flour within the limits of industrial quality. Alhendi et al. (2019) mentioned that the moisture content of flour produced from four Iraqi wheat varieties was between 14.4 and 14.7% (ww), which agrees with the moisture content that was reported in this study. The two studies followed the same method for producing flour.

Ash or mineral content of the produced flour is shown in s in Table 1. The highest ash values were found in the FPI which were between 1.1 and 1.2% and the lowest was found in the FPB which were between 0.84 and 0.86%. There were significant differences between FPB and FPI for all produced flour. Although ash content of produced flour was mostly significantly different, ash content was less than the Iraqi limit (1.2% dw) (Quality Standard of Iraq 37, 1988). Kaur et al. (2011) mentioned that ash content was from 0.50% to 0.62%, which is lower than the ash content of flour in this study. Ash content of flour was higher because of the high extraction rate of the produced flour, which was 80% compared to common extraction rate, which was 71-73% (Hassan et al., 2015; Posner & Deyoe, 1986). Alhendi et al. (2019) stated that the ash content of flour produced from four Iraqi wheat varieties was between 0.81 to 0.93%, and the extraction rate of the flour was 80%, which is similar to the extraction rate of this study.

Gluten and gluten index values of the produced flour are shown in Table 1. Gluten content of FPB was higher than other produced flour; however, some increments were not significantly different. Wet gluten was significantly different between the three flours produced at the first mill, while there was no significant difference between the flour produced at the second mill. Flour produced from the first mills had higher gluten index than others and that was due to the wheat mixture used in the first mills, which was 40% Australian wheat compared to other wheat mixtures, which were 10% Australian wheat. The quality and quantity of wheat gluten are known to be controlled by a wheat variety (Hadnadev et al., 2011).

The particle size distribution of the produced flour was presented in Table 1. The first and third industry mills produced very similar flour in terms of particle size, which was 2% larger than 50gg for both mills and 43% and 44% for particle size less than 10xx for both mills respectively. While the second industry mill produced a lower amount of 50gg (0.3%) and more amount of 10xx particle size (57%), which refers to a fine particle size compared to other FPI counterparts although the wheat mixture of second and third industry mills was same. The difference was probably due to adjustment of the industry mills. For FPB, the particle size was generally finer than other flour counterparts; the percentage of flour with particle size more than 50gg was between 0.2% and 0.7%, and the amount of flour with a particle size less than 10xx were between 86% and 94%. The particle size of FPQ was 8%g (above 50gg) and between 46% and 48% for particle size less than 10xx. All the produced flour had more than 40% (the minimum amount according to Quality Standard of Iraq 37 (1988) particle size less than 10xx. The similarity of particle size of FPQ and FPB individually was expected because of the use of the same mill and same adjustment in all mixtures. FPI and FPB were within the allowable limit of particle size bigger than 50gg, which is 5% of the produced flour (Data from SCGP), while all the FPQs were more than 5%. However, FPQ was close to FPI in the amount of particle size less than 10xx. Particle size influences the flour properties; reducing the particle size of the flour leads to increase starch damage and increase the surface area that causes more dough absorption and consequently more dough stickiness (Gaines, 1985). Further, Bressiani et al. (2017) reported that particle size affects the functionality of the gluten network and subsequently the bread volume. Therefore, FPQ and FPB should be controlled to be similar to FPI to express its quality appropriately.

Table 1: Chemical and physical properties of flour produced from three different industry mills, Buhler, and Quadrumat mill from three different wheat samples

Silo	Milling type	Moisture (%)	Ash (%) at dw*	Wet gluten% at 14%ww**	Gluten index (%)	Above 50gg sieve% (g/g)	Pass 10xx sieve% (g/g)
Altaji (truck 1)	Industry 1	12.9	1.09 ± 1.74a	29.2 ± 0.2b	66.0 ± 1.4b	2.0	43
	Buhler	12.9	0.87 ± 0.00b	30.0 ± 0.0a	72.9 ± 0.6a	0.2	94
	Quadrumat	15.6	1.03 ± 0.00ab	28.0 ± 0.0c	64.0 ± 1.4b	8.0	48
Khan Bani Saad (truck 2)	Industry 2	12.4	1.18 ± 0.00a	27.8 ± 0.7a	39.2 ± 0.9a	0.3	57
	Buhler	11.6	0.86 ± 0.00c	30.5 ± 0.7a	29.3 ± 3.8b	0.4	93
	Quadrumat	14.9	0.96 ± 0.00b	29.0 ± 0.5a	47.9 ± 0.6a	8.0	46
Khan Bani Saad (truck 3)	Industry 3	14.0	1.10 ± 0.00a	24.0 ± 1.4b	44.9 ± 0.3a	2.0	44
	Buhler	12.0	0.86 ± 0.01b	31.3 ± 0.3a	38.0 ± 0.7b	0.7	86
	Quadrumat	14.8	0.95 ± 0.04b	29.3 ± 0.4a	38.0 ± 0.7a	8.0	46

Values are expressed as a mean ± SD. Means with different letters within the same column and silo are significantly different at $p<0.05$.
*dw (Dry weight)
**ww (Wet weight)

3.2 Farinograph Characteristics

Water absorption of FPB was higher than other produced flour, which was around 65% at 14% (ww) moisture content (Table 2). For FPI had water absorption 58.0% to 59.2%, which was the lowest compared to others, except for the first industry mill. Water absorption of FPQ had a wider value range, which was the lowest (58.1%) in the first sample and highest (63.2%) in the second sample (Table 2). Water absorption of FPI was closer to water absorption of FPQ than to FPB.

Abang Zaidel et al. (2009) mentioned that water absorption of flour between 61.4 and 65.4% is considered a strong flour, while between 57.5 and 61.5% is a weak flour. Hadnadev et al. (2011) reported that water absorption value is the greatest value of the farinograph parameters, which directly indicates the volume of the bakery products. However, Gaines (1985) stated that reducing particle sizes of flour were responsible for high water absorption due to increasing the starch damage, which is an acceptable explanation for increasing water absorption of FPB because the other farinograph parameters (Table 2) were not within the level of the strong flour. Diósi et al. (2015) reported that the grade A flour should have a minimum 60.0% water absorption and a minimum 10.0 min stability value, while the grade B should have a minimum 55.0% water absorption and a minimum 6.0 min stability value.

The dough stability values of produced flour was presented in Table 2. The stability of FPB was the lowest values (from 3.2 to 4.0 min) compared to other produced flour, which is the opposite of the water absorption values. Dough stability of FPQ was the highest value. Depending on the above wheat flour classification (Diósi et al., 2015), all the produced flours were weak and had stability values less than quality B except for FPQ sample 3, which was 6.1 min. High dough stability refers to a high-quality dough that suitable for bread production (Wahyono et al., 2016).

Dough development time of FPQ was longer than that of other produced flour except for the third sample, which was the same as the FPI. Dough-development time determines the optimum mixing time during dough formation. Some flour properties, such as gluten and protein content, gluten index, ash content, etc. influence dough development time (Abbasi et al., 2015). Wahyono et al. (2016) mentioned that increasing development time gives an indication to a high-quality dough that suitable for bread production.

The degree of softening (DOS), the lowering of the consistency line after 10 and 12 min of the development time point calculated in BU (Mohammed et al., 2012), of the produced flour was

Table 2: Farinograph characteristics of flour produced from three different industry mills, Buhler, and Quadrumat mill from three different wheat samples

Silo	Milling type	Water absorption (%)	Stability (min)	Development time (min)	DoS* (BU) 10 12min	Q number
Altaji (truck 1)	Industry 1	59.2	4.0	4.3	55, 87	63
	Buhler	64.6	3.2	4.2	93, 126	56
	Quadrumat	58.1	4.8	4.7	66, 96	65
Khan Bani Saad (truck 2)	Industry 2	59.2	4.8	4.8	47, 91	77
	Buhler	65.3	4.0	5.0	78, 117	67
	Quadrumat	63.2	5.9	6.0	36, 82	93
Khan Bani Saad (truck 3)	Industry 3	58.0	5.9	5.7	44, 94	86
	Buhler	65.3	3.5	4.4	65, 105	63
	Quadrumat	61.3	6.1	5.7	55, 91	78

presented in Table 2. The degree of softening values of FPB were the highest values compared to the other produced flours, while DOS for FPQ and FPI were closer to each other. A strong flour is characterized by a low degree of softening value ((Mohammed et al., 2012).

Farinograph quality number (FQN), is a time from the beginning of the mixing to a fall of 30 BU from the highest point of the curve (development time) (Weipert, 2006), of produced flour shown in Table 2. The lowest FQN was in FPB for all the three samples. There was no definite pattern between FPQ and FPI. High FQN indicates a strong flour (Mohammed et al., 2012), and it integrates the development time and stability, in addition to the degree of softening value (Weipert, 2006). Dencic et al. (2011) mentioned that the range of FQN of 140 cultivars was between 24.4 and 100.0 BU, and the FQN of the flour produced of this study was within the mentioned range.

3.3 Extensogram Characteristics

The extensogram characteristics of dough produced from different mills is shown in Table 3. The extensogram measures energy (cm^2), extensibility (mm), resistance (BU) after 50 mm, maximum resistance, and maximum resistance to extension ratio (R/E) (BU). The energy or the dough strength of FPQ was the highest compared to other produced flour for all the tested times (45, 90, and 135 min). However, the energy of FPQ was less than the reported energy (115, 116, and 106 cm^2) and (170, 145, and 135 cm^2) by the studies of Hassan et al. (2015) and Mohammed et al. (2012) respectively for the same resting times. Dough produced from FPB and FPI were closer to each other. The dough extensibility (mm) of FPB was higher than other produced flour for all the samples and for all the resting times (Table 3). The dough extensibility values of FPI and FPQ were close to each other (Table 3). The extensibility values of wheat flour mentioned by Mohammed et al. (2012) were 170, 145, and 135 mm for 45, 90, and 135 min respectively, which were within the range of this study. Increasing dough extensibility does not indicate a strong flour if the energy value and resistance are low. Resistance after 50 mm and maximum resistance of dough produced from FPQ were higher than other produced flour. The highest maximum resistance was in sample 2 of FPQ, which was 421, 574, and 557 BU for the three resting times, and they were less than the maximum resistance reported by Hassan et al. (2015), which were 510, 571, 538 BU. FPQ had higher maximum R/E ratio compare to other produced flour followed by FPI. From extensiogram characteristics, FPQ was the strongest flour followed by FPI.

Table 3: Extensogram characteristics of flour produced from three different industry mills, Buhler, and Quadrumat mill from three different wheat samples

Silo	Milling type	Energy (cm^2)			Extensibility (mm)			Resistance$_{50}$ (BU)			Max Resistance (BU)			Ratio (max)		
	(min)	45	90	135	45	90	135	45	90	135	45	90	135	45	90	135
Altaji	Industry 1	64	53	62	176	154	148	212	226	255	238	239	272	1.4	1.5	1.8
(truck 1)	Buhler	50	54	49	195	188	166	175	175	193	195	199	212	1.0	1.1	1.3
	Quadrumat	85	70	89	165	149	151	284	313	365	358	364	422	2.2	2.4	2.8
Khan Bani	Industry 2	35	35	27	129	116	107	197	207	165	205	227	191	1.6	2.0	1.8
Saad (truck 2)	Buhler	43	31	32	180	161	162	150	128	134	167	134	142	0.9	0.8	0.9
	Quadrumat	70	73	70	120	95	93	409	573	555	421	574	557	3.5	6.1	6.0
Khan Bani	Industry 3	40	34	26	119	97	94	251	238	190	254	258	218	2.1	2.7	2.3
Saad (truck 3)	Buhler	29	24	19	180	168	162	100	92	80	108	94	80	0.6	0.6	0.5
	Quadrumat	56	60	56	131	119	109	286	358	371	307	362	371	2.3	3.1	3.4

Table 4: Amylogram curve characteristics and falling number of flours produced from three different industry mills, Buhler, and Quadrumat mill from three different wheat samples

Silo	Milling type	Amylogram characteristics			Falling number (s)
		Begin of Gelatinization (°C)	Gelatinization temperature (°C)	Gelatinization maximum (AU)	
Altaji	Industry 1	62.1	87.8	1402	548 ±18a
(truck 1)	Buhler	60.4	85.8	1155	566 ± 16a
	Quadrumat	61.0	86.5	1270	586 ± 16a
Khan Bani	Industry 2	62.3	88.5	1444	595 ± 28a
Saad (truck 2)	Buhler	60.5	88.8	1414	606 ± 99a
	Quadrumat	61.3	89.9	1730	697 ± 44a
Khan Bani	Industry 3	61.9	88.4	1650	510 ± 58b
Saad (truck 3)	Buhler	60.5	89.6	1328	522 ± 5b
	Quadrumat	61.3	90.3	1629	693 ± 31a

3.4 Alpha Amylase Activity

Amylogram characteristics and falling number values are shown in Table 4. The maximum gelatinization (AU) and falling number (s) values of all the produced flours were high, which refers to low enzyme activity. This result agrees with the Alhendi et al. (2019) study, which mentioned that the falling number of four wheat varieties cultivated in Iraq were between 400 to 700s. The maximum gelatinization of flour A, B, and C were 545, 727, and 660 AU respectively (Kaur et al., 2011), which are less than all the maximum gelatinization of this study (Table 4). As well for falling number, the best falling number for bread production is between 250 and 300s (Polat & Yagdi, 2017), which is less than the values of the produced flour of this study (Table 4). In comparisons between samples, no definite pattern observed.

4 Conclusions

In conclusion, the quality of FPQ was the strongest of produced flour, while FPB was the weakest. Therefore adjustment of Buhler and Quadrumat mills should be considered to produce flour that its quality close to FPI. Generally, FPQ had closer properties to FPI than FPB. FPQ should be adjusted to express the wheat mixing in a suitable way or considering the differences when the wheat mixture percentage is determined.

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References

Abang Zaidel, D. N., Chin, N. L., Yusof, Y. A., Rahman, R. A. et al. (2009). Analysis and correlation studies on gluten quantity and quality during production. *Journal of Applied Sciences*, *9*(9), 1686–1694.

Abbasi, H., Seyedain Ardabili, S. M., Mohammadifar, M. A. & Emam-Djomeh, Z. (2015). Comparison of trial and error and genetic algorithm in neural network development for estimating farinograph properties of wheat-flour dough. *Nutrition and food sciences research*, *2*(3), 29–38.

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

Bressiani, J., Oro, T., Santetti, G. S., Almeida, J. L., Bertolin, T. E., Gomez, M. & Gutkoski, L. C. (2017). Properties of whole grain wheat flour and performance in bakery products as a function of particle size. *Journal of Cereal Science*, *75*, 269–277. https://doi.org/10.1016/j.jcs.2017.05.001

Dencic, S., Mladenov, N. & Kobiljski, B. (2011). Effects of genotype and environment on breadmaking quality in wheat. *International Journal of Plant Production*, *5*(1), 71–81.

Di Cagno, R., De Angelis, M., Lavermicocca, P., De Vincenzi, M., Giovannini, C., Faccia, M. & 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

Diósi, G., Móré, M. & Sipos, P. (2015). Role of the farinograph test in the wheat flour quality determination. *Acta Universitatis Sapientiae, Alimentaria*, *8*(1), 104–110.

Gaines, C. S. (1985). Associations among soft wheat-flour particle-size, protein-content, chlorine response, kernel hardness, milling quality, white layer cake volume, and sugar-snap cookie spread. *Cereal Chemistry*, *62*(4), 290–292.

Hadnadev, T. D., Pojic, M., Hadnadev, M., Torbica, A. et al. (2011). The role of empirical rheology in flour quality control. *Chapters*.

Hassan, E. G., Mustafa, A. M. I. & Elfaki, A. A. (2015). Effect of different starches on dough rheological properties of wheat flour.

Kaur, A., Bala, R., Singh, B. & 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.

Mohammed, I., Ahmed, A. R. & Senge, B. (2012). Dough rheology and bread quality of wheat-chickpea flour blends. *Industrial Crops and Products*, *36*(1), 196–202. https://doi.org/10.1016/j.indcrop.2011.09.006

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

Polat, P. O. K. & Yagdi, K. (2017). Investigations on the relationships between some quality characteristics in a winter wheat population. *Turkish Journal of Field Crops*, *22*(1), 108–113.

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

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

Wahyono, A., Lee, S.-B., Yeo, S.-H., Kang, W.-W. & Park, H.-D. (2016). Effects of concentration of jerusalem artichoke powder on the quality of artichoke-enriched bread fermented with mixed cultures of saccharomyces cerevisiae, torulaspora delbrueckii jk08 and pichia anomala jk04. *Emirates Journal of Food* *and Agriculture*, *28*(4), 242–250. https://doi.org/10.9755/ejfa.2015-12-1116

Weipert, D. (2006). 13 fundamentals of rheology and spectrometry.

Wieser, H. (2007). Chemistry of gluten proteins. *Food microbiology*, *24*(2), 115–119.

Yazar, G., Duvarci, O., Tavman, S. & Kokini, J. L. (2016). Non-linear rheological properties of soft wheat flour dough at different stages of farinograph mixing. *Applied Rheology*, *26*(5). https://doi.org/10.3933/ApplRheol-26-52508