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Research Article

Characterization of Iraqi domestic wheat flour and the correlation between chemical and rheological properties

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Abstract
Iraqi domestic wheat quantity increased dramatically during the last two years, and the Iraqi government is looking for self-sufficiency in wheat production. However, the quality of the wheat flour is more important than the quantity in terms of making the final product. Therefore, this study aimed to determine the quality of Iraqi domestic wheat. Also, the study aimed to conduct the correlation between the chemical and rheological properties of flour samples. The study included 29 flour samples. The results showed that protein content was 10.2 ± 0.4%, gluten content was 19.6 ± 5.0%, gluten index was 73.2 ± 29.8%, and the falling number was 610 ± 89s. Rheological properties were ranged from 1.8 to 9.5min for the stability, 50 to 260BU for the degree of softening (DoS), zero to 78cm^2 for the energy, and 4 to 220mm for the extensibility. The highest correlation was between the gluten index and the Farinograph and Extensiograph parameters. Gluten index was highly correlated to DoS ($r = -0.87$, $p < 0.0001$), followed by extensibility ($r = 0.76$, $p < 0.0001$), stability ($r = 0.72$, $p < 0.0001$), and energy ($r = 0.66$, $p < 0.0001$). The correlation between other studied chemical properties, protein and gluten content, and most rheological parameters was non-significant. In conclusion, Iraqi domestic wheat quality was varied, from very runny to moderate. The gluten index was a precise parameter can be used to predict wheat quality. Therefore, Iraqi wheat breeders should be strongly considered the wheat quality in their work in addition to the quantity.

Keywords: Iraqi domestic wheat, gluten index, correlation, rheology

Abbreviations: DoS – degree of softening

Introduction

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Wheat is considered one of the most important crops in the world (Shewry et al. 2002). The flour quality is generally determined by analyzing its chemical and rheological properties. The quality and quantity of gluten, wheat protein, are one the most important properties of wheat flour in terms of producing bread because gluten can be extended and retention the produced gas (Hadnađev et al. 2011). Protein quality and quantity, starch conditioned (damage), and enzymes are the main factors affecting the wheat quality, and these factors are controlled by a wheat variety, time and conditions of wheat harvest, and milling technology (Hrušková and Machová 2002). Dough rheology properties are used in predicting baking performance mainly by Farinograph and Extensiograph measurements. Farinograph determines water absorption, degree of softening, stability, and development time. These properties are beneficial in terms of optimizing baking quality (Yazar et al. 2016). While, the Extensograph device measures energy, extensibility, and resistance to extension of dough (Di Cagno et al. 2002). Gluten index measurement is a quicker method for determining the wheat quality (weak, normal, or strong) comparing to other methods such as Fariongraph or Extensiograph (Oikonomou et al. 2015). α-amylase activity in flour can be measured by Amylograph or Falling number. The more falling number value, the less α-amylase activity. A high level of α-amylase activity, less than 250 s falling number value, affects negatively the backing quality (Ral et al. 2016).

Iraqi domestic wheat quantity increased massively during the last two years. Wheat production amount was 2.4 and 2.3 million tons during 2017 and 2018 respectively, while the production of 2019 and 2020 was 4.7 and 5.2 million tons (Data from Grain Board of Iraq). The Iraqi government is looking for self-sufficiency in wheat production, which means to cover the flour amount distributed as a monthly ration to the Iraqi people. The Iraqi domestic wheat varieties were classified as weak wheat quality, therefore domestic wheat mixed with strong imported wheat to produce a suitable flour for Iraqi flatbread (Tanoor bread) (Alhendi et al. 2019). Wheat breeders in Iraq are focusing on quantity more than other factors such as diseases resistance or wheat quality. Therefore, this study aimed to determine the quality of Iraqi domestic wheat and to conduct the correlation between some chemical and rheological properties. Predicting rheological properties, which need more time, effort, and expensive equipment by some chemical measurements, which are simple, fast, and unexpansive is a useful alternative way to facilitate works.

Materials and Methods

Fourteen wheat flour samples were taken from industrial mills in Baghdad on a produced day, and the other 15 flour samples were produced at a laboratory level. The wheat used in this study was three degrees of domestic (Iraqi) wheat, and the extraction rate of the flour was 80%, which is the extraction rate of the industrial mills in Iraq (Alhendi et al. 2021). All the flour samples were products of the wheat that were harvested during 2020.

Produced Flour. Fifteen wheat samples were taken from Ninawa, Sulaymaniyah, and Wasit, three provinces of Iraq. The wheat quality of Ninawa and Sulaymaniyah is known to be weak, while the quality of wheat taken from Wasit is known to be strong (Data from Quality Control Department, Grain Board of Iraq). About 2 kg of wheat samples were cleaned and moisturized to 15% overnight (20-24h). The milling process was made by using the laboratory Buhler mill (Buhler MCKA 202, Buhler Group Company, Uzwil, Switzerland). The extraction rate of flour was 80 ± 2% by using sieve sizes for breaks (B): B1, 710µm and B2, 180µm, and sieves for reductions (C): C1, 212µm, and C2, 280µm.

Chemical Analyses. The moisture content of the flour samples was determined based on AACC (44-10) depending on the weight difference because of the drying. Protein content was measured depending on AACC (46-30) by using infrared procedure. Gluten and gluten index were conducted by following AACC (38-12), which depends on the flour washing and centrifuging the produced dough. The gluten of some flour samples was not formed mechanically, therefore were determined manually following AACC (38-10). The falling number was determined based on AACC (56-81).

Rheological Analyses. Farinograph was proceeded by following ICC (115/1) to determine water absorption, stability, development time, and degree of softening. Extensograph was conducted depending on AACC (54-10) to determine energy extensibility, resistance to extension, and ratio number. Flour samples were stored at least seven days before conducting rheological properties.

Statistical analyses. orrelation, regression, and frequency analyses of the data were made by using IBM SPSS Statistics – Version 23.0. Correlation ≥ 0.25 was considered sufficient to make the regression analysis.

Results and Discussion

The range and the frequency of the chemical values of the used flour samples are important issues in terms of determining the flour quality and illustrating the obtained results. The range and the frequency of the chemical properties of flour samples used in this study were stated in Fig. 1. The protein content range was 9.3% to 11.5%, and the mean was 10.19% ± 0.433. The range of the protein content was not cover high protein content, above 12.5%, because the flour samples were taken from industry mills or silos. Several wheat verities have been used, which might be described the middle to low content of the proteins, 10.5%. A wider range of protein content should be considered in future studies. The range of wet gluten was from <10% to about 28%, and the majority of the samples were above 20% with a mean of 19.6% ± 4.97. The wet gluten content range seemed wide and cover a high range, which might indicate the quality of Iraqi domestic wheat flour. Also, the wide range is considered desirable data in terms of determining the correlation with other chemical and rheological properties (Fig. 1). The ratio between wet gluten content and gluten content was extremely wide, from 0.9 to 2.5, and the mean was 1.92 ± 0.46. The gluten index range was < 10% to 100%. Increasing gluten index indicted the strength of dough (Hadnađev et al. 2011). Also, Sapirstein et al. (2007) stated that loaf volume was highly related to gluten strength and inversely correlated to non-gluten proteins. The range of falling number values was 450s to 850s, which means all flour samples had a few α-amylase activities. Falling number values were higher than the required range, 250 to 300 s, for baked products (Ral et al. 2016). Alhendi et al. (2019, 2021) stated that Iraqi domestic wheat had low α-amylase activity.

The range and the frequency of Farinograph and Extensiograph parameters expressed the variation of the Iraqi wheat flour quality clearly, although all the wheat used in this study was supposed to be produced for bread making. Farinograph parameters for 29 flour samples were placed in Fig. 2. Water absorption values ranged from 55.4% to 66.4%, and the mean value was 60.4% ± 3.02. Development time was between 1.8min to 6.2min, and stability was between 1.7min to 9.5min. The degree of softening, 12min after max, was between 50BU to 260BU. Compared with wheat classification in the literature, Diósi et al. (2015) mentioned that the A quality group should have a minimum of 60.0% water absorption and 10 min stability, and the B quality group should have a minimum of 55.0% water absorption with a minimum of 6 min stability. Depending on this classification, only 6 samples can be classified within B quality, had 6 min stability or more, out of 29 samples (Fig. 2), while there was no flour sample within A quality group. Extensiograph parameters for 24 flour samples were shown in Fig. 3. Five flour samples could not behold or formed during the analysis because the flour was extremely runny. The energy values of the flour samples were ranged from zero to 78cm^2, and the average was 39.8 ± 26.3cm^2. The extensibility values were between 4 to 220mm, and resistance to the extension was between 20BU to 300BU.

The correlation coefficients were conducted among chemical, Farinograph, and Extensiograph properties (Table 1). High significant correlations were observed between different parameters. Protein content was significantly correlated to gluten content, water absorption, and development time (Table 1). However, the linearity correlation was not high, R^2 = 0.136, 0.174, and 0.183 respectively. A significant correlation between protein and gluten content (Table 1) was expected and observed in several studies (Perten et al. 1992, Ionescu et al. 2010). However, Perten et al. (1992) mentioned that the correlation between protein and gluten content was r = 0.98, while in this study, it was only 0.37. This massive difference between the correlations might be described and indicated the quality of the domestic wheat verities, which was not really considered during breeding or hybridization procedures. Water absorption and development time were the only two parameters of Fariongraph correlated to the protein content when the correlation value ≥ 0.25 was considered an adequate correlation. The positive significant correlation of the protein content with water absorption and development time was observed, and this result agreed with the Nikolić et al. (2013) and Ram et al. (2005) studie.

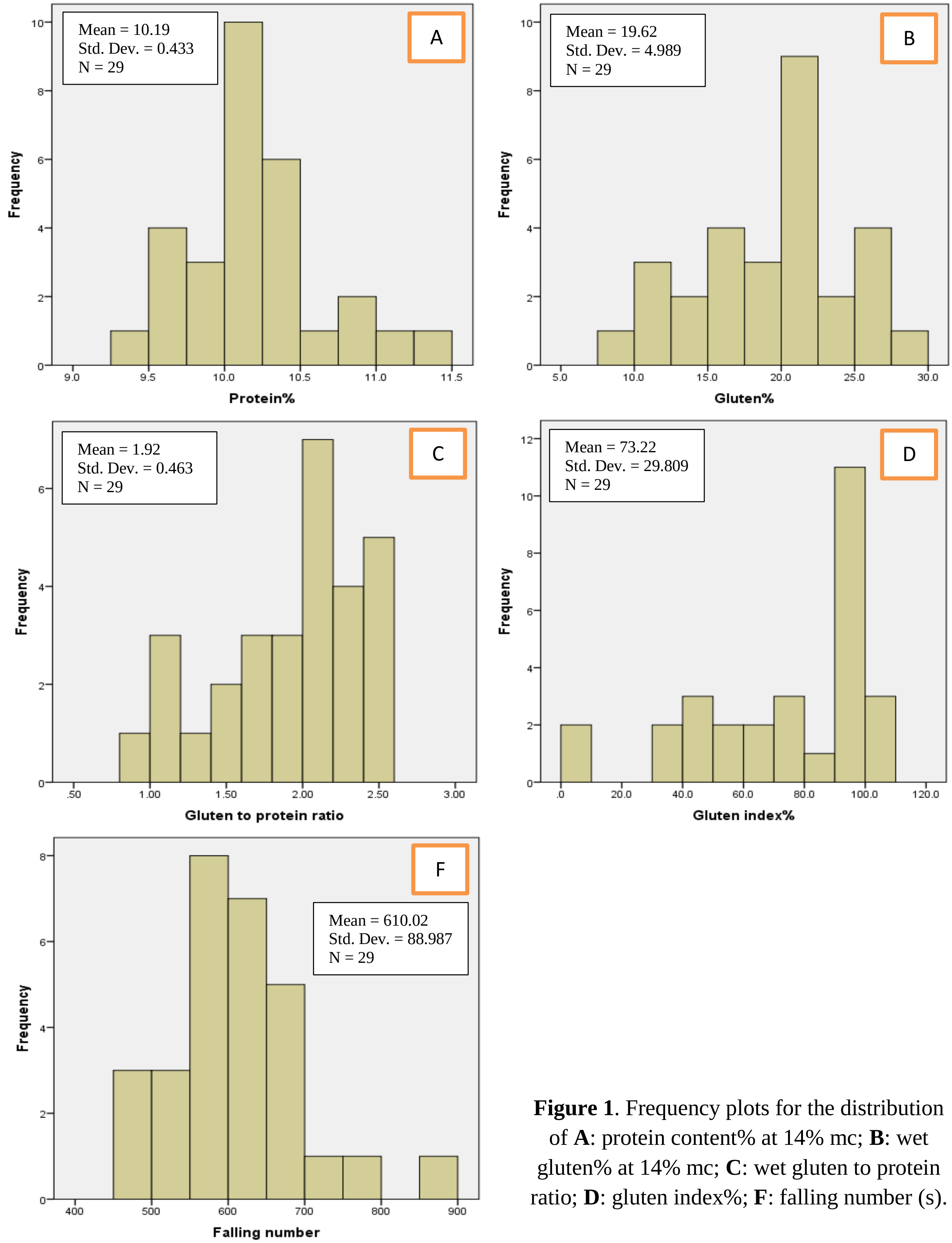

Figure 1. Frequency plots for the distribution of **A**: protein content% at 14% mc; **B**: wet gluten% at 14% mc; **C**: wet gluten to protein ratio; **D**: gluten index%; **F**: falling number (s).

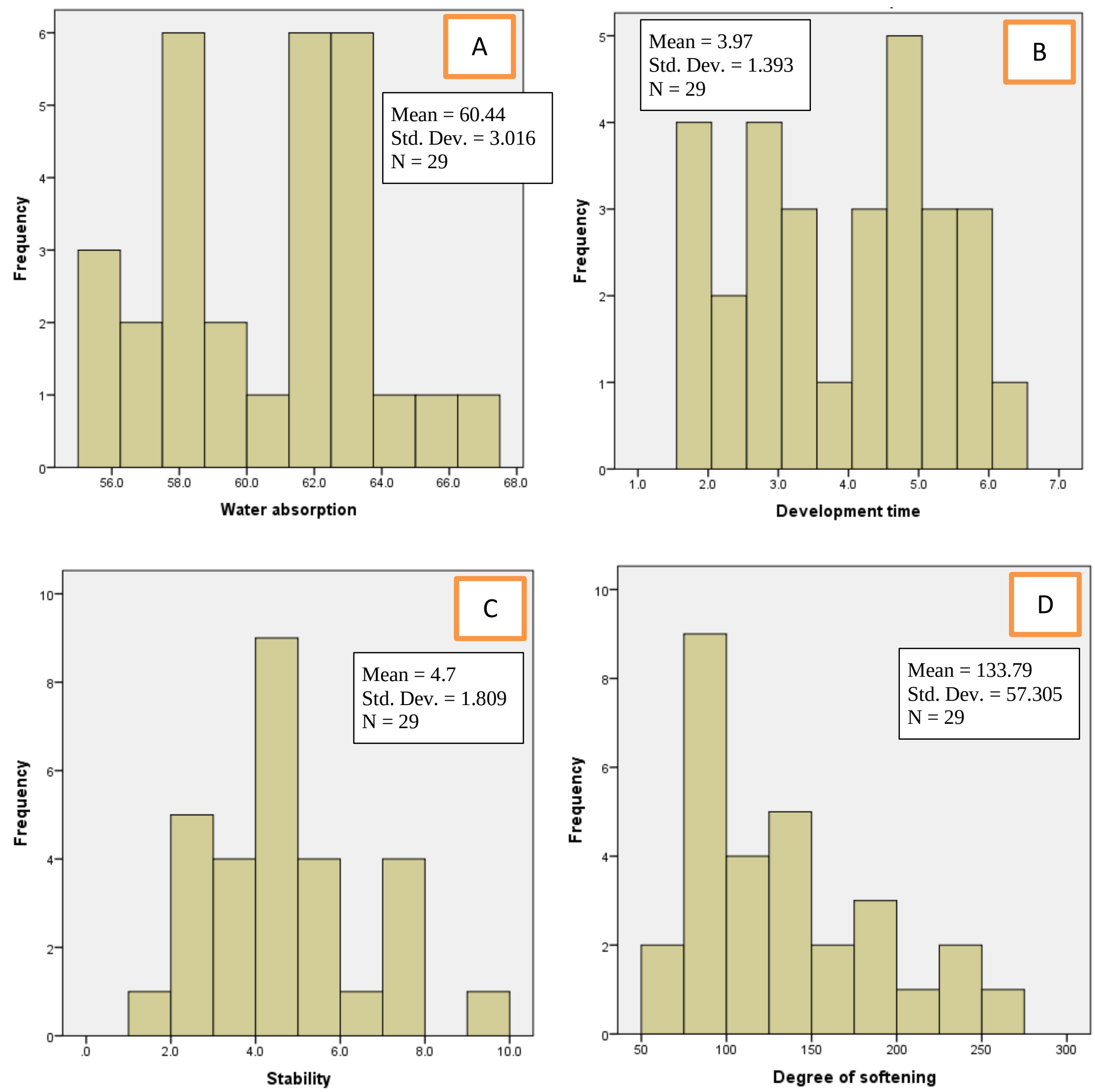

Figure 2. Frequency plots for the distribution of some Farinograph parameters, **A**: Water absorption (%); **B**: Development time (**min**); **C**: Stability (min); **D**: Degree of softening, 12 min after max, (BU).

However, the latter study mentioned a negative significant correlation between the protein content and the mixing tolerance index, which was not observed with the degree of softening of this study. Although there were several parameters of Extensiograph correlated to the protein content, such as energy and resistance to extension, there was no significant correlation. The highest correlation of protein content was with water absorption at a p-value < 0.001.

The gluten content correlation with chemical and rheological properties was shown in Table 1, and there was no correlation between gluten content and chemical or Farinograph parameters. There was no correlation between gluten content and gluten index for this study, and the same result had been reported by Perten et al. (1992) for commercial Swedish wheat samples. Nikolić et al. (2013) found that gluten content had a high negative correlation with water absorption and development time, and had no correlation with stability and degree of softening.

All the correlations were less than 0.25 except with protein content as mentioned above. The gluten content was correlated to all Extensiograph parameters except with extensibility, however, it was only significant with energy value (Table 1). The linearity correlation between gluten content and energy was not sufficient, R^2 = 0.189. The ratio between wet gluten content and protein content was between 0.9 to 2.5, which was truly wide. Ionescu et al. (2010) reported that the ratio between protein and gluten content differs depending on the used wheat verities. The ratio was between 1.91 and 2.2 for Romanian wheat varieties, between 2.27 to 2.90 for the Croatian wheat, and 2.6 for the Canadian wheat. Narrowing the ratio value might be referred to the consistency of the wheat flour quality. While worldwide protein and gluten content are the main properties for classifying wheat varieties, the rule did not apply for Iraqi domestic wheat at least regarding the current study. In conclusion, protein and gluten content of Iraqi domestic wheat were not useful data or could not be used to predict the quality of the wheat or flour, and this result confirmed that the wheat quality is not the main target for the Iraqi wheat breeder.

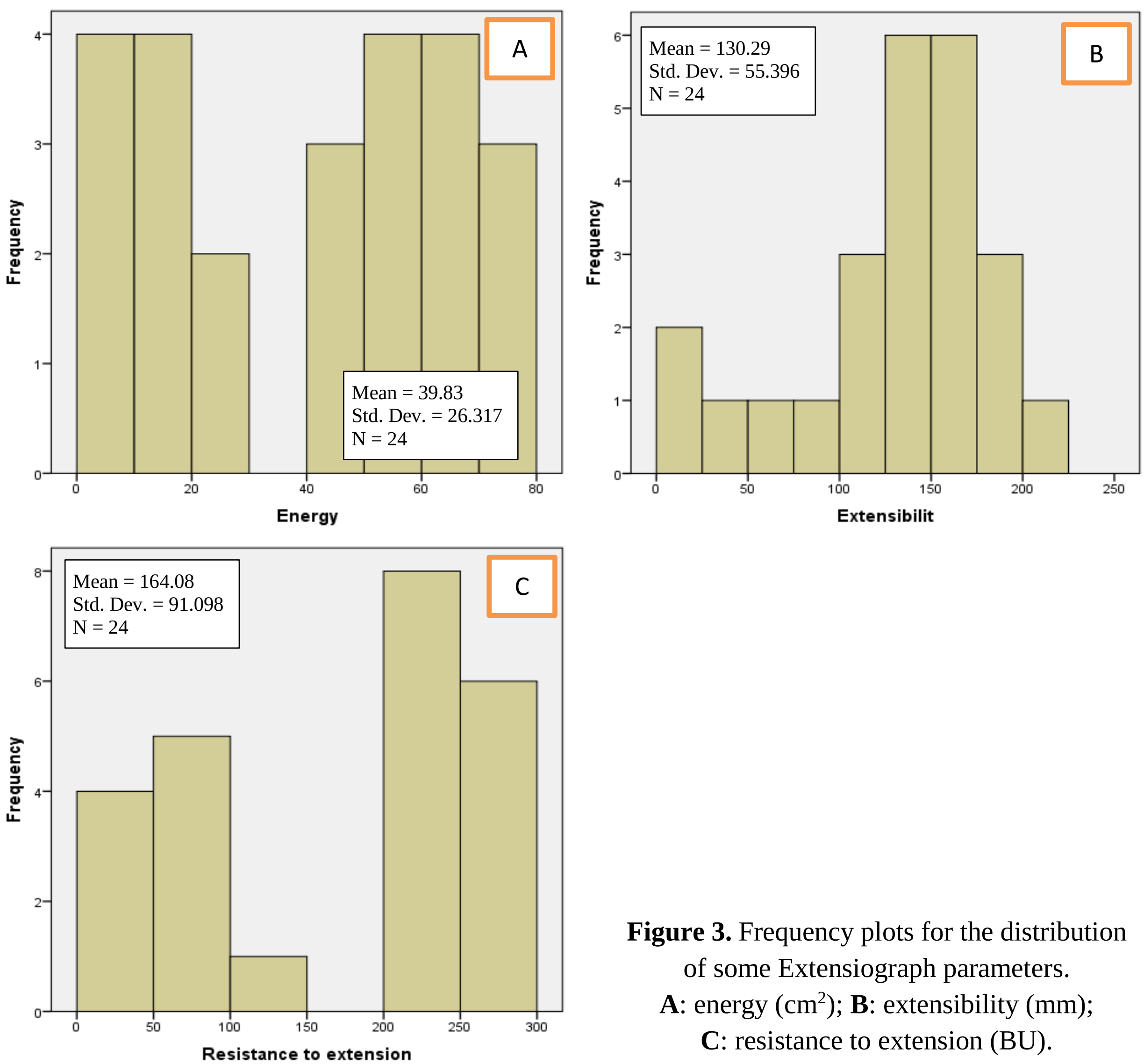

Figure 3. Frequency plots for the distribution of some Extensiograph parameters. **A**: energy (cm^2); **B**: extensibility (mm); **C**: resistance to extension (BU).

Table 1. Correlation coefficients of chemical and rheological properties of flour samples.

	PC	**GC**	**GI**	**FN**	**WA**	**DT**	**FS**	**DS**	**En**	**RE**	**Ext**
GC	0.37*										
GI	-0.11	0.08									
FN	-0.02	0.20	-0.09								
WA	0.42**	0.10	-0.57**	-0.24							
DT	0.43*	0.22	0.43*	-0.09	-0.04						
FS	0.03	0.21	0.72***	0.10	-0.58***	0.38*					
DS	-0.01	-0.19	-0.87***	-0.00	0.51	-0.45	-0.88***				
En	0.28	0.44*	0.66***	0.08	0.33	0.30	0.80**	0.84***			
RE	0.28	0.42	0.66***	0.04	-0.29	0.37*	0.72*	-0.77***	0.96***		
Ext	0.22	0.14	0.76***	-0.06	-0.27	0.40	0.65***	-0.86***	0.84**	0.78***	
RN	0.17	0.44	-0.64**	0.05	0.16	-0.14	0.30*	0.59**	-0.22	-0.15	-0.56**

PC, protein content at 14% mc; **GC**, wet gluten content at 14% mc; **GI**, gluten index; **FN**, falling number; **WA**, water absorption; **DT**, development time; **FS**, Fariongraph stability; **DS**, degree of softening (12 min after max); **En**, energy; **RE**, resistance to extension; **Ext**, extensibility; **RN**, ratio number.

*Significant at 0.05 level; **significant at 0.01 level; ***significant at 0.001 level.

Gluten index was not correlated to gluten content or protein content, however, it was highly correlated with some Farinograph parameters such as degree of softening and stability (Table 1). Also, gluten index was highly correlated, p-value < 0.0001 to Extensiograph parameters such as energy, resistance to extension, and e\xtensibility. The highest negative linearity correlation for gluten index was with a degree of softening, and the latter is well known to be negatively correlated to the strong flour (Sidhu and Bawa 2002). Also, the gluten index had a positive linearity correlation with stability, energy, and extensibility (Fig. 4), and all these parameters correlated positively with the strong flour (Huen et al. 2018). The predicted equations for some rheological parameters, degree of softening, stability, energy, etc., by gluten index value, indicated the importance of gluten index value in determining the flour quality. However, the correlation between gluten index and water absorption was negative. While increasing water absorption values are preferred by millers and bakers, the water absorption value has been reported to be affected by several factors such as protein content, particle size, starch damage, wheat hardness, etc. (Sapirstein et al. 2018). Some of these parameters correlated positively and others correlated negatively to the flour quality.

The falling number was not correlated with any chemical or rheological parameters (Table 1), and this result might be because of the few amount of α-amylase. Konopka et al. (2004) mentioned that there was a significant correlation between the falling number and dough extensibility and elasticity.

The correlation between Farinograph and Extensiograph parameters was presented in Table 1. Development time was significantly correlated to resistance to extension at p-value < 0.05. Stability was highly correlated to and extensibility at p-value < 0.0001 and significant correlated to other Extensiograph parameters at p-value < 0.05 and 0.001 (Table 1). The degree of softening was highly correlated to all Extensiograph parameters at p-value < 0.001.

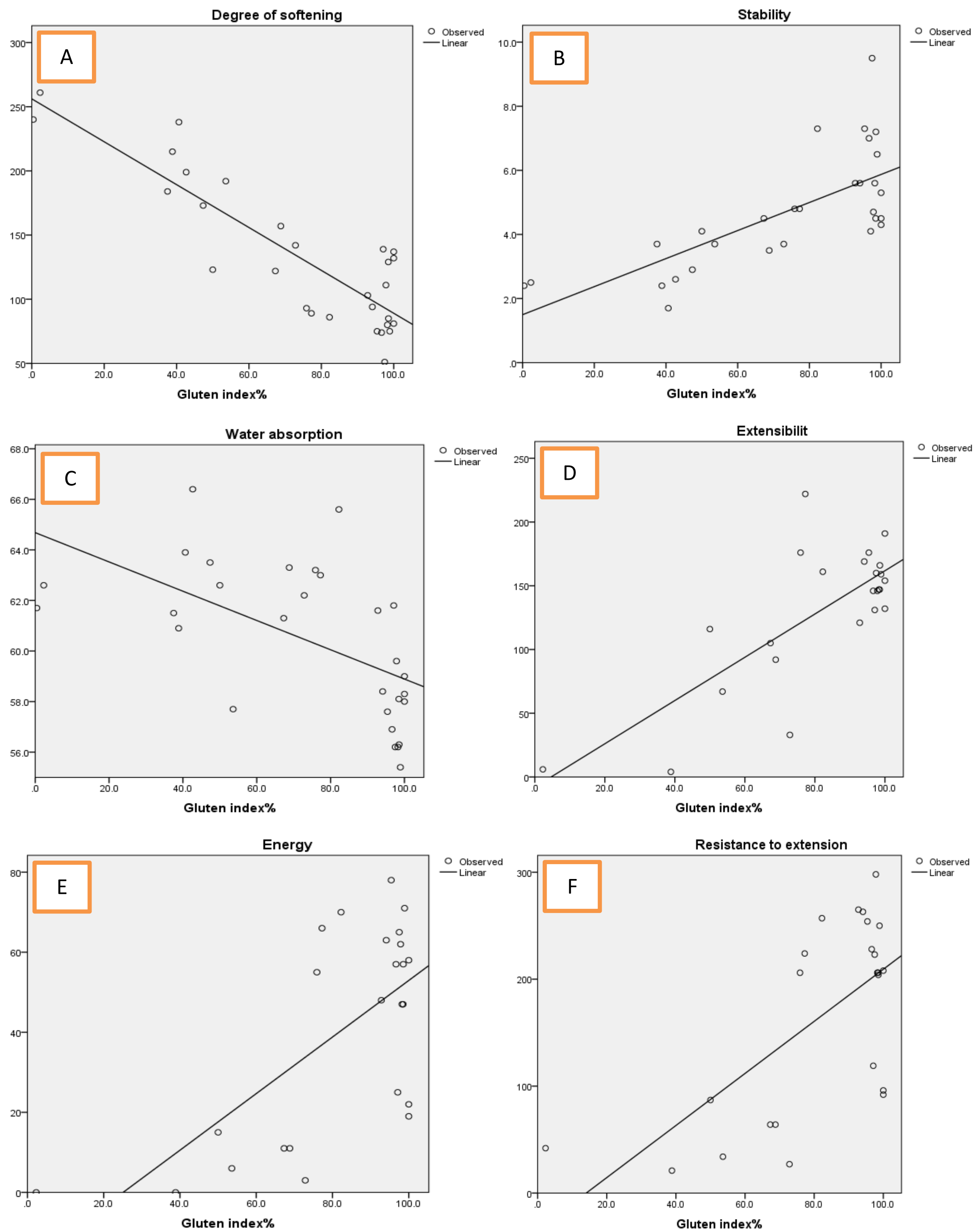

Figure 4. Gluten index% linearly correlated to the **A**: degree of softening; **B**: stability; **C**: water absorption; **D**: extensibility; **E**: energy; **F**: resistance to extension.

Because gluten index was the only chemical parameter that had a highly significant correlation with some Farinograph and Extensiograph parameters, therefore, the linearity between them was conducted (Fig. 4). The statistical data of the linearity correlation between gluten index and Farinograph and Extensiograph parameters were described in Table 2. The highest linearity was between gluten index and degree of softening (R^2 = 0.775, Table 2) followed by extensibility, R^2 = 0.571. The predicted equations of all the linearity correlations were presented in Table 2.

Table 2. Statistic data and equations of gluten index versus main parameters of Farinograph and Extensograph.

Variables Vs. gluten index	R Square	Adjusted R Square	Sta. Error	Equation
Degree of Softening	0.775	0.746	28.877	y = -1.671x+ 256.106
Stability	0.520	0.502	1.277	y = 0.044x + 1.497
Water absorption	0.328	0.303	2.518	y = -0.058x + 64.682
Extensibility	0.571	0.552	37.081	y = 1.696x – 7.869
Energy	0.440	0.414	20.144	y = 0.707x – 17.735
Resistance to extension	0.435	0.410	69.986	y = 2.435x – 34.252

Conclusions

Iraqi wheat flour quality produced during 2020 was extremely varied, and some of them were very runny that could not be held on an Extensiograph device. Therefore, the Iraqi wheat breeders should be highly considered the wheat quality through the breeding procedure. The protein and gluten content was not significantly correlated with the most Fariniograph and Extensiograph parameters, thus they have not considered a predicting value for wheat flour quality. While, gluten index was highly correlated with the most rheological properties, which can be considered a precise predicting value for flour quality.

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