






TECHNOLOGICAL AND BIOCHEMICAL ANALYSIS OF THE QUALITY OF FIVE ALGERIAN SOFT WHEAT (*Triticum aestivum*) VARIETIES: USE OF THE GLUTENINS PROFILES AS THE ALLELIC MARKERS

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ABSTRACT. The technological quality of wheat depends largely on the composition of the grain. The principal constituents responsible for the varietal differences are the storage proteins. This work has focused on technological and biochemical characterization of five varieties of soft wheat (*Triticum aestivum*) grown in Algeria: Anza; Arz; HD1220; Mahons Demias and Ain Abid. In addition, the polymorphisms of the high molecular weight glutenins subunits (HMW-GS) from 18 cereal varieties were analysed by SDS-PAGE and the obtained profiles were genetically defined. To achieve this work, the milling and the bread making values of the five varieties of wheat were determined. The physicochemical and technological analyses (proteins content, gluten content, starch content, amylase activity, sedimentation test, Chopin Alveograph test) were performed. The evaluation of the proteins levels indicated good rheological characteristics of a single variety: Ain Abid, who has interesting plastic properties (Good elasticity, good extensibility and a low sagging). A great diversity in three loci: GluA1, GluB1 and GluD1 was highlighted and the alleles positively correlated to the wheat quality were present in a remarkable way. These were alleles 2*, 1, 7-8, 7-9, 5-10 and 13-16. In addition, the associations in favour of a good quality were observed: allele 2* and allele 5-10; allele 17-18 and allele 2*; allele 1; allele 7-8.

Keywords: *Triticum aestivum*, milling quality, bread making quality, glutenins, allelic markers.

INTRODUCTION

The soft wheat (*Triticum aestivum*) is the first cereal cultivated in the world in terms of area and is the staple food of more than a third of the world population [1]. Improving the quality of wheat is progressing steadily and remains a goal of great magnitude. Indeed, the biochemical and the technological factors involved in the food products manufacture are many and the grain composition results from the expression of multiple genes more or less associated to the agronomic and the climatic factors in the wheat growing areas

[2]. In particular, many works have been involved in the study of the genetic control of grain protein composition and its impact on quality [3]. The diversity and the content of the storage proteins combined with the grain hardness can explain nearly 70% of the phenotypic variability of the baking strength [4].

The storage proteins are the gluten components responsible of the wheat varietal differences [3]. They play a key role in the bread-making process; the gliadins affect the elongation and the extensibility of the dough, while the glutenins influence its strength and elasticity [4]. The culture medium and fertilization are important in the expression of differences and changes of the technological behaviour that can have a variety. The protein knowledge and the technological characteristics of the wheat are of great interest for the orientation and the production use [5]. The glutenins identification by setting their electrophoretic profiles allows the establishment of positive or negative correlations between the proteins expression and the technological dough features such as toughness and extensibility [4].

In Algeria, cereal products occupy a strategic place in the food system and the national economy. Nevertheless, the challenge facing today is to reconcile the wheat production with the international quality standards, increase the diversity of crop varieties and accelerate their renewal. Therefore, it seemed appropriate and useful to assess the quality of the flours from Algerian bread wheat varieties. We conducted biochemical and technological analyses to determine if there was any correlation between the molecular markers and the technological quality of our varieties.

MATERIALS AND METHODS

Plant material

The plant material was mainly composed of soft wheat varieties grown in Algeria in the Region of Sidi BelAbbes. These varieties were provided by the Technical Institute of Field Crops. Thus, five varieties (Anza, Arz, HD1220, Mahons Demias and Ain Abid) previously preselected based on their vitreousness to the naked eye were used in our study. Also, seven wheat varieties (Sappo, Florence Aurore, Brimstone, Atlas 66, Soissons, Vilmorin 63 and Prinqual) provided by the UMR INRA, Clermont Ferrand (France) and Six local varieties (Ghiza 163, Sahel, Giza 164, Cham 6, Sajitari and Inkelab 91) were used as references in the SDS-PAGE.

Milling quality assessment

We determined the milling value of the five wheat varieties by evaluating some well-defined physicochemical parameters (Weight test, thousand kernel weight and ash content, moisture content). The moisture content of the studied flour was obtained by drying the sample (5 g) at 130 °C until obtaining a constant mass [6]. The extraction rate was determined by measuring the amount of the extracted flour after milling of one gram (1 g) of cleaned wheat [7]. The mineral content was determined in different flours by incineration of a sample of three grams (3 g) at 900 °C [6]. The thousand-kernel weight (TKW) was determined by counting the whole-wheat grains of a previously weighed sample [8]. The specific weight (weight of a hectolitre of grains) was measured in kilograms per hectolitres [9].

Protein content determination

The Kjeldahl method was used to determine the grain protein content by multiplying the value obtained by a specific conversion factor to cereals (5.70), according to the average of wheat amino acids composition [10].

Gluten levels evaluation

We manually obtained the gluten contents of the wheat samples by the dough preparing using malaxation under a trickle. The gluten proteins were hydrated, swollen and welded to form three-dimensional network and the obtained gluten was sucked off and weighed [11].

Amylase activity measurement

The amylase activity was assessed by calculating the Hagberg falling time (falling number). To do this, we have made a rapid bonding of a ground wheat suspension and the liquefaction time of the gelatinized starch was estimated [12].

Sedimentation test

The Zeleny index was determined according to ISO 5529. It represents the volume of sediments obtained from a flour suspended in a solution of lactic acid [10].

Chopin alveograph test

We prepared a dough by mixing 250 g of flour with salt water in a small mixer [10]. The alveograph curve was analyzed for parameters: P (the maximum over pressure needed to blow the dough bubble, expresses dough resistance), L (the length of the curve, expresses dough extensibility), P/L (configuration ratio of the alveograph curve), G (index of swelling) and W (baking strength).

Bread making test

To perform the test of bread making, we submitted the dough to a continuous and intensive mixing at two different speeds, which includes the same steps as the traditional kneading. The tempering was carried out at the same speed as that of the conventional kneading. However, the trouble arm was animated by a rotation twice as fast to incorporate large amounts of oxygen for better dough bleaching and improved gluten plastic qualities [6].

Glutenins extraction

The glutenins were extracted from the whole grain flour [13]. This was a sequential extraction by two basic solutions: solution A (propanol-1 50%); solution B (180 mM Tris-HCl pH8.8, 50% propanol). Initially, the gliadins contained in one grain of each variety were removed by extraction with 1 ml of solution A for 30 min under successive agitation at 65 °C and centrifugation for 1 min at 10.000 g. The resulting pellet was washed with 1 ml of solution A at 65 °C for 30 min, centrifuged at 10.000 g for 1 min and the supernatant was removed by suction. To ensure the complete removal of gliadins, the pellet was washed again for the third time with 0.5 ml of solution A, vortexed and centrifuged at 10.000 g for 5 min, and the supernatant removed by suction. The resulting pellet was used

as the initial source for the glutenins extraction. The glutenins extract was prepared by solubilisation of the pellet previously obtained with 100 ml of solution B containing 1% dithiothreitol. After incubation for 30 min at 65 °C and centrifugation for 5 min at 10.000 g, the mixture was added to 100 ml of solution B containing 1.4% 4-vinylpyridin, incubated for 15 min at 65 °C and centrifuged at 10.000 g for 10 min. The glutenins containing supernatant was recovered and stored at -20 °C.

SDS-PAGE analysis

The glutenins extracts of the different wheat varieties were analysed by polyacrylamide gel electrophoresis under denaturing conditions in the presence of sodium dodecyl sulphate (SDS-PAGE) [14,15]. The separation was performed on 12.8% polyacrylamide gel prepared in 125 mM Tris-HCl pH 8 containing 10% SDS. Before submitting the samples to SDS-PAGE, an aliquot of 100 ml of each extract (previously obtained from a single grain) was supplemented with 100 ml of loading buffer (65 mM Tris-HCl pH8, 2% SDS, 40% glycerol and 0.02% bromophenol blue). The samples were incubated at 65°C under stirring for 15 min, and then centrifuged at 10.000 g for 10 min [13]. The proteins separated by SDS-PAGE were revealed, using gels staining with 10% coomassie blue in 60% trichloroacetic. The electrophoretic profiles reading of the various glutenins was performed using the nomenclature established by Payne and Lawrence [16] and modified by Branlard *et al.* [17]. The known electrophoretic profiles of four varieties of soft wheat provided by Gérard Branlard (Clermont-Ferrand University, France) were used as controls in the establishment of the nomenclature of the HMW-GS alleles.

RESULTS AND DISCUSSION

Milling quality evaluation of the soft wheat varieties

The milling value determining is based on the assessment of the wheat flour ability to more or less meet some well-defined physicochemical characteristics: specific weight (SW), thousand kernel weight (TKW), ash content and moisture content [18].

Thus, we evaluated five parameters for the milling quality (Fig. 1). The Anza variety belonged to the small wheat class whose TKW was 34.07 g, while the remaining four varieties were an intermediate wheat with a TKW ranging from 35.81 to 45.23 g.

The SW is also a genetically controlled factor significantly influenced by the genotype [18]. The variety Anza SW was slightly higher compared to the standard (80.9 kg/Hl), while the Ain Abid variety had a slightly lower SW (71.74 kg/Hl). However, the varieties Arz, HD 1220 and Mahon Demias have shown values compliant with the standards included between 75.35 and 76.75 kg/Hl.

The minerals were present in small amounts in the wheat grain and even fewer in the endosperm, less than 1% [19]. The wheat contains the iron, the potassium, the magnesium, the manganese, the copper and the zinc, all these components are mainly distributed in the outer layers and the germ [20]. The ash content depends on the contamination rate of the starchy endosperm by the peripheral parts of the grain (envelopes and aleurone layer) and the seed during milling [21]. The mineralization depends on several factors: soil, genetic, climatic, physiological and technological factors (type of conditioning before milling, extraction rate) [8]. Furthermore, we found that the ash content of all wheat varieties was compliant to the norm.

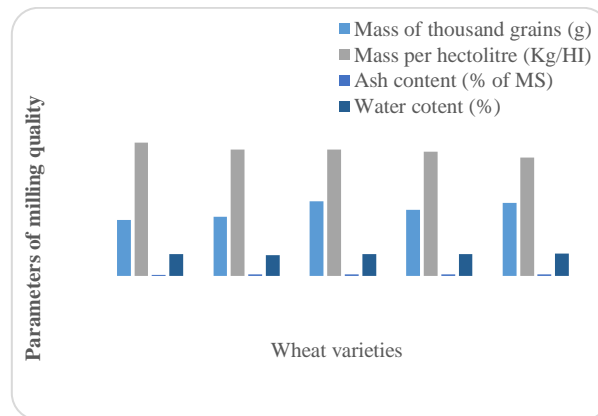


Fig. 1. Assessment of the milling quality. We evaluated the milling quality of five varieties of soft wheat. Therefore, we analysed four parameters (masse of thousand grains, Mass per hectolitre, ash content and water content).

The water content is an important parameter for obtaining a flour, which is preserved properly, indeed, its determination influences the precision of the various analyses related to the dry matter and their implementation [22]. The relative humidity is the amount of free water available in the sample responsible for many biological phenomena of the flour alterations. The declining of the water contents allows the classification of wheat samples as sparsely hydrated products [23]. We found that the humidity rate of the wheat varieties (12.74% to 13.67%) was more or less consistent and suitable for their conservation.

Baking quality characterization of the soft wheat varieties

The baking value depends mainly on both the amount and the quality of the storage proteins [24]. We appreciated the bread making of five varieties of soft wheat, using two different approaches, the first was indirect and involved the implementation of a series of physicochemical and technological analyses (Proteins content, gluten content, starch content, amylase activity test, sedimentation test and Chopin alveograph test), the second: the baking test, it was direct. The baking value defines the ability of the flour to give a good bread quality under suitable work conditions and baking performance. The indirect parameters of baking quality of five varieties of soft wheat were evaluated (Fig. 2). The protein content is a key criterion of baking quality [25]. It is governed by the gluten quality, which depends on the report glutenins/gliadins.

The environmental conditions greatly affect the expression of the grain proteins content. Indeed, numerous studies have shown that the content and the composition of the proteins vary depending on environmental factors such as the cultivation place and the level of nitrogen intake [26]. In addition, the protein content is also controlled by the genetic factors [27]. The expression levels of proteins depend essentially on the agronomic conditions and the plant development [28]. We obtained proteins proportions ranging from 9.2 to 12.18%, which corresponded to moderately proteins-rich varieties. The bread quality becomes very problematic when the flour protein content is less than 7% [29].

The amylase activity is the ability to break down starch into simple elements or fermentable sugars such as glucose and maltose. It is considered optimal if the falling number is between 200 and 300 S, which is essential for obtaining a large volume of

bread and a homogeneous and appreciable crumb [11]. The excessive or the insufficient presence of the alpha-amylase leads to a deterioration of the baking quality. Our results showed that the variety Anza was a hypodiastasic wheat with a falling number of 289 S (>250 S), while the varieties Ain Abid and Arz were hyperdiastasic wheats with a falling number of 147 and 134 S, respectively. In contrast, the remaining two varieties: HD1220 and Mahon Demias had a compliant falling number.

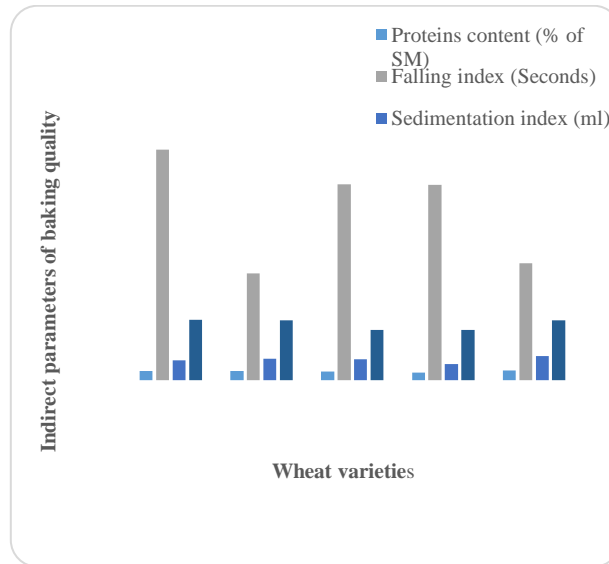


Fig. 2. Assessment of the baking values. We evaluated the indirect baking quality of five varieties of soft wheat. Therefore, we analysed four parameters (proteins content, falling index, sedimentation index and starch content).

The Zeleny index is an indicator of the proteins quality that essentially depends on the variety. However, the environmental conditions can affect the proteins content of the various fractions and in particular the gliadins [30, 31]. Moreover, the best Zeleny index was associated with the presence of the allele 'd', located on the Glu-A3 locus [3]. We obtained the Zeleny index values ranged between 20 and 30.5 ml. Comparing our results with the standards, we found that only the variety Ain Abid had a sedimentation rate of 30.5 ml, near the range recommended to the current bakery (30 and 40 ml) [32]. In addition, we observed an insufficient sedimentation rate (20 ml) of the variety Mahon Demias.

Elsewhere, we found that all our wheat varieties had a starch contents (63.25-75.75%), compliant to the standards and corroborated the data reported by Hemery *et al.* [33]. The nutritional value of cereals is also based on the carbohydrates present as starch that must be degraded by successive enzymes [34]. The gluten is a microemulsion stabilized by the protein network [35] and its properties become evident when the flour is hydrated, allowing the production of an expandable dough with good gas retaining properties [36]. The toughness (resistance to extensibility) of gluten can be explained by the presence of many disulfide covalent bonds that do not affect the elasticity, which is attributed to the ability of the HMW-SG repetitive domains to form hydrogen bonds [8].

As shown in Fig. 3, the flour strength was described according to their wet gluten content; the flour had a usual content ranging from 27 to 37% [37]. The wet gluten values

ranged between 20.27% and 32.88%, while the dry gluten rates suitable for bread making must be greater than 12.8% [7]. Thus, only the variety Ain Abid showed a satisfactory value of dry gluten, while the variety Mahon Demias had a rate of 6.87%. The gluten hydration capacity (GHC) ranges generally from 65 to 67% [38]. The variety Mahon Demias presented a GHC according to the standards. By contrast, the remaining varieties (Anza, Arz, Ain Abid and HD1220) have shown a low hydration capacity (Fig. 3).

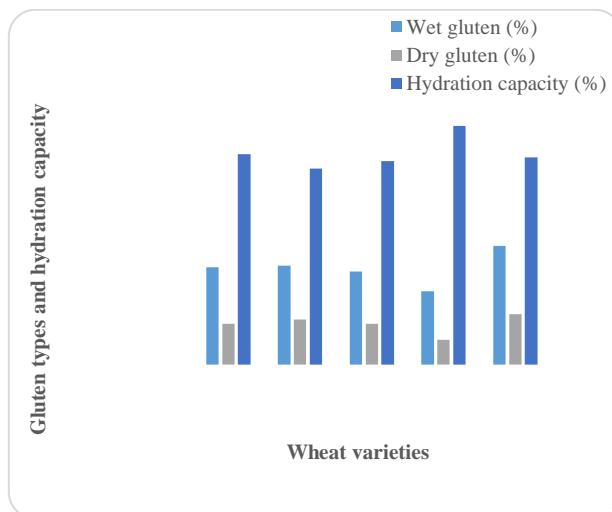


Fig. 3. *Gluten type and hydration capacity. We evaluated the gluten types and hydration capacity of five varieties of soft wheat. Therefore, we analysed three parameters (wet gluten, dry gluten and hydration).*

The Chopin alveograph test determines the flour baking strength (baking quality). It has a practical value, highly appreciated by the professionals of the second transformation. As shown in Fig. 4, the tenacity P of our flours ranged from 51.50 to 74.75 mm. The swelling (G) values fluctuated between 14.7 and 18.9. The configuration report (P/L) ranged from 1.08 to 2.66 was negatively correlated with the proteins content [11]. We found that the baking strength of our flours was ranged from 85 to 180 and the variety Ain Abid had the highest value. Despite its importance, the meaning of the baking strength is limited if we do not take into account the remaining alveographic characteristics [7].

In order to appreciate the baking properties of the previously mentioned five varieties, we conducted the bread-making test, which is the best means available to evaluate the baking quality [39]. The carbon dioxide produced and accumulated during the fermentation of wheat bread exerts an internal pressure on the impermeable gluten network, allowing the dough to rise the maintaining of the external structures [22]. This phenomenon is due to the dough strength, which corresponds to a reduction of the toughness (P) of gluten associated with an increase in its elastic resistance (L) [40]. The flour derived from the variety Mahon Demias presented variable characteristics. It was neither extensible, nor elastic and quickly released (Table 1). This was due to the high content of the gluten proteins, the rigidity and the tenacity of the gluten, and even to the low work of dough deformation.

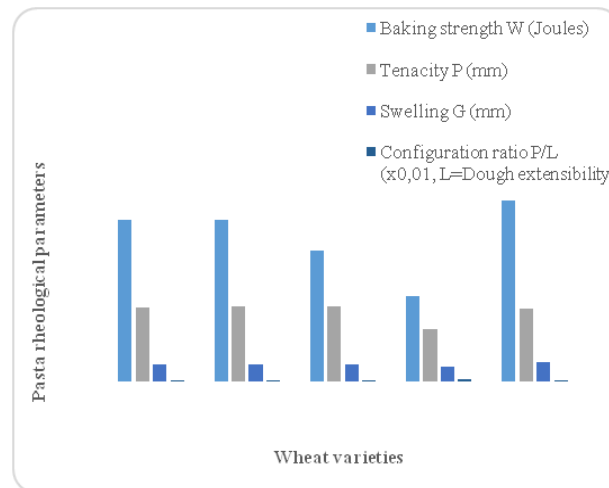


Fig. 4. Pasta rheological parameters. We evaluated the pasta rheological indicators of five varieties of soft wheat. Therefore, we analysed four parameters (baking strength, tenacity P, Swelling G and configuration ratio P/L).

Table 1. Rheological properties of dough and bread appearance of five soft wheat varieties

Characteristics		Varieties				
Dough aspects	Elasticity	Anza Inelastic	Arz Elastic	HD1220 Elastic	Mahon Demias Inelastic	Ain Abid Elastic
	Dough Extensibility	Fatty Extensible	Dry Extensible	Dry Extensible	Breakable No Extensible	Dry Extensible
	Relachment	Quick relachment	No relachment	No relachment	Quick relachment	No relachment
External bread conditions	Section	Flat	Round	Flat	Flat	Normal
	Volume	Poorly developed	Developed	Not EN developed	Not EN developed	Well developed
	Crest Fineness	Thick	fine	fine	Thick	Normal
Internal bread conditions	Crumb aspect	Inelastic	Sticky	Elastic	Sticky	Inelastic
	Porosity	Small	Tight	Tight	Irregular	Big

The bread volume is strongly associated with a high proteins content [4]. Our results confirmed that the baking strength of the flour was directly related to the quantity and the gluten quality evaluated using the Chopin alveograph. The varieties Arz and Ain Abid presented a specific volume compliant to the standards. Moreover, both the varieties HD1220 and Mahon Demias presented a reduced specific volume, which is certainly associated to the poor plastic quality of the flour. The identification of glutenins alleles when measuring the polymers weights highlights the interest of several parameters positively or negatively related to the flour characteristics such as the toughness, the dough extensibility, the P/L report and the bread volume [4]. Few studies have been conducted on the research of molecular markers (other than those coding for storage

proteins) associated with the bread volume [41]. The bread volume is determined by many factors particularly related to the effects of the proteins contents and their polymerisation. The extensibility shortcomings and the low bread volume represent two major problems when they are present in same farmer.

Glutenins polymorphism of the soft wheat varieties

Many works have been involved in the study of grain protein composition and its impact on wheat quality [3]. The diversity and the content of the storage proteins combined with the grain hardness can explain the phenotypic variability of the baking strength [4]. Indeed, proteomic analysis of the mature kernel aleurone layer in common and durum wheats revealed more than 1300 stained protein spots [42,43]. In *Triticum aestivum* genotypes had an average of 19% CBB stained aleurone layer spots more than *Triticum durum* genotypes. In this context, we were interested in the identification of the proteins belonging to the glutenins family.

The ability of the glutenins sub-units to join each other by disulphide bonds (S-S) is one of the main factors of bread wheat character [44]. The HMW-GS may bind to each other by disulphide and hydrogen bonding, promoting the S-S bonds formation at the polypeptide chain ends, which explains the dough resistance to extension [45]. The size of the chains thus formed depends on the nature and the number of the glutenins subunits and the dough processing conditions. The glutenins genetic polymorphism of five soft wheat varieties grown in Algeria were analysed by SDS-PAGE [15,17]. The mobility of the different glutenins sub-units were defined according to the nomenclature described by Payne and Lawrence [16] and modified by McIntosh and Lagudah [46].

The polymorphism results of HMW-GS obtained by SDS-PAGE are presented in Fig. 5 and Table 2. The different glutenins subunits detected for these soft wheats were quite varied regardless their genetic origin; we enumerated 12 different types of profiles (Table 2). In addition, there was a great diversity in the three loci GluA1, GluB1 and GluD1. Twelve different *Glu-1* alleles were found, three at *Glu-A1*, seven at *Glu-B1* and three at the *Glu-D1* locus (Table 3). At the *Glu-A1* locus, *Glu-A1b* encoding for subunit 2* was the most frequent allele with 66.66%, followed by alleles *a* and *c* with 22.22% and 11.11%, respectively. Otherwise, at the *Glu-B1* locus, the most frequent allele was *Glu-B1b* encoding for 7+8 subunits with a frequency of 27.77%. Alleles *i* (22.22%) and *c* (16.66%) were less frequent. Alleles *d* encoding for (6+8), *f* encoding for (13+16) and *h* encoding for (14+15) were found in one cultivar each. At the *Glu-D1* locus, subunits 2+12 encoded by *Glu-D1a* was predominant (66.66%). Allele *Glu-D1d* was found at a frequency of 27.77%. The less frequent allele was *Glu-D1b* (subunits 3+12).

The alleles positively correlated to the quality were remarkably present and included: 2*, 1, 7-8, 7-9, 5-10 and 13-16. The associations for a good quality could be observed (allele 2* and 5-10; allele 2* and allele 17-18; allele 1 and allele 7-8). Zhang et al. [47] have shown that *Glu-D1* and *Glu-B3* play very important roles in determining the dough properties. Also, other alleles such as *Glu-B3* and *Glu-B3G* contribute to the good bread-making quality [49].

The five varieties presented diagrams corresponding to these previously mentioned associations. Thus, the variety Anza and the variety Mahon Demias showed the diagram 2-2*-20-12, while the variety Arz gave us the diagram 2-2*-7-8-12. The association between the allele 2* and the allele 17-18 was observed in the variety HD 1220. The allele 7-8 was present together with the allele 1 in the variety Ain Abid. The profiles 13-16 and 14-15 were present in the varieties Atass 66 and Sappo, respectively. The identification

of HMW-GS of the soft wheat presents a double interest. Firstly, it is a complement to the electrophoretic analysis of gliadins and secondly, it plays an important role in the evaluation of the wheat quality. The LMW-GS form three groups of proteins with different mobilities (slow, medium and fast). Slow bands correspond to the zone A of LMW-GS, while the intermediate and fast bands correspond to the zones B, C, and D of LMW-GS [49,50]. These subunits of glutenins are closely related to the bread-making quality [3].



Fig. 5. SDS-PAGE analysis of HMW-GS and LMW-GS from 18 soft wheat varieties. The electrophoresis mobilities of glutenins separated using 12.8% polyacrylamide gel under denatured conditions. An aliquot of 100 μ l of each extract (previously obtained from a single grain) was deposited in each well. The wells corresponded to: 1: Sappo, 2: Arz, 3: Ain Abid, 4: Florance Aurore, 5: Soissons, 6: Anza, 7: Mahons demias, 8: Vilmorin 63, 9: HD 1220, 10: Ghiza 163, 11: Sahel 12: Prinqual, 13: Giza 164, 14: Atlas 66, 15: Brimstone, 16: Sajitari; 17: Soissons; 18: Cham6; 19: Inkilab 91; 20: Inkilab 91.

Table 2. Details of the genetic profiles of 18 soft wheat varieties. The genetic profiles of 18 soft varieties obtained by SDS-PAGE (see the wells in Fig. 5) are presented.

Type	Profiles	Wells	Varieties
I	1-2-7-8-12	3, 16	Ain Abid, Sajitari
II	1-5-7-9-10	13	Giza 164
III	1-2-17-18-12	10	Ghiza 163
IV	2*-5-7-9-10	18, 4	Cham6, Florance Aurore
V	2-2*-7-8-12	2	Arz
VI	2*-5-7-8-10	5 and 17, 11	Soissons, Sahel
VII	2-2*-20-12	6, 7	Anza, Mahons Demias
IX	2-2*-17-18-12	9, 12 and 20, 19	HD1220, Prinqual, Inkilab 91
IX	2-2*-14-15-12	1	Sappo
X	3-20-12	8	Vilmorin 63
XI	2-6-8-12	15	Brimstone
XII	2-2*-13-16-12	14	Atass 66

Table 3. Genetic variation and allelic frequencies of HMW glutenins subunits at the *Glu-1* loci of soft wheat germplasm cultivated in Algeria.

Locus	Allele	Subunits	Frequency (%)
<i>Glu-A1</i>	<i>a</i>	1	22.22
	<i>b</i>	2*	66.66
	<i>c</i>	Null	11.11
<i>Glu-B1</i>	<i>b</i>	7+8	7.77
	<i>c</i>	7+9	16.66
	<i>d</i>	6+8	5.55
	<i>e</i>	20	16.66
	<i>f</i>	13+16	5.55
	<i>i</i>	17+18	22.22
	<i>h</i>	14+15	5.55
	<i>Glu-D1</i>	<i>a</i>	2+12
<i>b</i>		3+12	5.55
<i>d</i>		5+10	27.77

Elsewhere, we analyzed the zone B of LMW-GS. These subunits correspond to the most basic group with a molecular weight ranged between 45 000 and 30 000 Da. However, this area presented many difficulties in interpreting the electrophoretic profiles because the type B subunits were much more numerous and highly aggregated. It is useful to remember that the interests of the varietal identification of HMW-GS and LMW-GS are multiple. It has a particularly interesting application in commercial transactions if there is a dispute on varietal purity and presents a tool to assess the diversity of plant material. The tenacity is also significantly influenced by several alleles of the HMW-GS and LMW-GS. The alleles *Glu-B1* 7-8, *Glu-D1* 5-10 and *Glu-A3a* were associated with the high toughness. The alleles *Glu-A1* 2*, *Glu-B1* 14-15 and 17-18, *Glu-D1* 2-12 and 3-12, *Glu-B3b* and *b'* were associated with a lower toughness. The swelling G or the extensibility L increased with the protein content; this result is well known but we observed here that the protein content was the most influencing parameter on the variation of the extensibility. Only a few subunits of glutenins are favorable: *Glu-A1* 2*, *Glu-B1* 14-15 and 17-18, *Glu-D1* 2-12, *Glu-B3b* and *b'*, and *Glu-D3c* [41]. The glutenins subunits favorable to the tenacity P (*Glu-B1* 7-8 and *Glu-D1* 5-10) were logically unfavorable to the extensibility. A balanced report P/L and a lower polydispersity index of polymers were more easily obtained with subunits *Glu-A1* 2*, *Glu-B1* 14-15 and 17-18, *Glu-D1* 2-12 and *Glu-B3b* and *b'*, rather than, with the subunits *Glu-B1* 7-8 and *Glu-D1* 5-10 [4]. The TKW is a very useful varietal criterion to predict the wheat behavior during the milling, it provides information on the uniformity of grains, their susceptibility to scald, the treatment influence and the water stress tolerance of varieties [8]. It represents a highly controlled characteristic by genetic factors. Several studies have shown that the genotype significantly contributes to the TKW variation [27].

CONCLUSION

We characterized five local wheat varieties endowed with important technological properties. The electrophoretic analysis of the HMW-GS polymorphism showed great diversity in three glutenins loci (*GluA1*, *GluB1* and *GLUD1*) and the alleles positively

correlated with the quality were remarkably present. Direct assessment of baking quality indicated a variation of the pasta characteristics during the different bread making operations. Indeed, indicators of milling and baking values were varied and globally appreciable. Moreover, some of these parameters were significantly correlated with their glutenins electrophoretic profiles. All our varieties presented the following characters: compliant ash content, more or less consistent humidity rate, lower tenacity P, negatively correlated configuration report (P/L) with the proteins content and usual wet gluten contents. However, each wheat variety presented some specific technological characteristics. The variety Ain Abid was the unique wheat with an interesting plastic properties and the variety Arz had a high baking strength, while, the variety HD 1220 had a poor plastic quality, it was elastic, extensible and did not relax.

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Authorship Contributions. Arbia ABBES designed the study, collected and analyzed the data, interpreted the results and wrote the manuscript. Hocine RECHRECHE participated in data analysis, supervised the writing of the manuscript. Asma MEDOURI and Zahira ABBES participated in the review and editing of the final manuscript. Mohammed BENALI supervised the study design and participated in data analysis.

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