Agriculture and Food

AIMS Agriculture and Food, 9(2): 531–550.
DOI: 10.3934/agrfood.2024030
Received: 30 November 2023
Revised: 16 April 2024
Accepted: 30 April 2024
Published: 16 May 2024

http://www.aimspress.com/journal/agriculture

Research article

Breadmaking and protein characteristics of wheat (*Triticum aestivum* L.) genotypes tolerant against drought and heat in Algeria

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Abstract: The primary staple of the Algerian population is wheat, and due to climate change, it is necessary to look for wheat genotypes with a high yield, drought and heat tolerance, and disease resistance, in addition to high quality for bread-making and other foodstuffs. Our objective of this study was to investigate 17 genotypes of *Triticum aestivum* L., including 10 traditionally cultivated, 2

recently introduced, and 5 currently in development, with the goal of identifying those exhibiting high-quality attributes for breadmaking and superior technological properties, while maintaining low levels of immunoreactive gluten. We conducted analyses on chemical composition, immunoreactive gluten content, as well as the secondary structure of proteins and the conformation of starch in flours obtained from different wheat bread genotypes grown in similar watering and other conditions. Additionally, the rheological characteristics of the dough were measured using an alveograph and rheoviscosimeter. We also explored the physical properties and technological attributes relevant to the bread-making process. The major results indicated low heterogeneity among genotypes concerning immunoreactivity. The characteristics of 17 *Triticum aestivum* L. genotypes form four groups included: Group A: Traditional, recently, or not yet cultivated in Algeria, with the highest β-sheet, W values, and protein contents; B: Highest protein content, lowest β-sheet, and medium W and P/L values. C: Four of the traditional, recently, or not yet cultivated genotypes with the highest bread specific volume, low protein, and W and P/L values. Group D: Traditional genotypes, with the lowest specific volume of bread and a low protein content. Some of the traditional cultivated wheat genotypes in Algeria could be changed, although almost all the drought and disease resistant genotypes could be used for bread-making, which was excellent news because of global warming.

Keywords: bread wheat genotypes; flour characteristics; dough properties; immunoreactivity; baking quality

1. Introduction

Bread and other products made with bread wheat (*Triticum aestivum* L.) or durum wheat (*Triticum durum*) form the food staple in the Algerian diet [1], as in other countries of the Mediterranean basin. The daily bread consumption is 314 to 505 g per person, representing a significant source of energy and nutrients. Therefore, the bread nutritional quality evaluation is important for safeguarding public health [2]. In addition, the technological quality of wheat flour for breadmaking and other products depends on the content and structure of the gluten proteins, as well as the starch granule characteristics. Thus, these physical and rheological properties should be evaluated to cultivate the best wheat genotypes, in agreement with agricultural properties such as yield, disease resistance, and drought and heat tolerance in the current climate change.

In terms of nutritional quality, cereals do not contain as many anti-physiological factors as legumes. However, a minority of people suffer from one of the so-called wheat-related diseases due to proteins after the ingestion of wheat-base foods, such as wheat allergy, non-celiac wheat sensitivity, and celiac disease [3]. This last one is the most complicated and serious disease, characterized by total or subtotal intestinal villous atrophy leading to poor nutrient absorption [4]. Its most common symptoms include malnutrition, diarrhea, growth retardation, anemia, and fatigue. The only effective treatment is a strict, lifelong gluten-free diet [5]. None of the commercial bread wheat genotypes or their subproducts are suitable for inclusion in wheat-free (currently gluten-free) foodstuffs because even 20 mg/kg could be dangerous for people with any of the wheat-related diseases.

Several alternative solutions have been developed for celiac disease, including those aimed at selecting wheat genotypes with low levels of toxic epitopes [6–9]. This approach paves the way for the development of wheat genotypes that are non-toxic to celiac disease through genetic improvement

programs. However, for breeders, it could be challenging to preserve the viscoelastic properties while producing wheat that is non-toxic for celiac disease [10].

To look for an application type of wheat genotype, it is first necessary to characterize their proteins, flours, doughs, and breads. In this context, we aim to analyze 17 bread wheat genotypes, 12 of them already cultivated in Algeria, for their protein properties, the physicochemical composition of the flours, the rheological properties of the dough, and the technological properties of the produced bread.

2. Materials and methods

2.1. Wheat grains

Seventeen genotype samples of bread wheat (*Triticum aestivum* L.) were provided by both Field Crop Institute Agricultural (ITGC) and Agro-Multi Investment and Services (AXIUM), Constantine, Algeria. Supplementary Table S1 presents a list of studied genotypes, their pedigree, origins, as well as different shapes (oval or elongated), colors ranging from white to red and the degree of drought and heat tolerance. The wheat seeds were from three types : a) Traditionally cultivated in Algeria (Ain Abid, Akhamoukh, Anforeta, Anapo, Arz, Boumerzoug, El Hachimia, Hidhab, Massine and Tidis); b) recently cultivated (Andana and Palesio), and c) no yet cultivated in Algeria (Ain El Bey, Bordj Mehis, Medracen, Nif Encer and Yacine). All the wheat grains were grown in similar conditions without water restrictions.

2.2. White flour preparation

After removing impurities, wheat grains were set at 15% humidity, and rested for 24 h. After this period, moisture was adjusted at 16.5% for 20 min prior to the milling in a Buhler laboratory test miller (MLU-202, Bühler, Uzwil, Switzerland), like a commercial flour.

2.3. Flours analysis

2.3.1. Chemical composition

The white flour analysis was carried out with at least three replicates. Chemical composition of wheat flours was determined according to AACC methods as follows: Protein (AACC 46-16, N × 5.54), ash (AACC 08-12), moisture (AACC 44-01), and fat contents (AACC 30-10) [11].

2.3.2. Immunoreactive gluten quantitation

The gluten content was analyzed by the R5-sandwich ELISA kit, RIDASCREEN Gliadin Assay R7001 (R-Biopharm AG, Darmstadt, Germany). Each flour sample was extracted twice with the cocktail solution recommended by the kit instructions. The absorbance was measured at 450 nm in a microplate reader (Bio-Rad, iMark. Berkeley, CA, USA). The reactive gliadin was quantified by interpolation of the calibration curves calculated using the gliadin standard solutions provided in the kit and the double concentration corresponded to gluten.

2.3.3. Analysis of Fourier transformed infrared (FTIR) spectra

The secondary structure of protein as well as the crystalline and amorphous starch fractions of the flours were studied by Fourier transform infrared spectroscopy (FTIR) using an IRAffinity-1S Fourier Transform Infrared Spectrometer (Shimadzu Scientific Instruments Inc., Columbia, MD, USA) equipped with a single-reflection diamond attenuated total reflection (ATR) crystal and a mercury-cadmium-telluride (MCT) detector. The spectra were recorded in the range of 4000 to 400 cm^{-1}, with 20 scans and a resolution of 8 cm^{-1}, against the background, with five replicates. The spectra were analyzed using the Origin software (version 8.0724 PRO, Origin Lab Corporation, Northampton, MA., USA) and PeakFit software 4.6 (SYSTAT Software Inc. San Jose, CA, USA). The spectra were deconvoluted and curve fitted to obtain percentages of secondary structure components using the PeakFit software.

The analysis of starch conformation was conducted through the measurement of the absorbance intensity ratio R, which is equal to I (1047 cm^{-1})/I (1022 cm^{-1}) [12]. The absorbance intensity at 1047 cm^{-1} corresponds to the crystalline fraction, while that at 1022 cm^{-1} corresponds to the amorphous fraction.

2.4. Evaluation of the rheological properties of dough

2.4.1. Alveograph parameters

The alveographic parameters deformation energy (W) and tenacity/extensibility (P/L) ratio were determined using a Chopin alveograph (Alveolink NG, Villeneuve-La-Garenne, France) as described by the AACC Method 54-30.02 [11].

2.4.2. Flow test

The dough flow test was measured with a rheoviscosimeter (Haake MessTechnik Gmbh Co, Karlsruhe, Germany) equipped with a parallel plate geometry (50 mm diameter, 4.5 mm gap). Dough was prepared from wheat flour, 2% salt with variable absorption and then mixed with Kenwood mixer (Model KM210, Kenwood Ltd., Havant, England) for 2 min at 58 rpm and 2 min at 112 rpm. The dough was let to rest for 10 min before being placed between the parallel plates of the rheometer. Excess dough was removed, and the exposed edges were coated with mineral oil to prevent drying. After 10 min, the rheological data were analyzed using the HAAKE Rheo Win software version 2.09 over a shear rate range of 0.01–30 rad/s equivalent to 0.001–4.77 s^{-1} for 3 min at 25 ℃. The number of measuring points was 100 and each test was performed in triplicate. The apparent viscosity was determined using the power Ostwald law model [13]:

$$\boldsymbol{\eta_{ap} = K.\gamma^{n-1}} \quad (1)$$

where $\boldsymbol{\eta_{ap}}$: Apparent viscosity (Pa.s); $\boldsymbol{\gamma}$: shear rate (s^{-1}); and n: flow behavior index. K (Consistency index, $Pa.s^n$) represents the stress required to obtain a shear rate of 1 s^{-1}.

2.5. Breadmaking and evaluation of the produced breads

Bread was prepared according to the following formulation: 100 g of flour, variable volumes of water, 2 g dry yeast, 4 g sugar, and 2 g salt. All the ingredients were blended with a "Kenwood Chef KM400" (Kenwood, Havant, UK) domestic blender for 2 min at a low speed (speed 2) and 8 min at a medium speed (speed 4). The dough was divided into 80 g round-shaped portions. These samples were placed in an incubation chamber (Memmert, Schwabach, Germany) at 40 ℃ for 30 min. Then, samples were baked in a laboratory oven with air circulation at 230 ℃ for 20 min [14].

All the bread parameters were measured after 45 min at room temperature (28–30 ℃). The bread samples were weighed to determine weight loss during baking; their specific volume and crust color were estimated and crumb cells were also analyzed. All measurements were performed in triplicate [14].

2.5.1. Weight loss and specific volume

Weight loss (WL) was calculated as the difference between the weight of the dough and the weight of the bread, expressed as a proportion.

The specific volume of the bread ($cm^3.g^{-1}$) was determined by dividing the volume of the bread by its weight. The volume of the bread was measured by the small seed displacement method. After placing the loaf into the container, it was subsequently filled with seeds. The extra rapeseeds (equal to the volume of bread) were measured in a graduated cylinder [15].

2.5.2. Color analysis

The method of He et al. [16], was used to determine the color of the crust of the bread, using the Color Grab color extracting application (version 3.6.1, 2017, Loomatix Ltd., Munchen, Germany). To maintain the integrity of color capture unaffected by ambient light, a sealed polystyrene box (39 × 17 × 28 cm) was utilized, incorporating a 1.2W5 V white LED to obtain an evenly scattered light on top of the sample. The CIE-$L^*a^*b^*$ color space mode was chosen, mathematical color model based on the sensitivity of the human visual spectrum, where L^* indicates lightness, a^* and b^* indicate the redness +/greenness, and the yellowness +/blueness, respectively. Measurements of color were acquired from five different locations on the crusts.

2.5.3. Crumb cell analysis

Image J software (1.43u; Java1.7.0–2132 bit, Wayne Rasband, National Institute of Mental Health (NIH), Bethesda, MD, USA) was used to perform image processing. The bread was horizontally sliced into two pieces, and subsequent images of the slices were captured and saved in TIFF format. To keep only the bread crumb, each image was cropped and then converted to 8-bit grayscale to obtain black (crumb pores) and white (crumb) thresholds. The measured parameters were: Cell count, average cell size, circularity, and solidity.

2.6. Statistical analysis

A one-way analysis of variance (ANOVA) was carried out to assess for any significant differences

between the means using the Statistical software (version 7.0.61.0, Statistical, Statsoft Inc, Tulsa, OK, USA). Significant differences ($p < 0.05$) were determined by Duncan's multiple range test. To examine the distribution of the bread wheat genotypes under study and establish correlations between the chemical composition of flour, dough properties, and bread quality, we conducted both Hierarchical Clustering Analysis (HCA) and correlation using the statistical software R version 4.3.0 [17].

3. Results and discussion

3.1. Flour characteristics

3.1.1. Chemical composition

The chemical composition of the studied flours is summarized in Table 1. Variable trends were observed for flour protein, fat, and ash, as expected for flours from different genotypes and cultivation conditions. Anapo showed the lowest protein content (10.96%), while the highest one (16.32%) was for Yacine. According to Olakanmi et al. [18], the gluten content is low (7–12%) or high (12–18%) and constitutes 80–85% of the total protein in wheat flour. It is considered the principal effector of the dough properties [19]. Our studied genotypes contained gluten from 44.52 % to 79.92% of the total protein, as evaluated as immunoreactive gluten, which principally quantifies alpha-gliadins, as explained in the following subsection. There were differences in the fat content of the samples. The genotype Hidhab showed the highest fat content (1.41%), while the genotype Yacine had the lowest (0.75%). The fat content in cereals is typically low; however, it could influence the quality and texture of food products. This impact is attributed to its capacity to interact with proteins owing to their amphipathic nature and to form inclusion complexes with starch. Ash content ranged from 0.39 to 0.64%, as seen in the genotypes Andana and El Hachimia, respectively. The ash content in wheat flour ranges from 0.4 to 1.7% [20]. In addition, the ash content is negatively correlated with the activity of proteolytic and amylolytic enzymes. To ensure good product quality, it is important to have a low ash content [21].

The chemical composition is essential for considering the nutritional quality, and it is very important for reaching our goal of having enough protein and gluten content for successful breadmaking procedures.

3.1.2. Immunoreactive gluten

As shown in Table 1, our results showed low heterogeneity among genotypes regarding immunoreactivity; the cultivar Boumerzoug presented the highest value (95.6 g kg^{-1}) and Medracen the lowest one (61.4 g kg^{-1}). A reduction of 36% immunoreactivity is not enough to consider it as an ingredient for the preparation of gluten-free foodstuffs, but it could be usable information for specialists in genetic modification. Additionally, the gluten content is important information about the quality of the flour for breadmaking. In agreement with our findings, Hamid et al. [22] reported a narrow range of gliadin antigenicity in 20 wheat flours from samples cultivated on an experimental farm in India. Riberio et al. [8] published similar results, even by comparison of modern and landraces of *T. turgidum*. In contrast, immunoreactive gluten was highly variable in 27 wheat flours [9,23]. However, in the study of Huang et al. [23], the values for 20 of the genotypes were in the same magnitude order, but the rest were highly variable; one of them even had 20 times the lowest content of the samples cultivated in different countries and conditions. Interestingly, the immunoreactive gluten content in our samples was not related

to the crude protein content. It is because the heterogenicity of the gliadins in each sample and the immunoreactivity are more related to the α-gliadin content than to the total protein or gluten content. According to Prandi et al. [24], there is considerable variability in the quantity of immunogenic peptides among wheat cultivars, and the environmental effect could be lower than genetic origin.

Table 1. Chemical composition and gluten content of bread wheat flour (dry basis) for the studied genotypes.

Genotypes	Protein (%)	Fat (%)	Ash (%)	Gluten (g kg^{-1})
Ain Abid	12.52 ± 0.02^{f}	1.24 ± 0.02^{ghi}	0.58 ± 0.060^{ef}	92.0
Ain El Bey	12.04 ± 0.02^{e}	1.20 ± 0.02^{fgh}	0.51 ± 0.017^{cd}	88.6
Akhamoukh	11.98 ± 0.02^{e}	1.08 ± 0.04^{c}	0.55 ± 0.018^{de}	66.2
Anapo	10.96 ± 0.00^{a}	1.87 ± 0.02^{l}	0.46 ± 0.009^{b}	87.6
Andana	11.30 ± 0.02^{b}	1.16 ± 0.02^{def}	0.39 ± 0.005^{a}	64.4
Anforeta	11.18 ± 0.02^{b}	1.10 ± 0.02^{cd}	0.45 ± 0.012^{b}	74.6
Arz	11.50 ± 0.04^{c}	1.06 ± 0.02^{bc}	0.54 ± 0.003^{de}	66.2
Boumerzoug	15.51 ± 0.02^{m}	1.18 ± 0.02^{efg}	0.61 ± 0.004^{fg}	95.6
Bordj Mehis	13.54 ± 0.02^{i}	1.27 ± 0.02^{ij}	0.60 ± 0.012^{fg}	76.4
El Hachimia	14.19 ± 0.02^{k}	1.26 ± 0.02^{hij}	0.64 ± 0.017^{g}	72.0
Hidhab	12.84 ± 0.02^{g}	1.41 ± 0.02^{k}	0.53 ± 0.020^{d}	62.8
Massine	11.81 ± 0.02^{d}	1.00 ± 0.02^{b}	0.51 ± 0.002^{cd}	62.4
Medracen	13.79 ± 0.02^{j}	1.16 ± 0.02^{def}	0.53 ± 0.018^{d}	61.4
Nif Encer	13.55 ± 0.02^{i}	1.31 ± 0.02^{j}	0.52 ± 0.050^{cd}	84.6
Palesio	14.62 ± 0.02^{l}	1.12 ± 0.02^{cde}	0.47 ± 0.012^{bc}	73.6
Tidis	13.19 ± 0.02^{h}	1.16 ± 0.02^{def}	0.50 ± 0.013^{cd}	75.4
Yacine	16.23 ± 0.02^{n}	0.75 ± 0.02^{a}	0.61 ± 0.002^{fg}	74.6

Means within the same column labeled with different superscript letters indicate statistically significant differences ($p < 0.05$) based on the Duncan post hoc test.

3.1.3. Secondary structure of proteins and starch conformation analysis

The rheological properties of dough (section 3.2) and the physical properties of bread (section 3.3) are the results of the content and structure of proteins and starches in flours. Table 2 presents the proportion of each secondary structure component of proteins.

Overall, the amide I band showed dominance of the β-sheet structure, followed by the β-turn, then the α-helix. The β-sheet structure ranged from 24.97% to 43.10%, as observed in the cultivars Bordj Mehis and Medracen, respectively. The β-turn varied between 24.43% and 34.18%, corresponding to the Tidis and Medracen genotypes, respectively. The α-helix was found between 13.06% and 24.23% and corresponds successfully to the Yacine and Tidis genotypes. The random coil ranged from 10.32% to 26.92%.

Our results are in agreement with those obtained by Bock and Damodaran [25], where β-sheet was dominant, However, our findings are not consistent with those found by with those by Kłosok et al. [26] and Fetouhi et al. [27], who found that α-helix is the dominant structure of the gluten proteins.

Table 2. Protein structure and starch relative crystallinity of the bread wheat genotypes.

Genotypes	Protein structure				Starch
	β-sheet (%)	Random coil (%)	α-helix (%)	β-turn (%)	R ratio
Ain Abid	31.57	21.86	18.11	28.44	0.48
Ain El Bey	32.51	23.38	23.92	32.47	0.56
Akhamoukh	29.87	22.57	20.43	27.11	0.50
Anapo	35.39	22.23	16.76	25.59	0.50
Andana	23.02	23.48	19.83	33.64	0.51
Anforeta	31.80	23.41	19.32	25.44	0.52
Arz	29.76	22.66	20.88	26.67	0.51
Boumerzoug	38.82	17.02	16.94	27.19	0.55
Bordj Mehis	24.97	24.83	23.47	26.70	0.55
El Hachimia	28.29	22.80	22.21	26.67	0.54
Hidhab	42.43	13.60	14.04	29.91	0.48
Massine	29.60	22.18	20.34	27.84	0.50
Medracen	43.10	10.32	17.01	29.54	0.54
Nif Encer	39.38	10.66	15.75	34.18	0.52
Palesio	38.88	14.10	13.06	33.95	0.52
Tidis	27.98	23.33	24.23	24.43	0.54
Yacine	32.04	26.92	13.89	27.1	0.52

The secondary structure of gluten is strictly connected with the dough and bread quality. The content of β-sheet and β-turn structures are positively correlated with the viscoelasticity of the dough, whereas the content of the α-helix structure affects it negatively [28]. Therefore, β-sheet structures and disulfide bonds in the gluten matrix interact synergistically, influencing the formation of a dense and stable gluten network structure [19].

Respecting the starch relative crystallinity, the highest R ratio value was 0.56 for Ain El Bey, while the genotypes Ain Abid and Hidhab showed the lowest values, both at 0.48. The rest of the genotypes presented R values between 0.50 and 0.54 (Table 2). This parameter is frequently employed as an indicator of the arrangement of various starch components [29]. A significant increase in the R value indicates the dominance of a crystalline over an amorphous conformation, suggesting that starch has a pronounced tendency for retrogradation, which is related to the staleness, unpleasant taste, hard texture, and shorter shelf life of bread and baked goods [12,30]. We obtained a lower value than 0.67 for soft wheat dough reported by Fetouhi et al. [27]; therefore, our flours could exhibit a lower retrogradation propensity.

3.2. Rheological properties of dough

As shown in Table 3, the alveograph characteristics W and P/L indicate a wide variation among the analyzed wheat genotypes.

Dough strength (W) ranged from 144.5×10^{-4} to 352.5×10^{-4} J and ratio of tenacity to extensibility (P/L) varied from 0.63 to 3.81. W is regarded as an indicator of gluten strength because it depends on both the quantity and quality of gluten in the dough [31]. According to Bordes et al. [32], when the W value is below 150×10^{-4} J, the wheat flour falls into the category of low quality. Conversely,

if it exceeds 170 × 10^{-4} J, it is considered to be of standard quality, and it is classified as high quality when its W value ranges from 250 to 300× 10^{-4} J. Considering these scales, our wheat genotypes could be classified as standard or high quality, except for Anapo. The values of the tenacity/extensibility ratio P/L ranged from 0.63 for Anapo to 4.8 for Arz. When the value is within the range of 0.40 to 0.80, the dough has balanced gluten and is suitable for bread-making, while a P/L value lower than 0.40 indicates a very extendable dough. Higher P/L values, e.g., 1.50, indicate very strong doughs that are not extensible and are not suitable for bread-making [31].

Table 3. Rheological properties of dough for different bread wheat genotypes.

Genotypes	Alveograph parameters		Flow test parameters			
	Dough strength W (× 10^{-4} J)	P/L ratio	K (Pa.s^n)	n	χ^2	*R*
Ain Abid	243.0 ± 5.65^{d}	2.18 ± 0.10^{e}	155.76 ± 67.55 ^{a}	0.47 ± 0.09^{a}	0.43 ± 0.12	0.93 ± 0.01
Ain El Bey	184.0 ± 4.24^{b}	1.34 ± 0.08^{d}	69.03 ± 30.47^{a}	0.63 ± 0.04^{bcd}	0.49 ± 0.21	0.87 ± 0.02
Akhamoukh	218.5 ± 4.94^{c}	3.81 ± 0.05^{g}	93.20 ± 25.60^{a}	0.53 ± 0.10^{abc}	0.36 ± 0.26	0.93 ± 0.02
Anapo	144.5 ± 0.7^{a}	0.63 ± 0.00^{a}	54.60 ± 12.60^{a}	0.57 ± 0.05 ^{abc}	0.59 ± 0.06	0.87 ± 0.02
Andana	230 ± 1.41^{cd}	1.38 ± 0.00^{d}	67.43 ± 19.68^{a}	0.65 ± 0.03^{cd}	0.46 ± 0.24	0.86 ± 0.08
Anforeta	156.0 ± 14.14^{a}	2.65 ± 0.34^{f}	74.63 ± 3.87^{a}	0.55 ± 0.01 ^{abc}	0.84 ± 0.56	0.85 ± 0.08
Arz	183.5 ± 0.70^{b}	4.80 ± 0.02^{h}	80.46 ± 24.66^{a}	0.64 ± 0.01^{cd}	0.86 ± 0.29	0.79 ± 0.07
Boumerzoug	262.0 ± 2.82^{e}	0.82 ± 0.00^{ab}	86.03 ± 13.35^{a}	0.69 ± 0.05^{d}	0.88 ± 0.19	0.73 ± 0.09
Bordj Mehis	327.5 ± 0.70^{f}	0.93 ± 0.03^{bc}	78.30 ± 32.36^{a}	0.56 ± 0.10 ^{abc}	0.38 ± 0.14	0.91 ± 0.04
El Hachimia	322.0 ± 7.07^{f}	1.24 ± 0.00^{d}	86.26 ± 35.37^{a}	0.59 ± 0.04 ^{abcd}	0.75 ± 0.02	0.84 ± 0.02
Hidhab	231.5 ± 10.60^{cd}	1.29 ± 0.02^{d}	119.73 ± 12.23^{a}	0.50 ± 0.04^{a}	0.37 ± 0.17	0.93 ± 0.03
Massine	266.5 ± 0.70^{e}	1.31 ± 0.00^{d}	87.66 ± 23.13^{a}	0.56 ± 0.03 ^{abc}	0.60 ± 0.07	0.87 ± 0.02
Medracen	337.5 ± 3.53^{fg}	1.15 ± 0.01^{cd}	92.20 ± 20.69^{a}	0.63 ± 0.05^{bcd}	0.84 ± 0.57	0.80 ± 0.13
Nif Encer	271.0 ± 4.24^{e}	1.15 ± 0.03^{cd}	453.33 ± 453.89^{b}	0.51 ± 0.08^{ab}	0.68 ± 0.24	0.87 ± 0.06
Palesio	352.5 ± 10.60^{g}	0.64 ± 0.03^{a}	106.20 ± 24.02^{a}	0.55 ± 0.03 ^{abc}	0.61 ± 0.24	0.88 ± 0.05
Tidis	276.0 ± 25.45^{e}	2.79 ± 0.29^{f}	133.00 ± 11.26^{a}	0.54 ± 0.05 ^{abc}	1.46 ± 0.12	0.78 ± 0.04
Yacine	265.5 ± 4.94^{e}	1.42 ± 0.01^{d}	146.66 ± 35.00^{a}	0.54 ± 0.09 ^{abc}	1.24 ± 0.51	0.79 ± 0.07

Means within the same column labeled with different superscript letters indicate statistically significant differences ($p < 0.05$) based on the Duncan post hoc test.

The coefficient of consistency (K), flow behavior index (n), R-value (statistical correlation coefficient), and chi-square (χ^2) are presented in Table 3. The power-law model showed low χ^2 (0.36–1.46), and high R values (0.73–0.93) for all our wheat genotypes. The highest value of the consistency coefficients (K) was for the Nif Encer dough (453.3 Pa.s^n) and the lowest value was for the Anapo dough (54.6 Pa.s^n). Except for the Nif Encer, the dough samples were not statistically different ($p > 0.05$) in their K consistency coefficient. According to Kırbaş et al. [33], dough consistency is positively correlated with the hydration capacity of flours. The flow behavior index (n) of the samples ranged from 0.47 for the Ain Abid genotype to 0.69 for the Boumerzoug one. This parameter indicates the degree of non-Newtonian behavior of the dough. The values of n in the entire batch of paste samples were below 1, indicating pseudoplasticity (shear-thinning). In pseudoplastic substances, viscosity decreases with an increase in shear rate because the connections between the components of the material break under the influence of shear, breaking interactions among the components of the system [34].

3.3. Physical properties of breads

3.3.1. Weight loss and specific volume

The Results of weight loss and specific volume are shown in Table 4. The weight loss of the loaves changed from 13.3% for bread made with the Akhamoukh genotype to 16.7% for bread made with the Anapo genotype.

Table 4. Weight loss and specific volume of the loaves made with different bread wheat genotypes.

Genotypes	Weight loss (%)	Specific volume ($cm^3\ g^{-1}$)
Ain Abid	15.90 ± 0.43^{def}	2.32 ± 0.11^{b}
Ain El Bey	15.79 ± 0.80^{cdef}	2.99 ± 0.13^{ef}
Akhamoukh	13.29 ± 0.67^{a}	2.10 ± 0.10^{a}
Anapo	16.73 ± 0.85^{f}	3.33 ± 0.07^{gh}
Andana	16.30 ± 1.17^{ef}	3.16 ± 0.03^{fg}
Anforeta	15.69 ± 1.08^{cdef}	2.31 ± 0.04^{b}
Arz	14.48 ± 0.69^{abcde}	2.36 ± 0.05^{b}
Boumerzoug	15.52 ± 1.09^{cdef}	3.14 ± 0.06^{fg}
Bordj Mehis	14.37 ± 0.41^{abcd}	2.93 ± 0.30^{e}
El Hachimia	14.70 ± 1.03^{abcde}	2.50 ± 0.05^{bc}
Hidhab	15.43 ± 0.32^{bcdef}	2.69 ± 0.03^{cd}
Massine	16.60 ± 1.45^{f}	3.31 ± 0.21^{gh}
Medracen	15.63 ± 0.76^{cdef}	2.78 ± 0.12^{de}
Nif Encer	15.20 ± 1.22^{bcdef}	2.78 ± 0.09^{de}
Palesio	14.51 ± 0.32^{abcde}	3.49 ± 0.08^{h}
Tidis	13.60 ± 1.23^{ab}	2.78 ± 0.06^{de}
Yacine	13.93 ± 1.45^{abc}	3.22 ± 0.08^{g}

Means within the same column labeled with different superscript letters indicate statistically significant differences ($p < 0.05$) based on the Duncan post hoc test.

According to Mikolasova et al. [20], baking losses should vary optimally from 9–12%, but in his study, it was higher depending on the amount of oil added to the bread-making mix. The protein-water binding action prevents water evaporation and, consequently, reduces weight loss [35]. Concerning the specific volume of bread loaf (Table 4), bread made with Yacine flour presented the highest specific volume (3.22 $cm^3\ g^{-1}$), while bread made with Akhamoukh presented the lowest one (2.10 $cm^3\ g^{-1}$). In general, flours from 7 out of 17 cultivars produced a specific volume (around 3 $cm^3\ g^{-1}$) comparable to the average of commercial bread; the rest of the loaves were lower (2.1 to 2.8 $cm^3\ g^{-1}$). The low specific volume of bread is associated with a reduced gas retention capacity. This parameter is influenced by several factors, including the dilution effect of dietary fibers, the gluten network, interactions between fibers and the gluten content and its quality, reduced dough extensibility, and changes in enzymatic activity [36].

3.3.2. Crust color parameters and crumb structure

The values of brightness *L** of the crust varied from 22.8 for Medracen to 52.06 for Ain Abid. Regarding the parameter *a**, the Nif Encer crust had the highest value (24.43), whereas the lowest value was for the Ain Abid (10.6) (Table 5).

Table 5. Crust color of the loaves made with different bread wheat genotypes.

Genotypes	*L**	*a**	*b**
Ain Abid	52.06 ± 5.50^{f}	10.60 ± 3.90^{a}	47.96 ± 3.56^{h}
Ain El Bey	36.43 ± 11.30^{abcd}	16.70 ± 1.40^{bc}	35.33 ± 6.35^{def}
Akhamoukh	47.50 ± 4.24^{ef}	13.73 ± 1.10^{ab}	40.50 ± 1.57^{fg}
Anapo	43.86 ± 9.12^{def}	18.50 ± 5.54^{bcd}	39.36 ± 1.93^{efg}
Andana	33.16 ± 3.58^{abcd}	22.13 ± 0.46^{cde}	35.73 ± 1.86^{def}
Anforeta	43.56 ± 6.62^{def}	16.90 ± 5.53^{bc}	43.36 ± 1.42^{gh}
Arz	33.66 ± 4.36^{abcd}	24.33 ± 1.64^{e}	35.60 ± 3.37^{def}
Boumerzoug	27.76 ± 11.67^{abc}	20.26 ± 4.31^{cde}	28.16 ± 7.97^{abc}
Bordj Mehis	25.70 ± 1.80^{ab}	18.40 ± 0.78^{bcd}	26.23 ± 0.15^{a}
El Hachimia	26.86 ± 5.17^{ab}	22.13 ± 1.59^{cde}	30.73 ± 3.24^{abcd}
Hidhab	39.83 ± 4.73^{cde}	22.50 ± 2.08^{cde}	34.20 ± 0.60^{bcdef}
Massine	41.96 ± 7.89^{def}	17.93 ± 4.80^{bcd}	33.30 ± 0.10^{bcde}
Medracen	22.80 ± 6.06^{a}	20.56 ± 1.90^{cde}	27.66 ± 4.72^{ab}
Nif Encer	33.00 ± 5.02^{abcd}	24.43 ± 0.92^{e}	34.80 ± 1.08^{cdef}
Palesio	23.26 ± 3.98^{a}	22.03 ± 2.89^{cde}	29.26 ± 4.09^{abcd}
Tidis	35.80 ± 4.76^{abcd}	23.50 ± 2.57^{de}	36.06 ± 0.57^{def}
Yacine	22.93 ± 6.02^{a}	23.40 ± 1.08^{de}	29.50 ± 5.21^{abcd}

Means within the same column labeled with different superscript letters indicate statistically significant differences ($p < 0.05$) based on the Duncan post hoc test.

The color data also showed that the yellow *b** value significantly varied among all the loaves' crusts, ranging from 26.23 for Bordj Mehis to 47.96 for Ain Abid. The color of the bread crust is influenced by factors such as the ingredients, the baking process, and their interactions, such as caramelization or the Maillard reaction. Finally, the color of bread correlates with its quality and consumer acceptance [35].

The image analysis of the crumb (Table 6) reveals significant differences among the samples.

The number of cells ranged from 223.66 to 1352.66, corresponding to Arz and El Hachimia, respectively. The highest value of the cells was found for Ain Abid bread (2.16 mm^2), while the smaller one was for the bread made with El Hachimia. A reduced number of cells and a larger average size are indicative of an aerated structure [37]. Circularity, an indicator of alveolus symmetry, ranged from 0.77 to 0.86. Achieving perfect circularity in bread is challenging due to pressure differences in the gas bubbles and the changes occurring during the process [38]. Concerning solidity, it was similar among the samples (0.83 to 0.87). A lower solidity indicates an irregular shape of gas cells, while a higher solidity suggests a more regular shape [34].

Table 6. Crumb structure of the loaves made with different bread wheat genotypes.

Genotypes	Cell count	Average cell size (mm^2)	Circularity	Solidity
Ain Abid	320.33 ± 2.51^{b}	2.16 ± 0.02^{k}	0.81 ± 0.002^{def}	0.87 ± 0.001^{hi}
Ain El Bey	329.33 ± 8.50^{b}	1.26 ± 0.09^{j}	0.81 ± 0.010^{cde}	0.85 ± 0.010^{cde}
Akhamoukh	478.66 ± 4.50^{f}	1.18 ± 0.02^{i}	0.82 ± 0.000^{f}	0.86 ± 0.000^{defg}
Anapo	553.33 ± 7.02^{g}	0.81 ± 0.01^{g}	0.80 ± 0.001^{bcd}	0.85 ± 0.001^{def}
Andana	695.66 ± 2.08^{i}	0.42 ± 0.01^{bc}	0.82 ± 0.001^{f}	0.85 ± 0.001^{def}
Anforeta	373.00 ± 4.58^{c}	0.81 ± 0.01^{g}	0.82 ± 0.001^{f}	0.87 ± 0.001^{hij}
Arz	223.66 ± 7.37^{a}	0.47 ± 0.03^{d}	0.86 ± 0.010^{h}	0.87 ± 0.010^{j}
Boumerzoug	557.33 ± 3.05^{g}	0.60 ± 0.02^{e}	0.84 ± 0.010^{g}	0.86 ± 0.005^{ghi}
Bordj Mehis	446.00 ± 5.00^{d}	1.12 ± 0.06^{h}	0.77 ± 0.006^{a}	0.83 ± 0.002^{a}
El Hachimia	1352.66 ± 8.50^{n}	0.31 ± 0.01^{a}	0.82 ± 0.007^{f}	0.86 ± 0.004^{ghi}
Hidhab	988.66 ± 3.51^{k}	0.46 ± 0.01^{cd}	0.82 ± 0.003^{ef}	0.86 ± 0.002^{efgh}
Massine	459.33 ± 13.27^{e}	0.56 ± 0.01^{e}	0.82 ± 0.000^{f}	0.87 ± 0.000^{ij}
Medracen	1131.00 ± 2.64^{m}	0.40 ± 0.02^{b}	0.79 ± 0.005^{b}	0.85 ± 0.001^{cd}
Nif Encer	1060.66 ± 0.57^{l}	0.46 ± 0.00^{cd}	0.78 ± 0.001^{bc}	0.85 ± 0.000^{cd}
Palesio	692.00 ± 7.54^{i}	0.73 ± 0.00^{f}	0.77 ± 0.001^{a}	0.84 ± 0.001^{ab}
Tidis	738.33 ± 2.51^{j}	0.49 ± 0.00^{d}	0.80 ± 0.001^{bc}	0.85 ± 0.001^{cd}
Yacine	631.00 ± 7.54^{h}	0.57 ± 0.00^{e}	0.80 ± 0.001^{bc}	0.84 ± 0.002^{bc}

Means within the same column labeled with different superscript letters indicate statistically significant differences ($p < 0.05$) based on the Duncan post hoc test.

3.4. Principal component analysis and Hierarchical Clustering Analysis

Principal component analysis (PCA) determined the different relationships between the quality characteristics of flour, dough, and bread for the 17 studied wheat genotypes. The projection of the studied variables on the PCA biplot (Figure 1) was defined by the first two dimensions (1 and 2).

These two dimensions accounted for about 27.1% and 14.8% of the explained variance, respectively. By incorporating five dimensions, the PCA captured a more comprehensive view of the dataset's structure, contributing to a cumulative explained variance of 53.3%, 63.3%, and 70.7% for the third, fourth, and fifth dimensions, respectively (Table 7). The first PCA dimension was mainly characterized by dough strength (W), protein content, cell count, β-sheet, specific volume, R ratio, the color parameter *a** of the crust, and β-turn, which showed significant positive correlations; and by the color parameters *L** and *b** of the crust, solidity, circularity, P/L ratio, random coil, α-helix, and cell size, which were significantly negatively correlated. The second dimension was mainly characterized by significant positive correlations of α-helix, R ratio, random coil, ash, and P/L ratio and by negative correlations of β-sheet, fat content, the *L** and *b** of the crust, β-turn, and weight loss (WL) (Figure 1, Table 7).

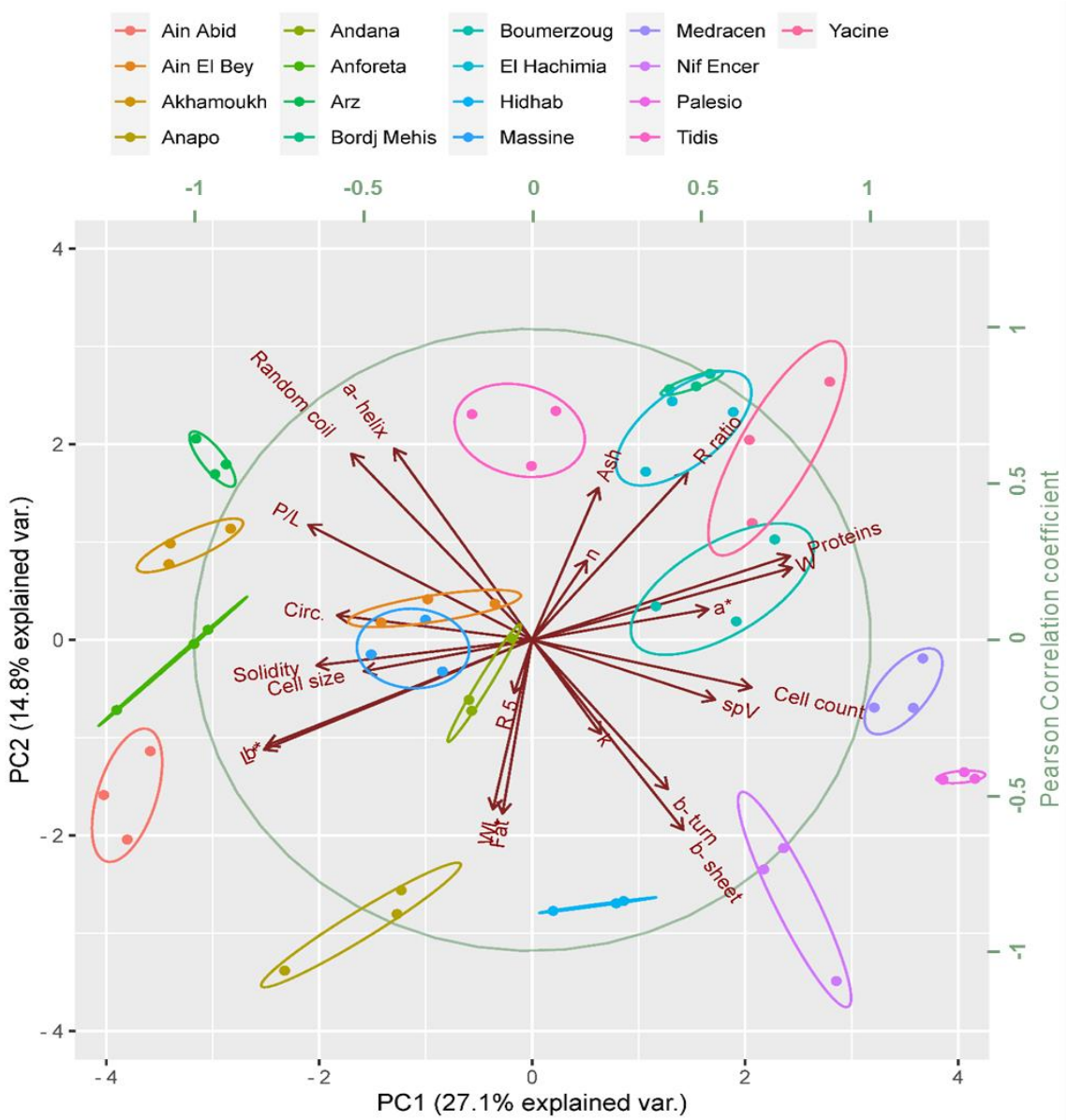

Figure 1. Biplot of the principal component analysis of chemical characteristic of flours, secondary structure of flours proteins, amounts of wheat gluten, R ratio, rheological properties of dough, physical characteristics of breads for 17 bread wheat genotypes. The circle refers to the correlation circle, whereas the colored ellipses are 68% confidence intervals for genotypes.

The third PCA dimension, which explained 11.4% of the variance, complemented either PCA1 by offering insights into the contribution of solidity and circularity or PCA2 by showing the significant projection of cell size and gluten content (Table 7).

The hierarchical clustering analysis revealed four groups (Figure 2). In Group 1, there were Palesio, Medracen, Hidhab, and Nif Encer, with high protein content, the highest β-sheet, and good alveograph parameters. In Group 2, El Hachimia, Bodj Mehis, Tidis, and Yacine showed high protein content with the lowest content of β-sheet and intermediate values of alveograph parameters. Group 3 included Anapo, Ain El Bey, Massine, Boumerzoug, and Andana, with the lowest protein content, low

alveograph parameters, and the highest specific volume of the loaves. Group 4 included Ain Abid, Arz, Akhamoukh, and Anforeta, with low protein containing moderate β-sheet, the poorest alveograph parameters, and the smallest specific volume of bread.

Protein content was positively correlated with W (r = 0.69, $p < 0.05$), which agrees with findings by Randall and Moss [39] and Poblaciones et al. [40]. It was also negatively correlated with the L^* value of the crust (r = −0.65, $p < 0.05$). These correlations suggest that wheat flour with a higher protein content resulted in increased baking strength and a darker crust color, which can be attributed to the Maillard reaction [41]. These findings indicate the favorable impact of protein content on dough and bread quality. As noted by Li et al. [19], the dough strength properties of wheat flours are influenced not only by the quantity of proteins but also by their quality. Ash content was correlated negatively with the yellowness b^* of the crust ($r = -0.56$, $p < 0.05$) and positively with the protein content ($r = 0.64$, $p < 0.05$).

Table 7. Pearson correlation tests exploring the link between the variables and the first five PCA dimensions of the standardized data. Only statistics (*r*: correlation coefficient and *p*-value) of significant variables ($p < 0.05$) are shown.

Variables	PCA dim 1 (Var. = 27.1%)		PCA dim 2 (Var. = 14.8%)		PCA dim 3 (Var. = 11.4%)		PCA dim 4 (Var. = 10.0%)		PCA dim 5 (Var. = 7.4%)	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value
a^*	0.521	<0.001	NS	NS	−0.527	<0.001	NS	NS	NS	NS
α helix	−0.407	0.003	0.615	<0.001	NS	NS	0.290	0.039	NS	NS
Ash	NS	NS	0.490	<0.001	NS	NS	−0.540	<0.001	0.497	<0.001
b^*	−0.783	<0.001	−0.338	0.015	NS	NS	NS	NS	NS	NS
β sheet	0.446	0.001	−0.610	<0.001	NS	NS	−0.284	0.043	0.350	0.012
β turn	0.400	0.004	−0.480	<0.001	NS	NS	NS	NS	NS	NS
Cell count	0.648	<0.001	NS	NS	−0.328	0.019	NS	NS	NS	NS
Cell size	−0.497	<0.001	NS	NS	0.718	<0.001	NS	NS	NS	NS
Circ.	−0.576	<0.001	NS	NS	−0.606	<0.001	NS	NS	0.457	0.001
Fat	NS	NS	−0.557	<0.001	NS	NS	NS	NS	NS	NS
K	NS	NS	−0.302	0.031	NS	NS	−0.357	0.010	NS	NS
L^*	−0.792	<0.001	−0.352	0.011	NS	NS	NS	NS	NS	NS
n	NS	NS	NS	NS	NS	NS	0.588	<0.001	0.414	0.003
P/L	−0.660	<0.001	0.368	0.008	−0.396	0.004	−0.285	0.043	NS	NS
Proteins	0.761	<0.001	NS	NS	NS	NS	−0.379	0.006	NS	NS
R 5	NS	NS	NS	NS	0.658	<0.001	NS	NS	0.576	<0.001
R ratio	0.458	0.001	0.541	<0.001	NS	NS	0.300	0.032	NS	NS
Random coil	−0.534	<0.001	0.599	<0.001	NS	NS	NS	NS	NS	NS
Solidity	−0.636	<0.001	NS	NS	−0.515	<0.001	NS	NS	0.420	0.002
spV	0.540	<0.001	NS	NS	NS	NS	0.557	<0.001	NS	NS
W	0.767	<0.001	NS	NS	NS	NS	NS	NS	NS	NS
WL	NS	NS	−0.545	<0.001	NS	NS	0.496	<0.001	NS	NS

Abbreviations: Var.: percentage of explained variance, NS: non-significant correlation, $p > 0.05$).

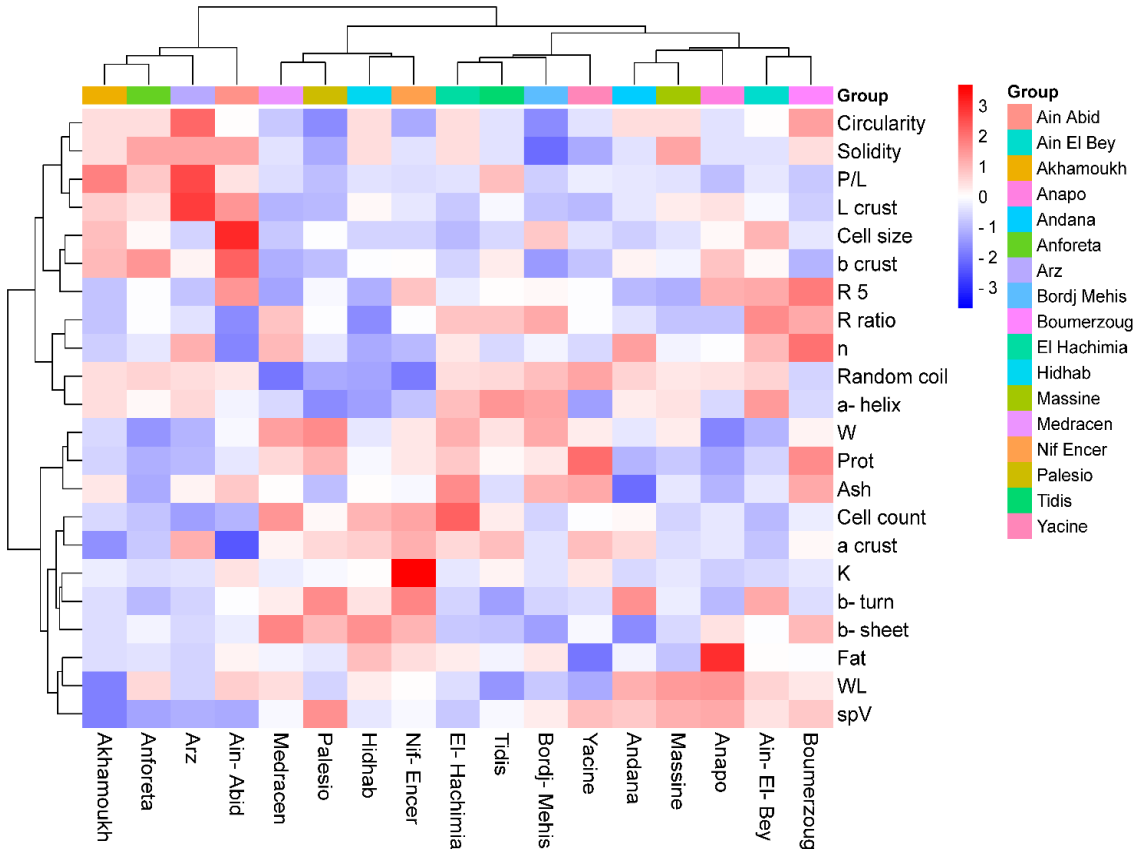

Figure 2. Heatmap and hierarchical clustering analysis of bread wheat genotypes based on the Ward's method and Euclidian distance**.** Red and blue colors imply high and low values, respectively.

The β-sheet structure was correlated negatively with random coil (r = −0.85, $p < 0.05$) and α-helix (r = −0.71, $p < 0.05$). The random coil was correlated positively with α-helix (r = 0.56, $p < 0.05$) and count cell (r=0.55, $p<0.05$) and negatively with β-turn (r = −0.52, $p < 0.05$). The R ratio was correlated positively with n (r = 0.57, $p < 0.05$) and negatively with L^* (r = −0.54, $p < 0.05$). W was correlated negatively with L^* (r = −0.64, $p < 0.05$), b^*(r = −0.50, $p < 0.05$) and circularity (r = −0.54, $p < 0.05$) and correlated positively with count cell (r = 0.50, $p < 0.05$). These correlations imply that higher dough strength leads to an increased cell number with non-circular shapes and a darker crust color. According to Sun et al. [42], the stronger wheat flour increased the dough's void fraction. In our loaves, the weight loss was negatively correlated with the P values (r = −0.65, $p < 0.05$).

The specific volume showed a negative correlation with P/L ratio (r = −0.73, $p < 0.05$), in line with previous findings by Pasqualone et al. [43]. This correlation suggests that higher flour tenacity has a detrimental effect on breadmaking. The specific volume was correlated negatively with L^* (r = −0.55, $p < 0.05$) and solidity (r = −0.51, $p < 0.05$) and positively with a^* (r = 0.52, $p < 0.05$). The P/L ratio was correlated negatively with a^* (r = −0.65, $p < 0.05$) and positively with L^* (r = 0.77, $p < 0.05$), circularity (r = 0.57, $p < 0.05$) and solidity (r = 0.50, $p < 0.05$).

The L^* was correlated negatively with a^* (r = −0.87, $p < 0.05$) and count cell (r = −0.57, $p < 0.05$) and positively with circularity (r = 0.62, $p < 0.05$) and solidity (r = 0.67, $p < 0.05$).

4. Conclusions

The genotypes of *Triticum aestivum* L. tolerant to drought and heat can be grouped according to the properties found in this study. Group 1 included traditional, recently or not yet cultivated genotypes in Algeria with high protein content, the highest proportion of β-sheet, and the best alveograph parameters. Group 2 had the highest protein content, the lowest content of β-sheet, and good alveograph parameters. Group 3 comprised traditional, recently cultivated, or not yet cultivated genotypes that had the best specific volume of bread in spite of their low protein concentration and medium alveograph values. Group 4 was formed with only traditionally cultivated genotypes that presented the lowest specific volume of bread and a low protein content, which could be used for the preparation of other foodstuffs as cookies because of their properties. The genotypes Hidhab and Medracen are distinguished as superior selections due to their exceptional attributes in terms of quantity and quality of proteins, less immunoreactive gluten content, and notable tolerance to both drought and heat. In conclusion, we were able to identify high-quality attributes for breadmaking in the majority of the 17 studied wheat flours, which is good news in the middle of global warming because they are drought- and heat-tolerant genotypes. However, the evaluated parameters there were no predictors of the potentiality for breadmaking, although all of the genotypes have nutritive components.

Use of AI tools declaration

The authors declare that they have not used Artificial Intelligence (AI) tools in the creation of this article.

Aknowledgements

The authors are grateful to the staff of the Laboratory of the Cereals Subsidiary-Zibans El Kantra, Biskra CIC—The Mills Sidi R'ghiss, Oum el Bouaghi-Algeria and the Development and Analysis Center in Agro-Industry AGRODIV Group (CDAAI) Constantine-Algeria. Also, thanks to A.V. Bolaños-Villar for English and format edition.

Conflict of interest

All the authors declare that they have no conflicts of interest with the work presented.

Author contributions

Hamida Mahroug conducted the milling of wheat grains, FTIR analysis and deconvolution, Alveograph tests, and evaluated the physical properties of bread. Adra Mouelef conducted the chemical analysis of flour. Hamida Mahroug and Ana Maria collaborated on writing the manuscript. Hayat Bourekoua and Hamida Mahroug designed the experiments. Ana Maria conducted R5 sandwich ELISA and contributed to reviewing and editing. Fairouz Djeghim conducted flow tests. Awatif Fetouhi performed baseline correction and calculated the R ratio. Abdelkader Benbelkcen provided the genotypes. Haroun Chenchouni and Mohammed El Hadef El Okki performed statistical analysis. Nedjla Silini helped in the preparation of the grains for milling. All authors participated in manuscript review.

Supplementary

Table S1. Detailed list of *Triticum aestivum* L. genotypes.

	Genotypes	Origin	Years of release	C/L	Pedigree	Shape/color	Drought tolerance	Heat tolerance
1	Ain Abid	Algeria/Spain	1998	C	AS81189A	Oval/ red	2	1
2	Ain el Bey	Algeria/CIMMYT	Under way	L	Mahon Démias*²/Boumerzoug *CBTDZ-KB015-011-2Kb-3Sé-OKb-0Kb*	Elongated/white	2	2
3	Akhamoukh	Algeria/CIMMYT	2014	C	Irena/Babax/Pastor CMSS96M05638T-040Y-010S-010M-010S-4M-0Y	Elongated/white	3	2
4	Anapo	PRO-SE-ME Italy	2009	C	EG-52× BEL 118	Oval/ red	2	1
5	Andana	PRO-SE-ME Italy	2012	C	Line cimmyt× eridiano	Oval/ red	1	1
6	Anforeta	PRO-SE-ME Italy	2011	C	EG 83× BEL 118	Oval/white	1	1
7	Arz	Algeria	1998	C	MAYO 54/LR64//TAC S"/3/LR64// TZPP /Y54	Oval/ red	3	3
8	Boumerzoug	Algeria/CIMMYT	2014	C	CMSS93B00255S-48Y-010M-010Y-010M-7Y-0M-4KBY-0KBY-0M	Oval/ red	3	3
9	Bordj Mehis	Algeria/CIMMYT	Under way	L	Nac/TH.Ac//3*Pvn/3/Mirlo/Buc/4/2*Pastor/5/Kachu/6/Kachu	Oval/white	2	2
10	El Hachimia	Algeria/CIMMYT	2021	C	Kachu♯1//Wbll*²/Kukuna	Oval/white	2	2
11	Hidhab	Algeria	1985	C	HD1220/3*kal/Nac	Elongated/white	3	3
12	Massine	Algeria/CIMMYT	2014	C	Pastor CM85295-0101TOPY-2M-0Y-0M-3Y-0M-0SY	Elongated/white	3	3
13	Medracen	Algeria/CIMMYT	Under way	L	ITP40/AKURI *CMSS07Y00441S-0B-099Y-099M-099NJ-099NJ-4WGY-0B*	Elongated/white	3	3
14	Nif Encer	Algeria/CIMMYT	Under way	L	KAUZ*2/MNV//KAUZ/3/MILAN/4/BAV92/5/ CHYAK *CMSS07B00100S-099M-099Y-099M-3WGY-0B*	Elongated/white	3	2
15	Palesio	Italy	2022	C	Pandas x Recital (Orso x (Bezostaja x S1) x (Generoso 7 x C. Marzabotto x Mexique-267(R-267)/9369)	Oval/ red	1	1
16	Tidis	Algeria/CIMMYT Mexico	2014	C	IRENA CM91575-28Y-OM-0Y-2M-0Y-	Oval/white	3	2
17	Yacine	Algeria/CIMMYT	Under way	L	OASIS/SKAUZ//4*BCN*2/3/PASTOR	Oval/white	2	2

C: Cultivated; L: Line; Least tolerant (score of 1) to most tolerant (score of 5) according to Field Crop Institute Agricultural Research.

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