INTERRELATIONS BETWEEN THE NUTRITIONAL AND TECHNOLOGICAL CHARACTERS OF WHEAT GRAINS

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ABSTRACT - The objectives of this research were to define correlations between nutritional, rheological and physiological factors between the genotypes and to identify the genotype x environment existing relationships in the sense of the expression of desirable assimilates. The experiment took place in five growing environments with two sowing times, May 15 and June 15 in the 2019 harvest and in two different geographic locations (Cachoeira do Sul and Santo Augusto), and a time of May 15 during the 2019 harvest in São Gabriel, located in the state of Rio Grande do Sul. The experimental design used was randomized blocks, organized in a factorial scheme, with five (culture environments) x five (wheat genotypes) in four replications, totaling 100 experimental units. Nutritional and technological characters of wheat grains were evaluated. There is a linear relationship between the group of rheological variables and the physiological characters of wheat grains.

Keywords: amino acids, BLUP, canonical correlation, genetic parameters, *Triticum aestivum*.

INTER-RELAÇÕES ENTRE CARACTERES NUTRICIONAIS E TECNOLÓGICOS DE GRÃOS DE TRIGO

RESUMO - Os objetivos desta pesquisa foram definir correlações entre fatores nutricionais, reológicos e fisiológicos de genótipos de trigo e identificar as relações genótipo x ambiente existentes no sentido da expressão de assimilados desejáveis. O experimento foi conduzido em cinco ambientes de cultivo, duas épocas de semeadura, 15 de maio e 15 de junho na safra 2019 e em duas localidades geográficas distintas, Cachoeira do Sul e Santo Augusto, além de uma época de 15 de maio durante a safra 2019 em São Gabriel, localidades do Estado do Rio Grande do Sul. O delineamento experimental utilizado foi em blocos casualizados, organizados em esquema fatorial, com cinco ambientes de cultivo x cinco genótipos de trigo, quatro repetições, totalizando 100 unidades experimentais. Caracteres nutricionais e tecnológicos de grãos de trigo foram avaliados. Existe relação linear entre o grupo de variáveis reológicas com os caracteres fisiológicos dos grãos de trigo.

Termos para indexação: *Triticum aestivum*, aminoácidos, parâmetros genéticos, BLUP, correlação canônica.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a cereal with the possibility of cultivation in a vast region of Brazil, although it stands out in the southern region of Brazil and regions of lower latitude with higher altitude. In these producing regions, the environmental variability is wide (Bornhofen, 2017). These adversities and large environmental variations can generate great difficulty in the positioning of cultivars since a genotype, when cultivated in different environments, regularly presents a degree of modification in productive performance, this is the result of the environmental component and it is the presence of genotype interaction × environment (Bornhofen et al., 2017).

With such environmental influence on the positioning of wheat crops, and the search for grains with higher technological quality, for the production of better-quality flours by the consumer market, it is important to

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evaluate their effects and their correlation in the nutritional scope of wheat grains. Understanding the factors related to grain yield and the nutraceutical assumptions of the wheat grain in relation to environmental influence is important to define the relationship between the environment and the metabolomics expression of the cultivars and its quantification, since the interaction between genotypes x environments is highly related with wheat grown in different environments or with sowing at different times (Cargnin et al., 2006).

These interactions between genotypes and environments can define the quality of industrial wheat, where the production of wheat flour and its destination will be defined. These qualitative parameters are related to genetic control and can define characteristics such as protein and starch content, grain hardness, yield milling, grain color and cob germination and also related to environmental factors such as soil type, sanity, grain filling, protein content, losses due to weather, damaged grains, presence of pests or diseases and grain moisture.

The technological quality of wheat flour is the most important factor for the bakery industries, since they aim to produce products that have high quality, meeting the demands of consumers. This quality can be verified through tests such as alveography, which seeks to estimate the gluten strength, amylase enzyme activity test by the number of falls and the investigation of the percentage of gluten (Broca et al., 2021). In this sense, the objectives of this research were to define correlations between nutritional, rheological and physiological factors between the genotypes and to identify the genotype x environment existing relationships in the sense of the expression of desirable assimilates.

MATERIAL AND METHODS

The experiment took place in five growing environments with two sowing times, May 15 and June 15 in the 2019 harvest and in two different geographic locations (Cachoeira do Sul and Santo Augusto), and a time of May 15 during the 2019 harvest in São Gabriel, located in the state of Rio Grande do Sul, and according to the Köppen climate classification, they fall into the Cfa type, humid subtropical (Kuinchtner & Buriol, 2001).

Five different wheat genotypes were also evaluated, these recommended for the state of Rio Grande do Sul. These genotypes are described below according to their main characteristics. These descriptors indicate the main characteristics of the genotypes, according to information from their breeders, such as the classification regarding the type of flour produced by the grains, characterized by the quantification of gluten.

The experimental design used was randomized blocks, organized in a factorial scheme, with five (culture environments) x five (wheat genotypes) in four replications, totaling 100 experimental units. Two sowing seasons were carried out, Season I (05/15) and Season II (06/15), the cultivation environments were Cachoeira do Sul - season I, Cachoeira do Sul - season II, Santo Augusto - season I, Santo Augusto - season II, São Gabriel - season I. The genotypes used in the experiment were BRS Parrudo, LG ORO, Mirante, ORS 1403 and Tbio Sinuelo, with 25 treatments. The experimental units consisted of five sowing lines, spaced at 0.20 m, five meters long, totaling five square meters. A population density of 330 viable seeds per square meter was used, and sowing was carried out on the same day for both cultivars within each environment, within the recommended agricultural zoning for each region.

Fertilization management took place according to the interpretation of the soil analysis of the area, using 250 kg ha^{-1} of NPK in the 08-25-20 formulation as base fertilization at sowing, and were also applied 50 kg ha^{-1} of nitrogen as a topdressing fertilizer, in the form of urea (46% of N) in a single application during the full tillering stage, crop protection managements (pest and disease control) were standardized for all environments and genotypes, following the Wheat Technical Recommendations (RCBPTT, 2012). The plants were harvested individually in each experimental unit, and the harvested seeds had the mass adjustment for moisture of 13% and the estimated production in kg ha^{-1}. From the grain production of each unit, samples of the grains were separated, where from one part the flour was produced through milling, removing samples of 500 grams of each treatment that were later submitted to the LC-ESI-qToF-MS method of mass spectrometry to quantify the intensities of the metabolites contained in the wheat seeds of each experimental unit and with the remainder, analyzes were carried out soon after harvest and after a period of six months of storage.

The physiological variables were evaluated, being germination potential (G, %), first germination count (FGC, %), electrical conductivity (EC, Ω-1), accelerated aging (AA, %) and field emergence (FE, %). For bread-making quality, the following were evaluated: humidity (H, %), dough extensibility in mm (L, mm), dough tenacity in mm (P, mm), falling number (FN, seconds), tenacity-extensibility ratio (PL, mm), gluten strength (W, 10^{-4} J), dry gluten basis (DG, %), wet gluten basis (WG, %) and water absorption by the dough (WA, %). To measure the proximate component, hectoliter mass (HM, g cm^3), crude protein in grain at harvest (CP_GH, %), lipids in grain at harvest (LIP_ GH, %), crude fiber in grain at harvest (CF _ GH, %), mineral material in grain at harvest (MM_ GH, %), starch in grain at harvest (CHO_ GH, %), crude protein in grain after storage (CP_AS, %), lipids in grain at harvest after storage (LIP_AS, %), crude fiber in grain after storage (CF_ AS, %), mineral material in grain after storage (MM_ AS, %), starch in grain after storage (CHO_ AS, %). The productivity and quantification of the following metabolites: leucine in grain (LEU, pmol), isoleucine in grain (ISOL, pmol), glycine in grain (GLY, pmol), serine in grain (SER, pmol), threonine in grain (THR, pmol), proline in grain (PRO, pmol), aspartate in grain (ASPA, pmol), phenylalanine in grain (PHEN, pmol), glutamine in (GLU, pmol), asparagine in grain (ASGI, pmol) and tryptophan in grain (TRY, pmol).

The collected data were analyzed for the purpose of verification of variance, using the test of normality and homogeneity of variances. Consider the following statistical model:

$$Y = Xr + Zg + Wi + e$$

Where: $\underline{Y}$ is the data vector, $\underline{r}$ is the vector of repetition effects (assumed to be fixed) added to the general mean, and include all repetitions from all locations, $\underline{g}$ is the vector of genotypic effects (assumed to be random), $\underline{i}$ is the vector of the effects of the interaction between genotypes x locations (random), where $\underline{e}$ is the vector of errors (random). The capital letters represent the incidence matrices for the referred effects, later, the estimates of the variance components and genetic parameters (REML) were performed. Variance components, genetic parameters, genotypic variance (CVg*), phenotypic variance (CVf*), broad sense heritability (H2), mean genotype heritability ($\hat{H}^2mg$), coefficient for determining the effects between genotypes and environments interaction (GEI), genotypic correlation between genotypes x environments performance (RGE), coefficient of genotypic variation (CVg*), residual coefficient of variation (CVr*), coefficient of variation of the proportion between genotypic and residual coefficient of variation (CV ratio*).

BLUP (Best Linear Unbiased Predictor) estimates were performed to obtain the components of the predicted means. Multi-trait I for nutritional indices in grain based on crude protein in grain at harvest (CP GH), lipids in grain at harvest (LIP GH), crude fiber in grain at harvest (CF GH), mineral material in grain at harvest (MM GH) and starch in grain at harvest (CHO GH). Physiological multi-trait II based on germination potential (G), first germination count (FGC), electrical conductivity (EC), accelerated aging (AA) and field emergence (FC) and Multi-trait III based on rheological characteristics extensibility of mass in mm (L), gluten strength (W). Subsequently, the canonical correlations were identified, which are based on the estimation of the maximum correlation between the groups of characters, in group I rheological characters (dough extensibility, dough tenacity, falling number, relationship between tenacity and extensibility, gluten strength, dry gluten basis, wet gluten basis, water absorption by the dough and hectoliter mass). Group II physiological characters (germination, first germination count, electrical conductivity, accelerated aging and field emergence). Group III referring to nutritional characteristics in grain at harvest (crude protein, lipids in grain, crude fiber grain, mineral material in grain and starch in grain) and Group IV responsible for the nutritional characteristics in grain after storage (crude protein in grain, lipids in grain, crude fiber in grain, mineral material in grain and starch in grain). Group V based on amino acids (leucine, isoleucine, glycine, serine, threonine, proline, aspartate, phenylalanine, glutamine, asparagine and tryptophan. Statistical analyzes were performed using the R software (R Core Team, 2021).

RESULTS AND DISCUSSION

The variables that differed statistically by the x^2 test at 5% probability were germination potential, first germination count, electrical conductivity, accelerated aging, field emergence, leucine, isoleucine, proline, aspartate, phenylalanine, tryptophan, mass extensibility in mm, gluten strength, crude protein in grain at harvest, lipids in grain at harvest, crude fiber in grain at harvest, mineral material in grain at harvest, starch in grain at harvest, crude protein in grain after storage, lipids in grain after storage, crude fiber in grain after storage, mineral material in grain after storage and starch in grain after storage.

In view of this, it can be said that the heritability presented in the REML analyzes of the rheological and nutritional variables at harvest and after storage (Table 1) was considered high for the factors gluten strength, crude protein in grain at harvest, crude fiber in grain at harvest, mineral material in grain at harvest, starch in grain at harvest, crude protein in grain after storage, mineral material in grain after storage, starch in grain after storage and lipids in grain after storage.

Table 1 - Analysis of variance components and genetic parameters for the rheological, nutritional at harvest, nutritional after grain storage, physiological and amino acid variables.

Parameters	L	W	CP GH	LIP GH	CF GH	MM GH	CHO GH	CP AS	LIP AS	CF AS	MM AS	CHO AS
σ²G	0.477	2926	1.39	0.016	0.0371	0.0124	4.17	1.34	0.0525	0.0262	0.0203	2.37
Heritability	0.355	0.0563	0.715	0.169	0.566	0.751	0.89	0.84	0.576	0.289	0.781	0.881
GEI *	0.573	0.32	0.279	0.568	0.3	0.176	0.0971	0.13	0.307	0.609	0.192	0.0907
H²mg*	0.75	0.372	0.927	0.572	0.895	0.951	0.978	0.968	0.895	0.695	0.952	0.978
Accuracy	0.866	0.61	0.963	0.756	0.946	0.975	0.989	0.984	0.946	0.833	0.975	0.989
RGE*	0.887	0.339	0.98	0.684	0.691	0.709	0.882	0.811	0.724	0.856	0.881	0.763
CVg* (%)	0.448	3.91	7.27	3.23	5.83	5.68	3.4	7.72	10.7	3.25	7.5	2.46
Cvr* (%)	0.203	13	0.652	4.03	2.84	1.76	0.411	1.46	4.84	1.94	1.37	0.439
CV ratio* (%)	2.21	0.301	11.2	0.803	2.05	3.22	8.28	5.27	2.22	1.68	5.47	5.6
Parameters	G	FGC	EC	AA	FE	LEU	ISOL	PRO	ASP	PHEN	TRY	
σ²G	62.9	64.5	371	89.7	322	1.61E+11	3.33E+10	3.03E+11	3.54E+11	1.99E+11	8.16E+12	
Heritability	0.276	0.303	0.571	0.201	0.142	5.60e- 2	1.01e- 1	1.96e- 1	2.97e- 1	2.30e- 1	3.14e- 1	
GEI	0.337	0.282	0.268	0.448	0.199	9.42e- 1	8.97e- 1	8.04e- 1	7.02e- 1	7.69e- 1	6.86e- 1	
H²mg	0.761	0.797	0.903	0.652	0.662	2.29e- 1	3.60e- 1	5.49e- 1	6.79e- 1	6.00e- 1	6.96e- 1	
Accuracy	0.872	0.893	0.95	0.807	0.813	4.79e- 1	6.00e- 1	7.41e- 1	8.24e- 1	7.74e- 1	8.34e- 1	
RGE	0.464	0.404	0.623	0.561	0.232	9.98e- 1	9.98e- 1	1.00e+ 0	9.99e- 1	9.99e- 1	1.00e+ 0	
CVg* (%)	4.93	5.34	29.4	5.35	17	7.85e+ 0	1.45e+ 1	2.28e+ 1	1.53e+ 1	2.65e+ 1	1.21e+ 1	
Cvr* (%)	5.85	6.26	15.6	7.08	36.5	1.49e+ 0	1.72e+ 0	7.01e- 1	5.31e- 1	1.10e+ 0	3.73e- 1	
CV ratio* (%)	0.843	0.854	1.88	0.756	0.465	5.26e+ 0	8.45e+ 0	3.25e+ 1	2.88e+ 1	2.40e+ 1	3.25e+ 1	

σ²G: Phenotypic variance; **GEI***: Coefficient for determining the effects of the genotype-environment interaction; **H²mg**: Mean heritability of the genotype; **GER***: Genotypic correlation between genotypes x environments ratio; **CVg***: Genotypic variation coefficient; **Cvr***: Coefficient of residual variation; **CV ratio***: Coefficient of variation of the ratio between genotypic and residual coefficient of variation; **L**: Mass extensibility in mm; **W**: Gluten strength; **CP GH**: Crude protein in grain at harvest; **LIP GH**: Lipids in grain at harvest; **CF GH**: Crude fiber in grain at harvest; **MM GH**: Mineral material in grain at harvest; **CHO GH**: Starch in grain at harvest; **CP AS**: Crude protein in grain after storage; **LIP AS**: Lipids in grain after storage; **CF AS**: Crude fiber in grain after storage; **MM AS**: Mineral material in grain after storage; **CHO AS**: Starch in grain after storage.; **G**: Germination Potential; **FGC**: First germination count; **EC**: Electrical conductivity; **AA**: Accelerated aging; **FE**: Field emergency; **LEU**: Leucine; **ISOL**: Isoleucine; **PRO**: Proline; **ASP**: Aspartate; **PHEN**: Phenylalanine; **TRY**: Tryptophan.

The GEI method indicates the participation of interaction effects in the total variation of the character (Yan et al., 200). The analysis of the rheological and nutritional variables at harvest and nutritional after 6 months of storage (Table 1) indicated that the factors mass extensibility in mm, gluten strength, lipids in grain at harvest, crude fiber in grain at harvest, lipids in grain after storage and crude fiber in grain after storage, showed greater effects of the interaction genotypes x environments with intensities of 0.573, 0.320, 0.568, 0.300, 0.307 and 0.609, respectively. For physiological parameters and amino acids, a greater intensity of the interaction effects was identified for germination and accelerated aging, with values of 0.337 and 0.448, respectively.

Heritability of the genotype average is estimated when using block averages as an evaluation and/or selection criterion (Resende, 2007). Classifications according to heritability values are also used for this evaluation, that being said, all the analyzed factors of the rheological and nutritional variables at harvest and nutritional after storage (Table 1) were considered high for this item, although in greater evidence for extensibility of mass in mm, crude protein in grain at harvest, crude fiber in grain at harvest, starch in grain at harvest, mineral material in grain at harvest, crude protein in grain after storage, mineral material in grain after storage, starch in grain after storage and lipids in grain after storage. The H^2mg value of REML Analyzes for Physiological parameters and amino acids were considered high for germination potential, first germination count, electrical conductivity, accelerated aging and field emergence, the other variables showed low heritability.

Accuracy is a parameter that can determine the experimental precision and in the analysis of genotype competition, and takes into account the level of genotypic variation of the character (Resende & Duarte, 2007). High accuracies express work that is more accurate and the closer to 1 this value, the higher the accuracy. Within the rheological and nutritional REML analyzes at harvest and nutritional after 6 months of storage, an extremely high accuracy was identified for all parameters, except for the gluten strength parameter, which showed medium accuracy. When evaluating the REML analyzes for physiological parameters and amino acids, only the physiological factors showed high accuracy: germination potential, first germination count, electrical conductivity, accelerated aging and field emergence.

The genotypic correlation between the genotypes x environments performance allows for the classification of the incident interaction into simple or complex, so that a high correlation indicates a simple interaction, with fewer distortions in the classification of genotypes in the environments (Pupin et al., 2015). This correlation was shown to be high for the rheological and nutritional REML analyzes at harvest and nutritional after 6 months of storage for: mass extensibility in mm, crude protein in grain at harvest, starch in grain at the harvest, mineral material in grain at harvest, crude protein in grain after storage, crude fiber in grain after storage, mineral material in grain after storage, starch in grain after storage and lipids in grain after storage showing (0.70< RGE) and reveal the highest participation of the interaction characterized as simple (Pupin et al., 2015).

Low coefficients (RGE<0.50) were expressed for the variables gluten strength, germination potential, first germination count, accelerated aging, field emergence, leucine, isoleucine, proline, aspartate, phenylalanine and tryptophan, for these variables it says the genotypic correlation between the environments indicates greater effects of the interaction of a complex nature, and results in less phenotypic stability of the genotypes (Rosado et al., 2012). The genotypic variation coefficient can quantify the magnitude of the genetic variation available for selection, therefore, it is desirable to obtain high values (Carvalho et al., 2016). This value was higher in the rheological and nutritional REML Analyzes at harvest and nutritional after 6 months of storage for: crude protein in grain at harvest 7.27%, crude protein in grain after storage 7.72%, lipids in grain after storage 10.7% and mineral matter after storage 7.5%. As for the values of REML analyzes for physiological parameters and amino acids, the same was higher for electrical conductivity 29.4% and field emergence 17%.

The residual coefficient of variation was superior in the rheological and nutritional REML analyzes at harvest and nutritional after 6 months of storage in terms of gluten strength 13% and for the REML analyzes for physiological parameters and amino acids (Table 1) the same was higher for the electrical conductivity factors 15.6% and field emergence 36.5%. Evaluating the coefficient of variation of the proportion between the coefficient of genotypic and residual variation for the parameters REML rheological and nutritional analyzes at harvest and nutritional after 6 months of storage (Table 1), a high variation in the variables crude protein in grain in the harvest, starch in grain at harvest, crude protein in grain after storage, mineral matter after storage and starch in grain after storage, due to the low coefficient of variation of the residue. As for the REML analysis for physiological parameters and amino acids, high values were not identified.

The following variables did not show significant results for the interaction: falling number, relationship between tenacity and extensibility, dry gluten basis, wet gluten basis, water absorption by the dough and hectoliter mass. The amino acids Glycine, Serine, Threonine, Glutamine and Asparagine showed no statistically significant differences in the REML/BLUP test. According to the evaluation of the REML/BLUP method for the analyzed physiological variables (Figure 1), a pure genetic gain was identified for the germination variables for the Mirante, ORS 1403 and Tbio Sinuelo genotypes, for the first germination count in the LG Oro genotypes, ORS 1403, Mirante and Tbio Sinuelo, for electrical conductivity in the genotypes ORS 1403 and BRS Parrudo, in the variable accelerated aging for the genotypes Mirante, LG Oro, ORS 1403 and Tbio Sinuelo and for field emergence there was pure genetic gain in the genotypes Tbio Sinuelo, LG Oro and ORS 1403. It was observed by the evaluation of the multi-trait graph for the physiological variables in the multi-character selection that only the Tbio Sinuelo genotype was selected.

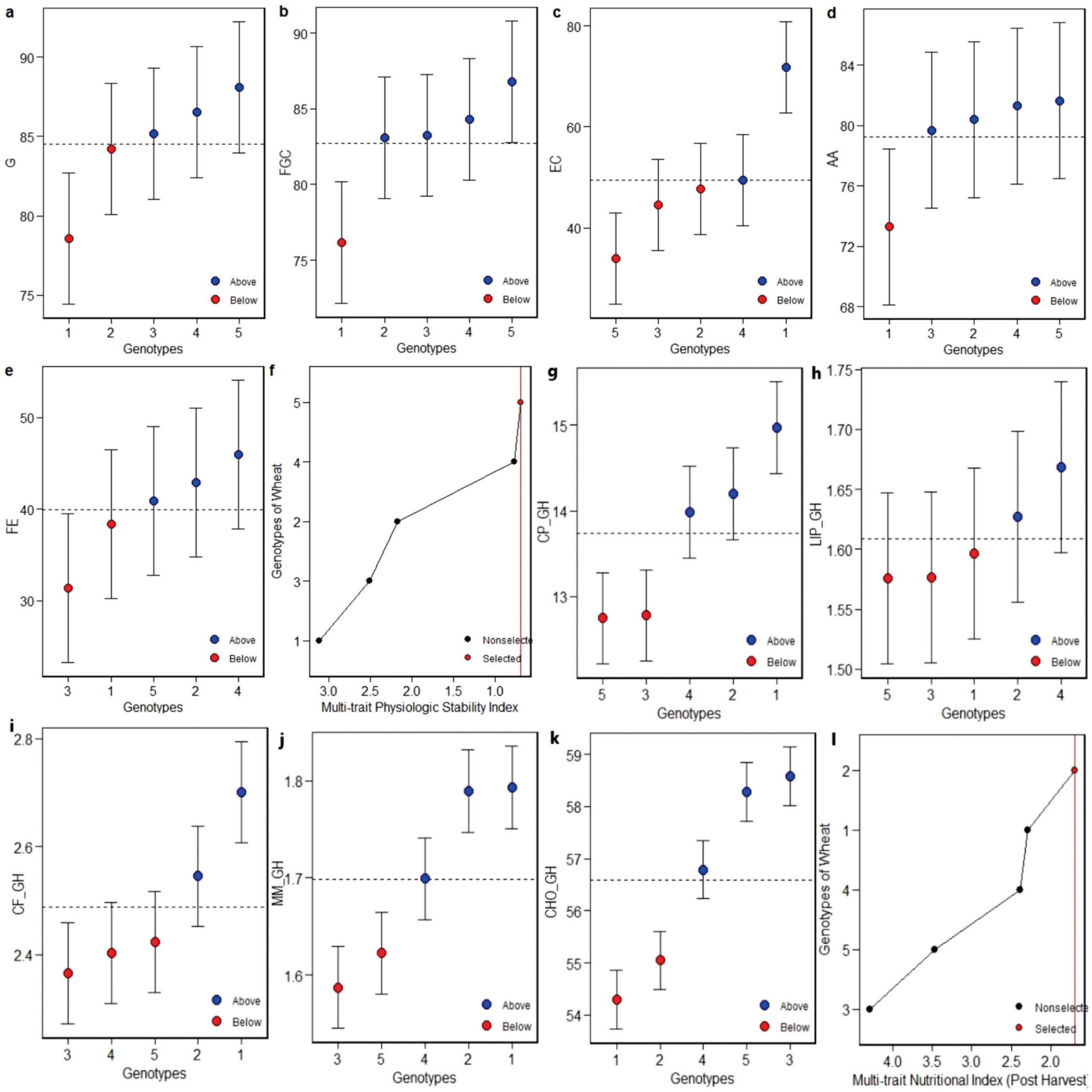

Figure 1 - Genetic value predictions via BLUP for physiological and nutritional variables: germination potential (G), first germination count (FGC), electrical conductivity (EC), accelerated aging (AA), field emergence (FE), crude protein in grain at harvest (CP_GH), lipids in grain at harvest (LIP_GH), crude fiber in grain at harvest (CF_GH), mineral material in grain at harvest (MM_GH) and starch in grain at harvest (CHO_GH).

Observing the results of the REML/BLUP method for the nutritional variables in grain at harvest (Figure 1) it was visualized pure genetic gain for grain protein at harvest for the genotypes ORS 1403, LG Oro and BRS Parrudo, for lipids in grain at harvest in the LG Oro and ORS 1403 genotypes, for crude fiber in grain at harvest in the LG Oro and BRS Parrudo genotypes, for the mineral matter in grain at harvest, the genotypes ORS 1403, LG Oro and BRS Parrudo showed pure genetic gain and for starch in grain at harvest the genotypes ORS 1403, Tbio Sinuelo and Mirante. For the multivariate analysis of the nutritional index at harvest, the LG Oro genotype was selected.

Pondering the evaluations carried out by the REML/BLUP methodology for the nutritional variables in grain after storage (Figure 2) we obtained the identification of pure genetic gain for the parameters grain protein after storage for the genotypes BRS Parrudo and LG Oro, for lipids in grain after storage for the genotypes ORS 1403, Mirantes, Tbio Sinuelo and LG Oro, for crude fiber in grain after storage for the genotypes Tbio Sinuelo, Mirante and BRS Parrudo, for the variable mineral matter in grain after storage in the LG genotypes Oro and BRS Parrudo and for the variable starch in grain after storage in the genotypes Mirante, Tbio Sinuelo and ORS 1403. Within the multivariate analysis of the nutritional index after storage, the LG Oro genotype was selected.

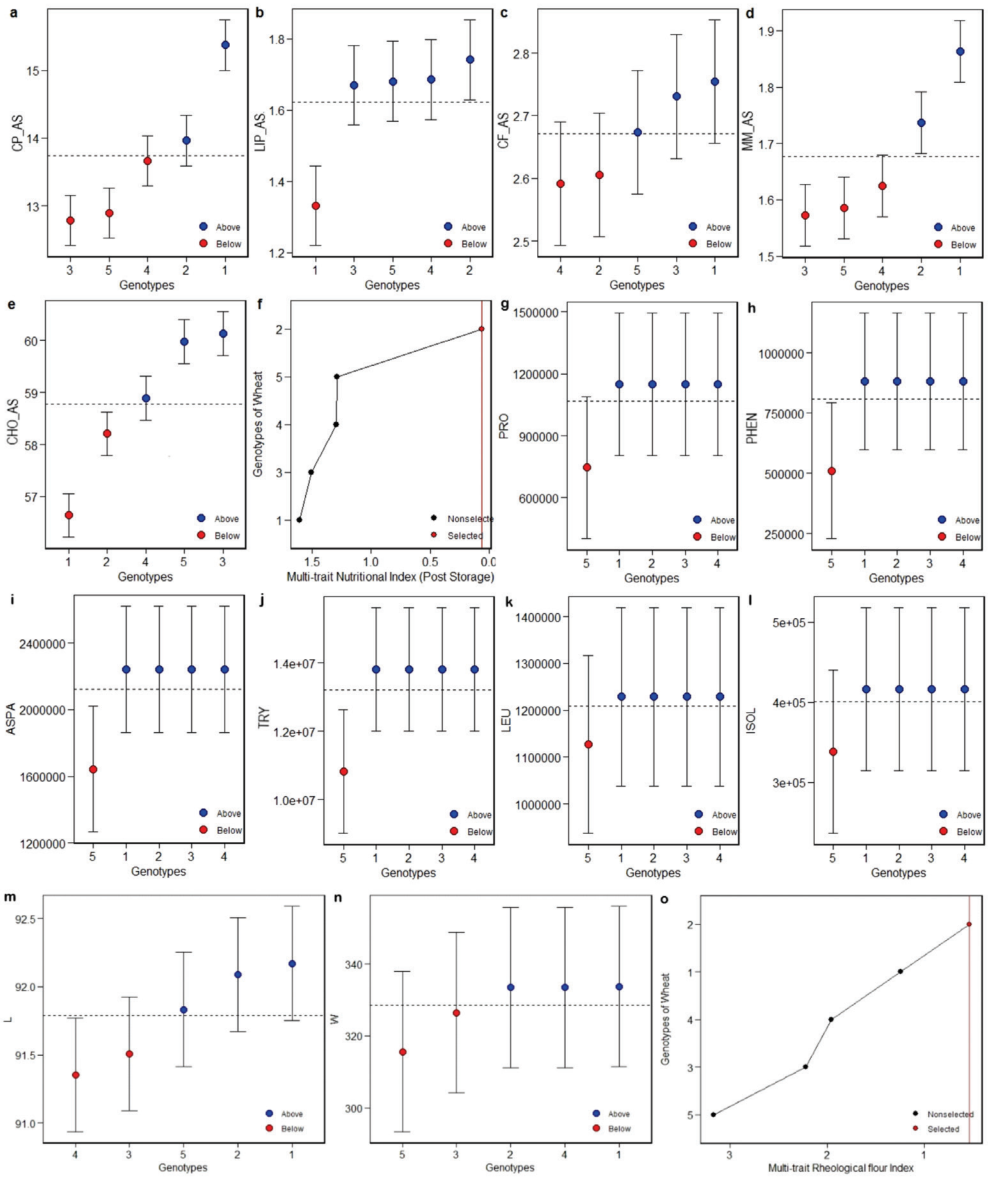

Figure 2 - Genetic value predictions via BLUP for nutritional variables in grain after storage crude protein in grain after storage (CP_AS), lipids in grain after storage (LIP_AS), crude fiber in grain after storage (CF_AS), mineral material in grain after storage (MM_AS) and starch in grain after storage (CHO_AS), proline (PRO), phenylalanine (PHEN), asparagine (ASPA), tryptophan (TRY), leucine (LEU), isoleucine (ISOL), dough extensibility (L) and gluten strength (W).

For the quantification of metabolites, according to the evaluation of the results obtained with the REML/BLUP method (Figure 2), the identification of pure genetic gain for the variables proline, phenylalanine, asparagine, tryptophan, leucine and isoleucine in the genotypes BRS Parrudo, ORS 1403, Mirante and LG Oro. In the evaluation of the REML/BLUP method for the bakery variables, pure genetic gains were obtained in gluten strength for the genotypes ORS 1403, LG Oro and BRS Parrudo and dough extensibility in mm for the genotypes Tbio Sinuelo, LG Oro and BRS Parrudo. Based on the multivariate analysis of the rheological index of the flour, the LG Oro genotype was selected.

Evaluating the canonical loads obtained from the comparative analysis of the physiological and rheological characters (Table 2), the first canonical pair showed a negative correlation between the electrical conductivity, so that there is a reduction in the quality of the seed, consequently presenting through the decrease of the factors dough extensibility in mm, falling number, relationship between tenacity and extensibility, dry gluten basis, wet gluten basis and water absorption by the dough lower baking quality. Based on the second canonical pair, the seeds that showed a greater emergence in the field resulted in an increase in the ratio of tenacity to extensibility, gluten strength, dry gluten basis, wet gluten basis, water absorption by the dough and hectoliter mass in addition to decrease the mass extensibility in mm, mass tenacity in mm and falling number. The third canonical pair showed a positive correlation between the first germination count, so that there is an increase in the characters mass extensibility in mm, mass tenacity in mm and falling number and a decrease in the characters tenacity with extensibility, dry gluten basis, wet gluten basis, water absorption by the dough and hectoliter mass.

Table 2 - Loads of rheological and nutritional traits at harvest in canonical correlations between groups, in five wheat genotypes (*Triticum aestivum*) in five different environments.

Character	Canonical Pair				Character	Canonical Pair			
	1st	2nd	3rd	4th		1st	2nd	3rd	4th
Rheological characters					Rheological characters				
FN	-0.164	0.75	-0.4419	-0.464	FN	-0.0912	0.0116	0.9757	-0.199
W	0.991	-0.12	0.0389	-0.044	W	-0.8852	0.0407	-0.2608	0.383
WA	-0.105	-0.565	-0.5327	-0.621	WA	-0.1686	-0.9249	0.0469	-0.337
HM	-0.14	-0.398	0.2442	-0.873	HM	-0.2926	-0.3411	-0.1787	-0.875
Nutritional characters at harvest					Nutritional characters after storage				
CP GH	0.885	-0. 2792	0.0721	-0.313	CP AS	-0.717	0.118	-0.1952	0.658
LIP GH	-0.659	-0.1453	-0.0179	-0.607	LIP AS	0.462	-0.455	-0.2189	-0.632
CF GH	0.52	0.623	-0.1818	-0.431	CF AS	0.722	0.421	-0.0176	0.519
MM GH	0.823	-0.1807	-0.1408	-0.511	MM AS	-0.757	0.43	-0.2513	0.381
CHO GH	-0.797	0.0241	-0.2004	0.558	CHO AS	0.677	-0.122	-0.0396	-0.652

FN: Falling number; W: Gluten strength; WA: Water absorption by the mass; HM: hectoliter mass; CP GH: Crude protein in grain at harvest; LIP GH: Lipids in grain at harvest; CF GH: Crude fiber in grain at harvest; MM GH: Mineral material in grain at harvest; CHO GH: Starch in grain at harvest; CP AS: Crude protein in grain after storage; LIP AS: Lipids in grain after storage; CF AS: Crude fiber in grain after storage; MM AS: Mineral material in grain after storage; CHO AS: Starch in grain after storage. All parameters are significant at $1(x^2) > 0.001$.

The fourth canonical pair identified the existing correlation in the question of potential for positive germination for the characters extensibility of the dough in mm, dry gluten basis, wet gluten basis, water absorption by the dough and hectoliter mass so that when there is a greater potential for germination, these factors present a positive gain and a negative relationship for the characters: dough tenacity in mm, tenacity relationship with extensibility and gluten strength. The high germination potential is directly linked to the good quality of the starch available in grain, having a direct relationship with the quality of bakery. In the evaluation of the fifth canonical pair, there was a positive interaction between the accelerated aging character and the characters of group 2, dough tenacity in mm, gluten strength, dry gluten basis, water absorption by the dough and hectoliter mass and a negative correlation, bringing an inverse relationship between tenacity and extensibility.

Pires et al. (2011) states that the reserve proteins contained in the endosperm of the grain are the main determinants of the functional properties of wheat flour and the viscoelastic properties of the dough. According to Gutkoski et al. (2007), the high rate of damaged starch contained in wheat flour can significantly affect the percentage of water absorption in farinography and the extensibility and resistance of the dough to extension in alveography. Based on this, it can be observed that this relationship of higher rheological quality is linked with the highest qualitative levels of seeds.

In view of the analysis of the canonical loads of the physiological and nutritional characters at harvest (Table 2), a positive correlation was identified in the first canonical pair for the electrical conductivity character for the lipids in grain at harvest and crude fiber in grain at harvest, there was also inverse correlation for crude protein in grain at harvest and starch in grain at harvest. This correlation may be due to the fact that the increased electrical conductivity may mean lower seed vigor rates, which may be a consequence of the starchy degradation in the endosperm. There was, in the second canonical pair, the identification of a negative correlation for the accelerated aging character, bringing the reduction of the factors crude protein in grain at harvest, crude fiber in grain at harvest and mineral material in grain at harvest with this inversion also obtained a greater expression of lipids in grain at harvest and starch in grain at harvest. According to Maia et al. (2007), seed aging causes a delay in the germination process, lower embryo growth and increased susceptibility to environmental stresses, eventually leading to loss of viability, which can cause a reduction in the expression of certain metabolites when this character is increased.

In the third canonical pair, there was a positive correlation of emergence in the field, evidencing the characters crude fiber in grain at harvest and mineral material in grain at harvest, the inverse was also identified for crude protein in grain at harvest. When evaluating the fourth canonical pair, the existing correlation for the first germination count was positive, although bringing with this correlation a decrease in the characters crude protein in grain at harvest, lipids in grain at harvest, crude fiber in grain at harvest and mineral material in grain at harvest. There was a positive correlation when evaluating the fifth canonical pair for germination potential, so that the characters crude fiber in grain at harvest and starch in grain at harvest were evidenced. Conversely, there was a decrease in crude protein in grain at harvest, lipids in grain at harvest and mineral material in grain at harvest. These correlations may indicate that in the occurrence of greater seed vigor there is a change in the expression of metabolites such as crude fiber in grain at harvest, as stated by Bazzo et al. (2021) seeds with high vigor may have better physiological potential.

Based on the evaluation of canonical correlations of physiological and nutritional characters after storage (Table 2) the first canonical pair showed a negative correlation for electrical conductivity, evidencing an increase in lipid characters in grain after storage and starch in grain after storage and inverse correlation for crude protein in grain after storage and crude fiber in grain after storage. The second canonical pair showed a positive link between germination potential, resulting in higher expression of lipids in grain after storage and starch in grain after storage and negative correlation for crude protein in grain after storage, crude fiber in grain after storage and mineral material in grain after storage.

The third canonical pair showed a positive correlation for emergence in the field, providing an increase in the expression of lipid characters in grain after storage, crude fiber in grain after storage and starch in grain after storage and reduction to crude protein in grain after storage and mineral material in grain after storage. Henning et al. (2010) identified that in more vigorous seeds there are higher contents of assimilates such as starch and soluble sugars, as well as a greater capacity to mobilize reserves during germination, in line with the results obtained in these relationships.

It was observed in the fourth canonical pair for the accelerated aging character a positive correlation with the lipid character in grain after storage and inversely with crude protein in grain after storage and crude fiber in grain after storage. The fifth canonical pair showed a negative correlation between the first germination count, providing an increase in the expression of lipids in grain after storage and crude fiber in grain after storage and inverse for mineral material in grain after storage. With the qualitative increase of physiological characters, an increase in the expression of lipids stored in grain can be evidenced, this is defined since in the biochemical aspect, vigor involves biosynthesis of energy and metabolic compounds, closely related to the quantification of nucleic acids, carbohydrates and lipids (Henning, 2010).

When evaluating the canonical charges of the physiological characters and amino acids (Table 3), it was defined by the observation of the first canonical pair the existence of a positive correlation for the electrical conductivity character, demonstrating a positive relationship in the expression of leucine in grain, Isoleucine in grain, glycine in grain, threonine in grain, proline in grain, aspartate in grain, phenylalanine in grain, glutamine in grain, asparagine in grain and tryptophan in grain. An inverse correlation was also identified for serine in grain.

Table 3 - Loads of rheological characters and amino acids in the canonical correlations (r) between groups, in five wheat genotypes (*Triticum aestivum*) in five different environments.

Character	Canonical Pair				Character	Canonical Pair					Character	Canonical Pair				
	1st	2nd	3rd	4th		1st	2nd	3rd	4th	5th		1st	2nd	3rd	4th	5th
	Rheological characters					Nutritional characters at harvest						Nutritional characters after storage				
FN	0.639	0.38666	0.214	-0.6292	CP GH	-0.832	0.2899	0.322	0.287	-0.193	CP AS	0.459	-0.688	-0.345	0.0299	-0.443
W	0.283	-0.6395	-0.713	0.0479	LIP GH	0.566	-0.1163	-0.144	0.6419	-0.483	LIP AS	-0.33	0.364	0.86	0.058	0.124
WA	0.443	-0.5276	0.703	0.1783	CF GH	-0.138	0.0177	0.837	0.4662	0.25	CF AS	-0.311	0.432	-0.432	0.6434	-0.341
HM	0.613	-0.0066	0.357	0.7046	MM GH	-0.667	0.228	0.585	0.0862	-0.392	MM AS	0.617	-0.362	-0.28	-0.1756	-0.616
					CHO GH	0.536	-0.5498	-0.569	-0.148	0.253	CHO AS	-0.181	0.642	0.34	0.1233	0.652
	Amino acid characters					Amino acid characters						Amino acid characters				
LEU	0.3445	-0.136	0.775	-0.1602	LEU	0.491	-0.3557	0.646	0.3149	0.1404	LEU	-0.5989	-0.35	0.369	-0.5092	-0.043
ISOL	0.3129	-0.2273	0.753	-0.1907	ISOL	0.449	-0.3261	0.692	0.3491	0.1366	ISOL	-0.6261	-0.403	0.371	-0.4449	-0.067
GLY	0.6097	-0.2053	0.67	-0.0052	GLY	0.3	-0.2725	0.751	0.0614	0.2565	GLY	-0.5474	-0.508	0.117	-0.5284	0.1974
SER	0.3991	0.301	0.716	0.01311	SER	0.644	-0.4624	0.117	-0.4082	0.2801	SER	-0.2036	0.195	0.279	-0.6676	0.569
THR	0.5646	-0.0877	0.633	-0.0928	THR	0.225	-0.3833	0.616	0.3292	0.2899	THR	-0.3821	-0.533	0.168	-0.5938	-0.0685
PRO	0.1352	-0.508	0.637	-0.1829	PRO	0.31	-0.2268	0.809	0.3894	-0.0258	PRO	-0.6927	-0.506	0.442	-0.1433	-0.1344
ASPA	-0.1634	-0.8658	0.164	-0.0733	ASPA	-0.174	-0.0329	0.729	0.3341	-0.2527	ASPA	-0.4598	-0.622	0.382	0.4243	-0.1952
PHEN	0.184	-0.098	0.791	-0.279	PHEN	0.666	-0.1784	0.609	0.3143	0.0894	PHEN	-0.7574	-0.15	0.346	-0.4191	-0.0741
GLU	0.2773	-0.816	0.217	0.12397	GLU	-0.344	-0.2841	0.839	0.2038	-0.0445	GLU	-0.2803	-0.897	0.296	0.0839	-0.0121
ASGI	0.4397	-0.5827	0.181	0.10421	ASGI	-0.431	-0.3601	0.697	0.3752	0.1075	ASGI	-0.0976	-0.949	0.174	-0.1031	-0.1688
TRY	-0.0299	-0.4603	0.653	-0.2766	TRY	0.477	-0.0558	0.754	0.3691	-0.0881	TRY	-0.8317	-0.302	0.413	-0.0555	-0.1472

FN: Falling umber; W: Gluten strength; WA: Water absorption by the mass; HM: hectoliter mass; CP GH: Crude protein in grain at harvest; LIP GH: Lipids in grain at harvest; CF GH: Crude fiber in grain at harvest; MM GH: Mineral material in grain at harvest; CHO GH: Starch in grain at harvest; LEU: Leucine in grain; ISOL: Isoleucine in grain; GLY: Glycine in grain; SER: Serine in grain; THR: Threonine in grain; PRO: Proline in grain; ASPA: Aspartate in grain; PHEN: Phenylalanine in grain; GLU: Glutamine in grain; ASGI: Asparagine in grain; TRY: Tryptophan in grain, CP AS: Crude protein in grain after storage; LIP AS: Lipids in grain after storage; CF AS: Crude fiber in grain after storage; MM AS: Mineral material in grain after storage; CHO AS: Starch in grain after storage; All parameters are significant at 1(x^2) > 0.001.

For the second canonical pair, there was a positive relationship of accelerated aging and a decrease in the expression of the amino acids leucine in grain, isoleucine in grain, glycine in grain, serine in grain, threonine in grain, proline in grain, phenylalanine in grain and tryptophan in grain. The third canonical pair demonstrated the existence of a positive-sense correlation for germination potential, resulting in the expression of decreased expression of leucine in grain, isoleucine in grain, glycine in grain, threonine in grain, phenylalanine in grain, glutamine in grain and asparagine in grain and an opposite correlation for the amino acid aspartate in grain.

With the evaluation of the fourth canonical pair, a positive correlation was obtained for emergence in the field, showing the amino acids glycine in grain and serine in grain. In the fifth canonical pair, the positive relationship of the character first germination count was evidenced, resulting in an increase in the expression of serine in grain, aspartate in grain and glutamine in grain and the opposite for threonine in grain, and phenylalanine in grain.

In germination, in addition to energy from carbohydrates, the embryo grows at the expense of supplying amino acids. Hydrolysis of reserve proteins occurs, generating soluble nitrogenous fractions, including free amino acids, which then undergo inter-conversion to form new plant tissues. According to the canonical loads of the rheological and nutritional characters at harvest (Table 4). n the first canonical pair, a positive correlation was identified in the gluten strength character, providing a tendency to increase for the characters crude protein in grain at harvest, crude fiber in grain at harvest and mineral material in grain at harvest, so that the inverse relationship for lipids in grain at harvest and starch in grain at harvest. The second canonical pair showed a significant positive correlation for the falling number, providing the expression of crude fiber in grain at harvest and behaving in the opposite way to crude protein in grain at harvest, lipids in grain at harvest and mineral material in grain at harvest.

Caldeira et al. (2000) states that the behavior of wheat flour throughout the baking process has a strong relationship with the storage proteins found, so that some fractions of these proteins, such as gliadin and glutein, under hydration form the complex called gluten, which matches the positive relationship between gluten and proteins in grain found.

It was observed in the third canonical pair that it presents a negative correlation for the water absorption character by the mass due to the decrease in the expression of crude fiber in grain at harvest, mineral material in grain at harvest and starch in grain at harvest. In view of the negative correlation presented in the fourth canonical pair for the character hectoliter mass, there was an increase in the phenotypic expression for starch in grain at harvest and a decrease in the items crude protein in grain at the harvest, lipids in grain at the harvest, crude fiber in grain at the harvest and mineral material in grain at harvest.

Based on the results obtained from the canonical loads of the rheological and nutritional characters after storage (Table 3). In the first canonical pair, a negative correlation of gluten strength was identified, providing an increase for lipids in grain after storage, crude fiber in grain after storage and starch in grain after storage. The inverse correlation was obtained for crude protein in grain after storage and mineral material in grain after storage.

The second canonical pair showed a negative interaction for water absorption by the dough, resulting in higher expression of crude protein in grain after storage, crude fiber in grain after storage and mineral material in grain after storage and a decrease for lipids in grain after storage and starch in grain after storage. As in the correlations of grains at harvest, gluten strength is related to the quantification of storage proteins, since some of these proteins are responsible for gluten formation.

In the third canonical pair, a positive interaction in falling number was obtained, which provides a decrease in the expression of crude protein in grain after storage, lipids in grain after storage and mineral material in grain after storage. Evaluating the fourth canonical pair, a negative correlation was identified for hectoliter mass, favoring the expression of crude protein in grain after storage, crude fiber in grain after storage and mineral material in grain after storage and a decrease in the expression of lipids in grain after storage and starch in grain after storage. Once again, these correlations are consistent with those found for grains at harvest, since these factors are interconnected with the quantification of starchy endosperm present in grains.

According to the evaluation of the loads obtained by the rheological characters and amino acids (Table 3) in the canonical correlations, the first canonical pair identified that a positive correlation between the number of falls evidencing expression of the amino acids leucine in grain, isoleucine in grain, glycine in grain, serine in grain, threonine in grain, proline in grain, phenylalanine in grain, glutamine in grain, asparagine in grain and an inverse correlation was identified for aspartate in grain. The second canonical pair explained a negative correlation for gluten strength, maximizing the expression of serine in grain and minimizing the expression of leucine in grain, isoleucine in grain, glycine in grain, proline in grain, aspartate in grain, phenylalanine in grain, glutamine in grain, asparagine in grain and tryptophan in grain.

Table 4 - Loads of physiological and rheological characters in the canonical correlations (r) between groups, in five wheat genotypes (*Triticum aestivum*) in five different environments.

Character	Canonical Pair					Character	Canonical Pair					Character	Canonical Pair				
	1st	2nd	3rd	4th	5th		1st	2nd	3rd	4th	5th		1st	2nd	3rd	4th	5th
	Physiological characters						Physiological characters						Physiological characters				
G	0.3237	0.48	0.2235	0.7838	-0.0156	G	-0.5624	-0.103	0.4315	-0.0584	0.695	G	0.198	0.7346	-0.2647	0.459	-0.375
FGC	0.3216	0.424	0.4163	0.7263	-0.1273	FGC	-0.5709	-0.162	0.5422	0.10926	0.585	FGC	0.178	0.6521	-0.3432	0.349	-0.551
EC	-0.8652	0.298	0.0974	-0.1194	0.373	EC	0.8531	-0.379	-0.0496	-0.0075	0.355	EC	-0.975	0.0144	0.0654	0.114	0.18
AA	0.7218	0.552	0.3583	0.0498	0.2091	AA	-0.7668	-0.61	-0.0345	-0.0446	0.191	AA	0.355	0.0107	-0.667	0.625	-0.195
FE	-0.0516	0.774	-0.082	-0.2125	-0.5884	FE	0.0125	-0.45	0.6148	-0.6048	-0.231	FE	-0.106	0.3567	-0.8039	-0.343	0.312
	Rheological characters						Nutritional characters at harvest						Nutritional characters after storage				
L	-0.8802	-0.28	0.201	0.1733	0.0495	CP GH	-0.1248	-0.881	-0.119	-0.3999	-0.186	CP AS	-0.264	-0.641	-0.674	-0.2515	-0.0434
P	-0.0688	-0.124	0.1908	-0.1179	0.3713	LIP GH	0.3108	0.584	-0.0363	-0.3875	-0.641	LIP AS	0.297	0.642	0.136	0.6246	0.3004
FN	-0.269	-0.168	0.5157	-0.0524	0.0248	CF GH	0.6448	-0.483	0.2663	-0.4937	0.191	CF AS	-0.24	-0.245	0.564	-0.2795	0.6974
PL	-0.1059	0.135	-0.1733	-0.7587	-0.211	MM GH	-0.0121	-0.895	0.2205	-0.2158	-0.323	MM AS	-0.065	-0.866	-0.481	0.0211	-0.1156
W	0.0917	0.707	0.0322	-0.4916	0.2923	CHO GH	-0.2275	0.919	0.0451	0.0929	0.305	CHO AS	0.534	0.651	0.538	0.0172	0.0458
DG	-0.303	0.398	-0.4867	0.4527	0.1544												
WG	-0.2613	0.504	-0.4914	0.3995	-0.0375												
WA	-0.2582	0.525	-0.4143	0.429	0.1136												
HM	-0.0546	0.262	-0.2874	0.4083	0.3041												

G: Germination potential; FG: First germination count; EC: Electrical conductivity; AA: Accelerated aging; FE: Field emergency; L: Mass extensibility in mm; P: Mass tenacity in mm FN: Falling umber; PL: Relationship between tenacity and extensibility; W: Gluten strength; DG: Dry gluten basis; WG: Wet gluten basis; WA: Water absorption by the mass and HM: Hectoliter mass. CP GH: Crude protein in grain at harvest; LIP GH: Lipids in grain at harvest; CF GH: Crude fiber in grain at harvest; MM GH: Mineral material in grain at harvest and CHO GH: Starch in grain at harvest; CP AS: Crude protein in grain after storage; LIP AS: Lipids in grain after storage; CF AS: Crude fiber in grain after storage; MM AS: Mineral material in grain after storage; CHO AS: Starch in grain after storage; LEU: Leucine in grain; ISOL: Isoleucine in grain; GLY: Glycine in grain; SER: Serine in grain; THR: Threonine in grain; PRO: Proline in grain; ASPA: Aspartate in grain; PHEN: Phenylalanine in grain; GLU: Glutamine in grain; ASGI: Asparagine in grain; TRI: Tryptophan in grain. All parameters are significant at $1(x^2) > 0.001$.

The correlation existing in the third canonical pair was positive for water absorption by the dough, indicating an increase in the expression of all tested amino acids, these being leucine in grain, isoleucine in grain, glycine in grain, serine in grain, threonine in grain, proline in grain, aspartate in grain, phenylalanine in grain, glutamine in grain, asparagine in grain and tryptophan in grain. Based on the positive correlation identified for hectoliter mass, a maximization of the expression of glutamine in grain and asparagine in grain was obtained, the inverse was identified for leucine in grain, isoleucine in grain, proline in grain, phenylalanine in grain and tryptophan in grain.

The loads of the canonical correlations of nutritional characters at harvest and amino acids were also evaluated (Table 3). For the first canonical pair, a negative correlation was found for crude protein in grain at harvest, resulting in the maximization of the quantification of the amino acids leucine in grain, isoleucine in grain, glycine in grain, serine in grain, threonine in grain, proline in grain, phenylalanine in grain and tryptophan in grain.

The opposite was obtained for aspartate in grain, glutamine in grain and asparagine in grain. In the second canonical pair, a negative correlation was determined for starch in grain at harvest, being responsive to the decrease in the quantification of the amino acids leucine in grain, isoleucine in grain, glycine in grain, serine in grain, threonine in grain, proline in grain, phenylalanine in grain, glutamine in grain and asparagine in grain. These relationships express an increase for most amino acids when there is a reduction in proteins and greater expression of carbohydrates, which is more abundant in grains and may be related to a greater source of amino acids, although more studies on these relationships are needed.

It was defined by the quantification of the third canonical pair, positive interaction for crude fiber in grain at harvest, resulting in the maximization of the expression of both amino acids, these leucine in grain, isoleucine in grain, glycine in grain, serine in grain, threonine in grain, proline in grain, aspartate in grain, phenylalanine in grain, glutamine in grain, asparagine in grain and tryptophan in grain. The fourth canonical pair showed a significant positive interaction for lipids in grain at harvest, evidencing the expression of leucine in grain, isoleucine in grain, threonine in grain, proline in grain, aspartate in grain, phenylalanine in grain, glutamine in grain, asparagine in grain and tryptophan in grain. Contrary interaction was also identified for serine in grain. In the same way, positive interactions were identified for most amino acids when there was greater expression of crude fiber and lipids in grain harvest, which can be identified by the quantification of amino acids present in these macronutrients.

In view of the evaluation of the fifth canonical pair, a negative interaction was identified for mineral material in grain at harvest, potentiating the synthesis of the amino acids leucine in grain, isoleucine in grain, glycine in grain, serine in grain, threonine in grain and asparagine in grain, in addition, this evaluation showed a negative correlation for aspartate in grain. Mineral material in grain would basically be formed from inorganic bodies, which may be related to the higher expression of amino acids in their lower quantification.

The canonical loads of the correlations derived from the evaluations of nutritional characters after storage and amino acids (Table 4) showed in the first canonical pair a positive interaction for the first canonical pair in mineral material after storage correlated with the decrease in the quantification of the amino acids leucine in grain, isoleucine in grain, glycine in grain, serine in grain, threonine in grain, proline in grain, aspartate in grain, phenylalanine in grain, glutamine in grain and tryptophan in grain. The smaller amounts of mineral material in grains can bring about an increase in the expression of amino acids since this parameter is constituted by inorganic bodies, and they are basically less favored by amino acids.

The second canonical pair showed a negative interaction for crude protein in grain after storage, increasing the quantification of serine in grain and being contrary to leucine in grain, isoleucine in grain, glycine in grain, threonine in grain, proline in grain, aspartate in grain, phenylalanine in grain, glutamine in grain, asparagine in grain and tryptophan in grain.

The positive correlation found in the third canonical pair between lipids in grain after storage maximized the production of the amino acids leucine in grain, isoleucine in grain, glycine in grain, serine in grain, threonine in grain, proline in grain, aspartate in grain, phenylalanine in grain, glutamine in grain, asparagine in grain and tryptophan in grain. This correlation indicates that there is an increase in the expression of amino acids when there is a greater expression of macronutrients such as proteins and lipids after storage.

It was determined in the quantification of the fourth canonical pair positive correlation for crude fiber in grain after storage, maximizing the expression of aspartate in grain and being opposite for amino acids leucine in grain, isoleucine in grain, glycine in grain, serine in grain, threonine in grain, proline in grain, phenylalanine in grain and asparagine in grain. In the maximum expression of fiber there is a relation contrary to the greater production of amino acids, this may be due to its constitution that has a low amount of them.

The fifth canonical pair determined a positive interaction for starch in grain after storage, providing the production of glycine in grain and serine in grain, in addition to a decrease in proline in grain, aspartate in grain, asparagine in grain and tryptophan in grain. The highest concentration of starch after storage was not directly related to most amino acids, with only a few benefiting from their maximum expression and some being harmed, in addition to not having significance for many characters.

A positive heritability can be measured for most of the nutritional traits evaluated, in addition to the rheological aspects such as gluten strength and physiological aspects such as electrical conductivity and accelerated aging. There was also high accuracy for the nutritional and rheological factors, whereas the physiological and amino acids showed high accuracy only germination potential, first germination count, electrical conductivity, accelerated aging and field emergence, indicating a high reliability presented. In addition, there was no experimental interaction of the rheological factors falling number, tenacity and extensibility relationship, dry gluten basis, wet gluten basis, water absorption by the dough and hectoliter mass.

The genotypes ORS 1403 and Tbio Sinuelo showed a higher level of pure genetic gain for the physiological aspects, for the rheological and nutritional aspects at harvest the genotypes ORS 1403 and LG Oro and for the rheological and nutritional aspects after storage the genotypes BRS Parrudo, Mirante, LG Oro and Tbio Sinuelo, according to BLUP model. The multivariate index selected the LG Oro genotype for physiological and nutritional aspects at harvest and after storage, the Tbio Sinuelo genotype was selected for the physiological aspects. Being recommended for maximum expression of the aspects evaluated the use of genotypes ORS 1403, Tbio Sinuelo and LG Oro.

The correlations presented were significant for most characters, indicating the high incidence of canonical correlations between groups, with emphasis on the greater expression of rheological characters associated with higher grain quality expressed in physiological characters and also related to an increase or decrease in quantification of the amino acids present in grain. However, further studies are needed to define these correlations with greater precision.

CONCLUSIONS

1. The LG Oro genotype was more efficient in the expression of physiological and nutritional aspects at harvest and after storage; otherwise Tbio Sinuelo genotype was selected considering the rheological aspects.

2. ORS 1403, Tbio Sinuelo and LG Oro genotypes were recommended for maximum expression of both aspects evaluated.

3. There is a linear relationship between the group of rheological variables and the physiological characters of wheat grains.

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