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Physicochemical and bromatological quality evaluation for bread wheat production

Evaluación de la calidad fisicoquímica y bromatológica para la producción de trigos panaderos

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Abstract. Wheat is one of the most important protein sources for human beings. Several food products are elaborated from this cereal, such as bread. Mexican wheat breeding programs are focused on to identify those genotypes with high yields and bread quality. Therefore, the aim of this study was to evaluate the environmental effects over the Physicochemical and Bromatological quality parameters of Cal Blanco F2011, Matchett F2011 and RSM-Norman F2008 wheats sown at the experimental fields at Mexicali, Baja California, Querendaro, Michoacán and Tarimoro, Guanajuato, Mexico during the autumn-winter growing cycle for two consecutive years (2014-2016) under irrigation conditions. Grain Hectolitric weight (GHW); Weight of 1,000 grains (WTG), Grain Length, Width and Thickness; Flour Colour (L, a* and b*), the Percentages of Protein, Starch and Ashes, and Zeleny sedimentation tests (IZ) were determined. Wheat genotypes showed significant differences in most of the study variables and all the values were related to good bakery quality. GHW, WTG and most of the physicochemical quality values were strongly affected by the environmental factors over the genotype. The three genotypes showed acceptable ZI values, especially RSM-Norman F2008 grains from all the localities studied. Finally, these genotypes presented suitable Physicochemical and Bromatological qualities, and are recommended for irrigation conditions.

Keywords: Protein; Bakery Quality; Zeleny Index; Interaction; Grain.

Resumen. El trigo es uno de las fuentes más importantes de proteína para el ser humano. Varios productos alimenticios son elaborados con este cereal, como el pan. Los programas de mejoramiento de trigo en México se enfocan en identificar a aquellos genotipos con altos rendimientos y calidad panadera. Por lo tanto, el principal objetivo de la presente investigación fue evaluar los efectos ambientales sobre los parámetros de calidad fisicoquímica y bromatológica para los genotipos Cal Blanco F2011, Matchett F2011 y RSM-Norman F2008, sembrados en diferentes campos experimentales mexicanos. Las localidades estudiadas fueron los Municipios de Mexicali, Baja California, Queréndaro, Michoacán y Tarimoro, Guanajuato en México. Los genotipos se sembraron dos años consecutivos durante los ciclos otoño-inverno 2014-2016, bajo condiciones de riego. Se estudiaron los parámetros de Peso Hectolitro (PHL), Peso de 1.000 granos (PMG), Longitud, Ancho y Espesor del grano, Color de la Harina (L, a* y b*); porcentajes de Proteína, Almidón y Cenizas, e Índice de Zeleny (ZI). Los genotipos de trigo mostraron diferencias estadísticamente significativas en la mayoría de las variables. Inclusive, todas las variables se relacionaron con una buena calidad panadera. Las variables PHL y PMG, igual que la mayoría de los parámetros fisicoquímicos de calidad, fueron muy afectados por los factores ambientales sobre el genotipo. Los valores de IZ fueron aceptables en los tres genotipos estudiados, especialmente los granos de RSM-Norman F2008 para todas las localidades analizadas. Finalmente, los tres genotipos analizados mostraron valores fisicoquímicos y bromatológicos adecuados y son recomendados para sembrarse bajo condiciones de riego.

Palabras clave: Proteína; Calidad Panadera; Índice de Zeleny; Interacción; Grano.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the cereal most cultivated worldwide. Its grain is the most important protein source for human being. It has been used to produce flour and grits to create mainly several food products such as bread, cookies and pastas. To date, there are several studies in wheat quality that study several topics, such as physicochemical analysis, or agronomic parameters. Bromatological tests could complement these studies because they are economical and accessible tests. Accordingly, wheat flour quality is very important for obtaining an appropriate product. This quality is determined through chemical, physical, technological and rheological analyses of flour wheat (Pistón et al., 2011; de la Horra et al., 2012; Švec & Hruškova, 2014; Švec & Hruškova, 2015). Then, physicochemical and bromatological wheat qualities are crucial for bread marketing, and most of them are influenced by environmental conditions. Environmental conditions include certain parameters such as height from sea level, temperature, rainfall, sun radiation, among others. The phenotype is determined by the genotype and its interaction with the environment. So, the phenotype could be quantified by those physical and chemical analyses, but its genotype is analysed only by genetic tests. Successful bread wheat breading programs are focused on commercialize good physicochemical quality grains in order to obtain the minimum environmental variation over bread wheats (de la O Olán et al., 2012; Rodríguez et al., 2014). However, bread quality research sometimes has to overcome various difficulties. For example, there is not enough sample, the availability of adequate equipment is lacking in order to analyse and determine quality testing, such as rheological parameters (extensibility and viscoelasticity tests). In these cases, physicochemical and bromatological quality measurements are accessible options to evaluate the industrial destiny of the flour and wheat quality (de la Horra et al., 2012; Zhang et al., 2012; Bonafede et al., 2015). Measures of physiochemical characteristics [Flour Colour, Grain and Flour moisture, grain physical characteristics (i.e., grain hardness)], Agronomic parameters (Hectolitric weight, Mass of 1,000 grains) and some Bromatological Analyses (Protein, Starch, Zeleny Sedimentation Test, Ashes) could be available choices. These tests could be excellent options to evaluate bread quality if there are no Farinograph or Extensograph equipment available. Zeleny Sedimentation Values indicate protein quality by an easy methodology, which indicates low quality gluten proteins if sedimentation volume is fast. Grain hardness is a vital estimation for flour quality because the harder the grain, the more energy will be needed for grinding it. At the same time, bromatological assays give good protein and ash information for flour and grain characteristics, respectively (de la O Olán et al., 2010; Barak et al., 2013; Martínez et al., 2014; Švec & Hruškova, 2015). Added to this, industrial wheat flour quality is based on gluten protein quality (80-85% of total grain proteins), which are hydrated and oriented to form it. This protein composition is responsible for the viscoelastic dough properties (Rheological), such as dough mixing, strength and extensibility. Wheat grain proteins are classified by their solubility into Prolamins (Gliadins and Glutenins, soluble in alcohol), Albumins (Water soluble) and Globulins (Salt soluble). Hence, the environment effect over Gliadin and Glutenin protein expression (Allelic variation) results on different viscoelastic dough properties (phenotype) and its industrial final use (breads, cookies, cakes or tortillas) (Martínez et al., 2010; Izadi & Yazdi, 2012; Randhawa et al., 2013; Hernández et al. 2013). Thereby, the main objective of the present research was to evaluate the physicochemical, agronomical and bromatological parameters for three bread wheat genotypes harvested at different localities.

MATERIALS AND METHODS

In the present study three strong gluten bakery type wheat genotypes were evaluated: Cal Blanco F2011, Matchett F2011 and RSM-N Norman F2008. Genotypes were given by Resource Seeds International (RSI), with the purpose of obtaining flour extraction. Genotypes were sown on experimental fields at different localities: Baja California, Michoacan and Guanajuato States, Mexico in the autumn-winter cycles of 2014-2016, where localities were the study treatments. The first locality, Mexicali, in Baja California has an extreme arid climate, 90-135 mm mean annual rainfall, 22.6-27.5 °C mean annual temperature. The maximum temperature is in October-March, from 15-27.5 °C. It is located between 32° 39′ 48″ N and 115° 28′ 04″ W from Greenwich meridian, at a height of 8 m a.s.l. (CONAGUA, 2016). Yermosole and Xerosole soils are predominant. Tarimoro is located on the Guanajuato State. The climate is semi-warm, humid, yearly mean rainfall is from 730-680 mm, and yearly mean temperature is 20-15 °C. It is located at 20° 17′ 39″ N and 100° 45′ 20″ W, at a height of 1,770 m a.s.l. Querendaro, Michoacán the third location, has template climate. Yearly mean temperatures are from 19.2-19.3 °C. It is located between 19° 10′ 07″ N and 101° 53′ 59″ W, at a height of 1,840 m a.s.l. Inchú Coluvial and Podzolic with prairie soils are predominant, respectively. Wheat genotypes were developed under normal conditions (Five irrigations) together with a fertilization that consisted in NPK 295-108-30 as a total dose. This was fractionated during irrigation. Agronomical handling of experiments was performed by Resource Seeds International.

Whole wheat flour was obtained by a laboratory mill (Nixtamatic NCM1) with a sieving through a mesh (ASTM number 50) in Agroindustrial Products Quality and Food Analysis Laboratories at the Facultad de Ciencias Agricolas, Universidad Autonoma del Estado de Mexico (UAEMex).

Physicochemical and bromatological analyses. Physicochemical analyses such as Grain Hectolitric weight (GHW), Weight of 1,000 grains (WTG); Grain Length, Width and Thickness (SL, WS and TS, respectively) were performed in grains, and colour (L, a* and b*) was determined in flour. All measurements were made by triplicate. Seedburo Equipment Co., Chicago IL, USA. CHROMA METER CR-400 (Kinika Minolta) colour measurement instrument was used to determinate Lightness (L), Redness (a*) and Yellowness (b*) analyses (Araujo-Guzman et al., 2015). GHW was completed according to the NMX-FF-036-1996. Weight of 1,000 grains (mg) was made by a 10 sample average, each containing 100 grains (Castro et al., 2011).

Bromatological analyses included Protein % (P), Starch % (S), Grain Moisture % (GM), Flour Moisture (FM) %, Ash (A) % and Zeleny sedimentation tests (IZ). They were performed in flour samples, and Moisture was also performed in Grain samples (MG). All the variables were done by triplicate. Protein %, Ash %, and Grain (GM; %) and Flour Moisture (FM) % were performed by the AOAC 1999 Official Methods. Starch % content was estimated using K-TSTA Amyloglucosidase/α-Amylase method, AOAC Method 996.11 and AACC Method 76.13, MEGAZYME Total starch assay kit. IZ test was development according to NTE INEN-ISO 5529 (2013) Norm.

Data analyses. A Complete Randomized Block Design was used. ANOVA was conducted for each one of the variables ($P \leq 0.05$; n=3). Each genotype sample was performed from three different wheat rows samples to represent the sampling randomness.

The localities corresponded to the Treatments, and response variables corresponded to the physicochemical and bromatological analyses dates. Significant differences were compared using a Tukey Test ($P \leq 0.05$) with the Software SAS 9.0 (2000).

RESULTS

Physicochemical and bromatological analyses. There were significant differences ($P \leq 0.05$) in Hectolitric weight; Weight of 1,000 grains; Grain L, a* and b*, Grain Length;

Table 1. Mean squares for analyses of variance for genotype, locality and genotype × locality interaction for the physicochemical variables of industrial quality from Cal Blanco F2011, Matchett F2011 and RSM-N Norman F2008 Genotypes.
Tabla 1. Análisis de Varianza por genotipo, localidad e interacción para variables fisicoquímicas de calidad industrial de los genotipos Cal Blanco F2011, Matchett F2011 y RSM-Norman F2008.

SV	DF	GHW	WTG	GL	GW	GT	L	a*	b*
Genotype	2	7.26*	19623.58*	4.14*	0.047*	0.03*	11.89*	0.32*	1.87*
Locality	2	17.02*	13337.33*	0.11*	0.03*	0.08*	0.73*	0.38*	1.43*
Genotype × locality	4	5.32*	2992.45*	0.19*	0.00NS	0.03*	1.61*	0.04*	0.55*
Error	18	0.00	1.22	0.00	0.00	0.00	0.18	0.01	0.04
Total	26								

* Significant difference P=0.05; ** Significant difference P=0.01; NS = No significant. DF = Degree freedom; GHW = Grain Hectolitric weight; WTG = Weight of 1,000 grains; GL = Grain length; GW = Grain width; GT = Grain thickness and flour colour (L, a* and b*).
* Diferencia significativa P=0,05; ** Diferencia significativa P=0,01; NS = No significativo. DF = Grados de Libertad; GHW = Peso Hectolítrico; WTG = Peso de mil granos; GD = Longitud del grano; GW = Ancho del grano; GT = Espesor del grano y Color harina (L, a* y b*).

Table 2. Mean squares for analyses of variance for genotype, locality and genotype × locality interaction for the bromatological variables of Cal Blanco F2011, Matchett F2011 and RSM-N Norman F2008 genotypes.
Tabla 2. Análisis de Varianza por genotipo, localidad e interacción para variables bromatológicas de los genotipos Cal Blanco F2011, Matchett F2011 y RSM-Norman F2008.

SV	DF	P	S	A	IZ	MG	MF
Genotype	2	1.82 NS	128.49*	0.01*	9.92*	0.69*	0.26*
Locality	2	5.16*	54.54*	0.04*	0.70 NS	10.24*	7.30*
Genotype × locality	4	2.97*	20.78 NS	0.00*	1.09 NS	0.06 NS	0.41*
Error	18	0.58	14.81	0.00	0.96	0.46	0.13
Total	26						

* Significant difference P=0.05; ** Significant difference P=0.01; NS = No significant. DF = Degree freedom; P = Protein %; S = Starch %; A = Ash %; IZ = Zeleny tests; GM = Grain Moisture; MF = Flour Moisture.
* Diferencia significativa P=0,05; ** Diferencia significativa P=0,01; NS = No significativo. DF = Grados de libertad; P = Proteína %; S = Almidón %; A = Cenizas %; IZ = Índice de Zeleny; GM = Humedad del grano; MF = Humedad de la harina.

Table 3. Comparison of means of outstanding genotypes with statistically higher values for Cal Blanco F2011, Matchett F2011 and RSM-Norman F2008 for physicochemical and bromatological variables.
Tabla 3. Comparación de medias para genotipos con valores estadísticos significativos para las variables físicoquímicas y bromatológicas de los Genotyipos Cal Blanco F2011, Matchett F2011 and RSM-Norman F2008.

Variable	Genotype		
	Matchett F2011	Cal Blanco F2011	RSM-Norman F2008
GHW (kg/hL)	83.56 b	84.72 a	82.96 c
WTG (mg)	51.9 a	42.6 c	47.8 b
GL (mm)	7.24 a	5.89 c	6.63 b
GW (mm)	3.50 b	3.36 c	3.41 b
GT (mm)	3.00 b	2.98 b	3.09 a
L	86.07 b	86.76 a	84.51 c
a*	2.43 a	2.11 b	2.44 a
b*	11.50 c	12.41 a	11.90 b
S (%)	63.42 a	63.87 a	57.11 b
A (%)	1.33 c	1.52 a	1.42 b
ZI (mL)	64.78 b	66.33 a	66.78 a
GM (%)	11.97 a	11.42 c	11.79 a
FM (%)	12.38 a	12.31 a	12.06 b

P≤0.05 = LSD = Least significant difference. GHW = Grain Hectolitric weight; WTG = Weight of 1,000 grains; GL = Grain length; GW = Grain width; GT = Grain thickness and flour colour (L, a* and b*); P = Protein %; S = Starch %; A = Ash %; IZ = Zeleny tests; GM = Grain Moisture; MF = Flour Moisture. Means with different letters indicate significant differences among genotypes.
P≤0,05 = LSD = Diferencia mínima significativa. GHW = Peso Hectolítrico; WTG = Peso de 1.000 granos; GL = Ancho del Grano; GW = Ancho del grano; GT = Espesor del grano y Color de la harina (L, a* and b*); P = Proteína %; S = Almidón %; A = Cenizas %; IZ = Índice de Zeleny; GM = Humedad del grano; MF = Humedad de la Harina. Medias diferentes entre genotipos indican diferencias significativas.

Width and Thickness; Flour L, a* and b*. The only exception was Grain Width in the interaction (Table 1).

For bromatological analyses there were significant differences (P≤0.05) (Table 2) for the Factor genotype in all variables but % Protein. Thereafter, significant differences (P≤0.05) were found for all variables but Zeleny test at the Locality scale, and % Starch, Zeleny test, and Grain Moisture at the interaction scale (Table 2).

A Tukey test at 5% probability level was applied to determine significant differences between genotypes at localities for each of the study physicochemical and bromatological (Tables 3 and 4).

DISCUSSION

Physicochemical and bromatological analyses. The significant differences (P≤0.05) found per genotype among all study physicochemical parameters indicate that the genotypes studied had different genomic information for most of these variables. Many researches have reported that Hectolitric weight, Moisture, Weight of one thousand grains and Protein values are affected by the ambient conditions (Irrigation or temporal conditions), Genomic and their genotype per locality interactions, and also for some other non-controlled external factors (Balbuena et al., 2008; Velasco et al., 2012; Campuzano et al., 2015). Table 3 shows the means for genotypes resulting from RSM-Norman F2008, Cal Blanco F2011 and Matchett F2011 wheats for Hectolitric weight. The three genotypes studied revealed high GHW values (≥82 kg/hL); in addition, GHW is a very important yield quality factor and a quality parameter (de la O Olán et al., 2010; Rodríguez et al., 2014). NMX-FF-036-1996 indicates a 74 kg/hL as the minimum GHW value for quality for the wheat group one, so all the genotypes for the present research could be accepted in that group. Per Locality, the best GHW were reported at Mexicali, Baja California (Table 4). The present GHW results resulted slightly above results reported by Rodríguez et al. (2014) genotypes two years before (80-83.4 kg/hL) and Rodríguez et al. (2011) under irrigations conditions at the same Mexicali Valley locality. Durum or semidurum wheats could improve their GHW values when they are cultivated under good fertilization and irrigation conditions. So, even though Mexicali Valley is considered a dry and warm locality, its conditions resulted more favourable for Matchett F2011, Cal Blanco F2011 and RSM-Norman F2008 wheat geno-

Table 4. Comparison of means by locality for physicochemical and bromatological variables.
Tabla 4. Comparación de medias por localidad para las variables fisicoquímicas y bromatológicas.

Variable	Locality		
	Mexicali	Tarimoro	Querendaro
GHW (kg/hL)	84.80 a	84.24 b	82.18 c
WTG (mg)	49.8 a	49.6 b	43.0 c
LG (mm)	6.71 a	6.57 b	6.49 c
WG (mm)	3.41 b	3.49 a	3.37 b
TG (mm)	3.03 b	3.11 a	2.92 c
L	85.88 a	85.46 b	86.00 a
a*	2.53 a	2.33 b	2.12 c
b*	11.83 b	12.38 a	11.60 c
P (%)	10.11 b	10.16 b	11.44 a
S (%)	59.16 b	61.19 ab	64.06 a
ZI (mL)	1.52 a	1.43 b	1.32 c
GM (%)	10.51 c	12.16 b	12.51 a
FM (%)	11.44 c	12.08 b	13.22 a

P≤0.05 = LSD = Least significant difference. GHW = Grain Hectolitric weight; WTG = Weight of 1,000 grains; GD = Grain length; GW = Grain width; GT = Grain thickness and flour colour (L, a* and b*); P = Protein %; S = Starch %; A = Ash %; IZ = Zeleny tests; GM = Grain Moisture; MF = Flour Moisture. Means followed by different letters indicate significant differences among localities.
P≤0,05 = LSD = Diferencia mínima significativa. GHW = Peso Hectolítrico; WTG = Peso de 1.000 granos; GL = Ancho del Grano; GW = Ancho del grano; GT = Espesor del grano y Color de la harina (L, a* and b*); P = Proteína %; S = Almidón %; A = Cenizas %; IZ = Índice de Zeleny; GM = Humedad del grano; MF = Humedad de la Harina. Promedios seguidos por letras diferentes indican diferencias estadísticamente diferentes entre las localidades.

types (than some others wheat genotypes reported) because of the irrigation conditions and the agronomical handling used (Rodríguez et al., 2011; Rodríguez et al., 2014). Grain Hectolitric Weight resulted affected by the genotype, locality and the G × L interaction, similarly to other studies. Then, under adequate agronomical handling conditions, Grain Hectolitric weight can result in high values, although these values could be originated by ambient conditions and some other non-controllable factors. Nevertheless, under irrigation conditions and with an adequate agronomical handling, higher Hectolitric weight values could be produced than in temporal conditions. These Hectolitric weight values are excellent and recommended for bakery flour extraction genotypes (NMX-FF-036-1996; de O Olán et al., 2012a; Rodríguez et al, 2011; Rodríguez et al, 2014).

Weight of one thousand grains was slightly higher for some wheats sown in other localities. However, healthy wheats are considered appropriate with 49-43 mg (Table 4). Genotype, locality and G × L interaction affected this variable similarly to others wheat reports (de la Horra et al., 2012; Balbuena et al., 2008).

At the same time, starch content was affected only by the genotype and locality Factors. Starch contents in almost all genotypes were slightly higher than those reported by López et al. (2010) for healthy wheats (60%). Per genotype, starch content values were from 63 to 57% (Table 3), where RSM-Norman F2008 grains (57.11%) had less starch than the others genotypes from this research. For locality, Starch content was from 64 to 59% and Tarimoro and Querendaro resulted with more starch content than Mexicali (Table 4).

Grain characteristics were also similar to reported healthy wheats; RSM-Norman F2008 and Cal Blanco F2011 grains resulted smaller and rounded than other wheats (López et al., 2010). RSM-Norman F2008 grains resulted less thickly because they had less starch content. As starch is mainly endosperm component, it's presence could be the determinant factor for the grain weight values reported, and some grain characteristics (Balbuena et al., 2008; López et al., 2010; Campuzano et al., 2015). However, this genotype per locality interaction response could be suggested as a low inconsistency or as a good indicator during Crop breeding programs (Rodríguez et al., 2011).

Grain Moisture and Flour Ash obtained values were acceptable according to NMX-FF-036-1996, where moisture values are not recommended higher than 13% to reduce growth of microorganisms.

In Protein content by locality, Mexicali with Tarimoro, Guanajuato showed the lowest protein (10,11 and 10,16%, respectively) values, and Querendaro, Michoacan showed a similar protein (11,44%) content to some other studies (de la Horra et al., 2012; De la O et al., 2012; Hadži et al., 2013). Same Nitrogen fertilization was used during the whole growing cycle for all the wheats studied. Statistical differences could be originated for factors such as agronomical conditions. No Protein content values variation could suggest that protein profile and its codifying genes are similar in these Genotypes. Present genotypes could present acceptable Protein values. However, Protein content was too similar for the three genotypes; Protein expression could be affected by locality factor due to its Transcriptome or translation reactions (Martínez et al., 2012; Izadi & Yazdi, 2012; Randhawa et al., 2013). Breadmaking quality is mainly related to protein quantity and quality. Protein quantity is directly influenced by environmental factors, and protein quality is genetically controlled. Zeleny Test describes the quality of gluten proteins, which are responsible for dough quality. Gluten Protein ability is measured by swelling and settle capacities in slightly acid solution affected also by different composition and granulation of test components (milling). This hydration protein (swelling) is determined by its water absorption capacity; likewise, it has been used for the determination of flour quality.

The flour sedimentation degree in acid solutions (e.g., acid lactic) for a determinate period is considered a baking quality measure. This test, called Zeleny Value, is a fast and easy test that could be improved as a bread quality routine test. This swelling of the gluten protein in acid solutions directly affects the rate of sedimentation of a flour suspension. High Zeleny values are the result of high and good quality gluten and it is shown by slower sedimentation rates. This sedimentation rates are depending on protein composition that is mainly correlated with protein content or wheat hardness and loaf volume. Satisfactory quality Zeleny test values are mentioned for 55-60 mL. Matchett F2011, Cal Blanco F2011 and RSM-Norman F2008 flours showed values slightly above 60 mL, especially for RSM-Norman F2008 samples (Table 3). Present results are similar to other studies where Protein quantity was affected by locality and G X L interaction, but its quality has been reported with acceptable Zeleny values for all the genotypes (Hruškova & Faměra 2003; Hruškova et al., 2004; Švec & Hruškova, 2014). However, protein polymorphisms studies such as Glutenin and Gliadin polymorphisms should be achieved in order to corroborate this (Martínez et al., 2012; de la O Olán et al., 2012; Hernández et al., 2013; Wang et al., 2015).

Finally, physicochemical and bromatological characteristics such as Hectoliter weight; Weight of 1,000 grains; grain characteristics; Protein and Starch content and Zeleny values reported for the genotypes in Table 3 (Matchett F2011, Cal Blanco F2011 and RSM-Norman F2008) indicates their satisfactory bakery quality at all evaluated environmental localities (Mexicali, Baja California, Tarimoro, Guanajuato and Querendaro, Michoacan).

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