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Agronomic and quality evaluation of five wheat grain varieties used by the flour industry

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ABSTRACT

Objective: To evaluate the grain yield of five wheat (*Triticum aestivum* L.) genotypes.

Design/methodology/approach: Two field experiments were conducted during the spring-summer growing season of 2018 and 2019 in Durango, Mexico, using the Anahuac F75, Luminaria F2012, Norteña F2007, Durango, and Rayón F-89 genotypes. A 5 × 4 randomized complete block design was used. The soil had a clay texture and low fertility. NPK fertilization levels of 44-32-53 were applied, using 150 g per experimental unit distributed throughout the plant's growth cycle for each genotype. Subsequently, the grain was harvested, and characteristics such as hectoliter weight, 1000-grain weight, bulk density, and protein and starch content were evaluated for each genotype. The quality of the harvested grain was determined using techniques from the International Seed Testing Association (ISTA). Analysis of variance at $p<0.05$ showed that, for grain yield, the genotypes exhibited different yields, with values ranging from 3200 to 8700 kg ha^{-1}.

Results: protein content ranged from 10.5 to 11.7%, starch content from 51.6 to 62.2%, and hectoliter weight from 68 to 78 kg hL^{-1}. Regarding grain quality, the rayon variety was classified as quality 2, while the others were classified as quality 3; all wheat varieties had strong gluten.

Findings/conclusions: flour from the Luminaria variety can be used to produce tortillas and employed by the biscuit industry, the Norteña F2007 variety for the production of flour bread for biscuits, and none of the wheat evaluated varieties is recommended for planting in Durango to obtain flour for soup or semolina.

Keywords: Analysis protein, grain yield, starch, *Triticum aestivum.*

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INTRODUCTION

In Mexico, wheat is planted in 20 of the 32 states, 80 % of the production of this grain is concentrated in the northern zone of the country, in the states of Sonora, Sinaloa and Baja California with different types of irrigation systems, grain yields in the autumn-winter

planting cycle are, on average, 5,300 kg ha^{-1}. The other 20% is planted in the central region of Mexico, in the state of Guanajuato and in the state of Tlaxcala but in the spring-summer cycle under rainfed conditions, with average yields of 2,000 kg ha^{-1}. In 2016 the wheat production in Mexico was 3.8 million tons, of which 60% corresponded to the crystalline grain type and 40% to the bread grain type (SIAP, 2021). Unlike Canada and the United States, which classify grains according to their growth behavior, in Mexico wheat grains are classified into five groups on the basis of their gluten properties: 1, soft and hard in flour used in the mechanized boxed bread industry due to their elasticity, 2, medium strong used for handmade bread production, 3, weak slightly elastic used for tortilla and biscuit production, 4, medium non-stretchable with very strong gluten and 5, strong crystalline and short, used for pasta production (Galicia *et al.*, 2012). Mexico suffers an annual deficit of group 1 wheat grain estimated in 2.5 million tons, in order to compensate for this deficit; wheat grain is imported into the country, mainly from the USA (SAGARPA, 2017). During the spring-summer 2017 and autumn-winter 2017-2018 agricultural cycles, 2 thousand 887 hectares were planted in the state of Durango, with a production of 6 thousand 093 tons of wheat grain, the use of wheat is classified into soft, hard and crystalline (AGRICULTURE Durango, 2018). In Mexico, the wheat grain varieties with the highest quality; therefore, the ones with the highest demand by the banking industry are: Norteña F2007, Bárcenas S2002, Tacupeto F2001 and Kronstad F2001. Norteña is a variety recommended for its versatility, it is planted in the north of Mexico in the spring-summer cycle as well as in the central region in the autumn-winter cycle (Villaseñor *et al.*, 2012). In the state of Durango, an average of 6,093 tons of wheat grain is produced per year (SAGARPA 2017).

In Durango there is no knowledge of the total number of varieties used for flour production, nonetheless, there are wheat varieties of its own to be sown extensively under irrigation conditions: Luminaria F2012, Norteña F2007, Anahuac F75, Rayon F89 and Durango and for rainfed conditions: Pavón F-76, Anahuac F-75, Tlaxcala F-2000 and Náhuatl F-2000. One of the varieties planted in Mexico is the Luminaria F2012 variety which is a semi/dwarf of spring growth habit, approximately 0.84 m tall; its vegetative cycle is early, flowering takes 75 days and maturity takes 124 days, strong gluten, sowing under irrigation conditions recommended for altitudes of 1500 to 1800 amsl and rainfall of 450 to 600 mm (Solis *et al.*, 2014). The starch content of Luminaria F2012 wheat (60 to 68%) makes it a valuable source of energy in both animals and humans (Ponzio, 2010).

The acceptable content of total carbohydrates in wheat seed is 77 to 87%, proteins 10 to 12% and lipids 2%. The amount of protein, starch, oil and ash can be determined by Near-infrared (NIR) spectroscopy technology, which involves light interacting with a material, where electromagnetic radiation occurs in the form of waves. The DICKEY-john® INSTALAB 700 meter utilizes NIR technology, coupled with advanced mathematical and statistical analysis, to predict the percentage concentration of a specific constituent within a sample. For instance, moisture absorbs radiation in the 1.94 μm band of near infrared radiation, protein absorbs radiation in the 2.18 μm bands, and oil absorbs radiation in the 2.31 and 2.33 μm bands. By radiating a sample with a narrow band of radiation at a

specific wavelength, the composition of the sample can be predicted through analysis of the absorbed radiation.

The energy of the light absorbed by the sample is inversely proportional to the reflected light (Rodriguez, 2013). The objective of this work is to evaluate the agronomic behavior, as well as the quality of flour used in baking of five wheat varieties, sown in the Guadiana Valley in Durango, Mexico.

MATERIALS AND METHODS

Field work. Five grams of flour of each wheat variety were used: Anahuac F75, Norteña F2007 Rayon F89, Luminaria F2012 and Durango, which were provided by INIFAP-Durango, sown during the autumn-winter (A-W) planting cycle from January to July 2018 and autumn-winter (A-W) planting cycle from January to July 2019. The sowing locality was the experimental area of the Guadiana Valley Technological Institute located 23 km from the city of Durango, Mexico, with coordinates 24° 00' 36.5" N, 104° 26' 40" W. The field work consisted of: delimitation of the sowing area for a total of 5 treatments in an area of 1 m^2 and four replicates each, for a total area of 20 m^2; this was conducted under a randomized block experimental design in space and time for five treatments and four replicates. The soil was fallowed and bordered manually, sowing was done by spread using 50 g of seed per experimental unit, the seed was previously inoculated with six grams of AG_3 (giberellic acid) using a solution of 6% sugar as an adherent, eight spaced irrigations were made with 30 liters of water per experimental unit and only when the tensiometer marked a percentage of soil moisture below 30%. Fertilizations. was conducted using NPK (44-32-53) at a rate of 150 grams per 20 experimental units. Fertilizer applications were made at three critical growth stages: during seed germination, at the onset flowering, during gleaning and grain filling. In addition, soil analysis of the experimental area was carried out to determine the degree of fertilization, under the official Mexican standard (Official diary, 2002).

Evaluated variables

Hectoliter weights in kg hL^{-1} and grain moisture in % were evaluated using the DICKEY-john® GAC 2100 grain meter, ash content in % was determined in a RAYPA model HM-2® muffle at 600 °C for a period for 4 hours, the weight of 1000 seeds (g) was determined on a digital scale, seed density in kg m^{-3} and grain yield in kg ha^{-1} for each variety evaluated. The analysis of variance was conducted using a randomized block experimental design employing a statistical package (Olivares, 1994), only for hectoliter weight and grain yield, and when a minimum significant statistical difference was detected, a comparison of means was performed by $LSD_{0.05}$.

Evaluation of grain quality

The ROMER Series II Mill® was used to grind the grain until flour was obtained, passing through a 1.19-mm diameter sieve, then mashed until a fine powder was obtained. The bulk density was determined for each sample with three repeats and taking an average of the readings afterwards, the procedure was performed as follows:

1.5 ml eppendorf tubes were filled with flour of each wheat variety, previously tared, the content was weighed, and using the "density is equal to mass over volume" formula, their bulk density was determined in kg m^{-3}. To determine the amount of ash, 5 grams of flour of each wheat variety were placed in a porcelain crucible, subjected to temperatures up to 600 °C, incinerated for four hours, and allowed to cool, the weight was quantified and reported in percentage of ashes. The evaluation of protein, starch and ash content using NIR equipment was conducted as follows: 1) A type of filter was selected, filters for clear samples were preferred, 2) wheat was selected as the type of sample to be evaluated (the equipment contains 60 different types of calibrations for different types of commercial grains), the equipment then determines the blank (the infrared light lamp bombards the ceramic disc inside with beams of light, the equipment then collects the data of the blank and is ready to take the data of the sample). The variables to be evaluated were: bulk density in kg m^{-3}, ash content, and protein and starch percentage, the results were evaluated using a completely randomized design, with an analysis of variance at a $p<0.05$, and when a minimum significant difference was detected, a comparison of means was made by $LSD_{0.05}$, using statistical package (Olivares, 1994). For the determination of seed quality for sowing, we followed the seed analysis protocol (ISTA, 2016). Seed parameters were determined as percentage of viability, vain, malformed, damaged by insects, varietal purity, humidity, weight of 100 seeds in grams, equatorial diameter and polar diameter in mm, percentage of germination by flotation, 2% tetrazolium, visible fungal damage, mechanical damage and hectoliter weight in kg hL^{-1}.

RESULTS AND DISCUSSION

Soil analysis

The results of the physical, chemical and fertilization characteristics of the soil analysis in the experimental area are shown in Table 1. The results of the soil evaluation indicate low fertility, with nitrogen, phosphorus, potassium and magnesium deficiencies, with good calcium content, but with low organic matter content, and no salt problems. In a study of flour wheat grain yield of three different types of soil, (Flores *et al.*, 2021), reported the following physical and chemical characteristics: bulk density of 1,130 to 1,270 kg m^{-3}, with a soil texture from loam to clay, pH from 7.3 to 8. 2, considering a soil of medium fertility with low nitrogen, phosphorus and potassium content, Rayón F-89, Luminaria F2012 and Norteña F-2007 exhibited yields of 6,120, 6,600 and 7,160 kg ha^{-1} respectively; in this work the soil presented similar properties in terms of bulk density (1,100 kg m^{-3}), with a clayey soil texture and deficiencies in nitrogen, phosphorus and potassium content, obtaining grain yields of 3,200 kg ha^{-1}, with a reduction in grain yield of 52.2% in the Rayón F-89 variety; the Luminaria variety was superior in grain yield with 8700 kg ha^{-1} (24.13% increased yield).

Agronomic analysis

The results for moisture, hectoliter weight, bulk density and ash are shown in (Table 2). The comparison of hectolitric weight means indicate that all treatments behave similarly

Table 1. Results of soil analysis in the experimental area.

Physical analysis	
pH	7.8
Electrical conductivity	1300 dS m
Apparent density	1100 kg m^{-3}
Organic matter	1.2 %
Texture	
Sand	30.0%
Clay	63.3%
Slit	6.6%
Textural class	Clayey
Macro elements (%)	
Nitrogen	0.09
Phosphorous	0.5
Potassium	1.2
Calcium	0.79
Magnesium	0.10
Sulphur	3.4
Sodium	3.0
Micro elements mg kg^{-1}	
Copper	0.5
Iron	0.1
Manganese	0.4
Boron	0.09
Zinc	0.15
Cation exchange capacity (CEC)	
Potassium	0.06
Sodium	1.91
Calcium	15.00
Magnesium	1.83
Total cations (cmol L^{-1})	18.80

Table 2. Evaluated wheat grain results from the A-W planting cycle in northern Mexico.

Variety	Moisture (%)	Hectolitric weight (Kg hL^{-1})	Density (kg m^{-3})	Ash (%)	Weight of 1000 seeds (g)	Grain yield (Kg ha^{-1})
Anáhuac F75	9.4	68.9	740	2.2	35.8	4800[d]
Norteña F2007	13.2	68.5	820	1.4	37.6	6400[b]
Luminaria F2012	10.9	71.8	1260	1.7	48.5	8700[a]
Durango	11.1	68.1	860	2.1	38.3	5500[c]
Rayón F-89	11.2	74.2	790	1.5	32.3	3200[e]
Mean	11.1	70.3	890	1.78	38.5	
$LSD_{0.05}$		NS				101.36

Means followed by different letters within a column are significantly different at 5% probability level; NS, not significant.

with average weights of 70.3 kg hL^{-1}, regarding grain yield all varieties evaluated exhibited different values, being Luminaria F2012 the variety with the highest yield (8,700 kg ha^{-1}), Rayón F89 on the other hand, was the variety with the lowest yield (3,200 kg ha^{-1}). The weighting of 1000 seeds revealed that Luminaria F2012 was the variety with the heaviest seed (48.5 grams), followed by the Durango variety (38.0 grams), the other varieties evaluated presented similar weight. Bulk density ranged from 740 to 1260 kg m^{-3}, with an average of 890 kg m^{-3}. Ash content ranged from 2.2 to 1.4 %, with the Anahuac variety having 2.2 % and the Norteña F2007 variety 1.4%.

Evaluation of protein and starch amount in wheat grains

The comparison of means from the percentage of protein and starch contained in wheat grains is shown in (Table 3). It can be seen that the Rayon F-89 wheat variety with 10.5 % protein content was lower than the Norteña F2007 variety with 11.7%. In starch content Norteña F2007 with 62.2% was the one with the highest percentage compared to Anahuac F75 that presented the lowest content with 51.6%. (Bruening, 2009) reports wheat grain starch contents from 66.5 to 69.7 with an average of 68.2% and 13% protein, using the Perten DA7200® NIR spectrophotometer; in this work the starch contents found were 51.6 % in the Anahuac F75 wheat variety and 62.4 % in the Rayon F-89 variety, using the INSTALAB 700® NIR spectrophotometer.

Hectolitric weight

If the hectolitric weight value is 76 kg hL^{-1} or more, the flour quality obtained is considered as quality 1, values between 72 to 75 kg hL^{-1} categorize the flour as quality 2; values below 71 kg hL^{-1} classify the flour as quality 3. For this work, the rayon wheat variety is denominated as quality 2, while the others were classified as quality 3. Regarding starch content, grains are considered to be of strong quality if the starch content is above 45%, semi-strong if it is between 45 and 33%, and medium-strong if it is below 33%. In our case, all wheat varieties exhibited strong gluten. Refined flour with protein percentages equal or above 12% are considered to be very good, percentages from 10 and 12% are deemed good, and percentages below 10% are considered to be very poor. In this study all wheat varieties had protein content between 10 and 12% of good quality. Flour density

Table 3. Protein and starch content in wheat grains. Values followed by same superscript letter are not significantly different at $p<0.05$ according to Fisher's protected least significant difference.

Variety	Protein (%)	Starch (%)
Anáhuac F75	11.3^{a}	51.6^{c}
Norteña F2007	11.7^{a}	62.2^{a}
Luminaria F2012	11.2^{a}	57.8^{b}
Rayón F-89	10.5^{b}	60.4^{ab}
Durango	11.4^{a}	60.4^{ab}
$LSD_{0.05}$	0.958	3.32

values of 900 kg m^{-3} or more are considered to be very good, from 700 to 800 kg m^{-3} good and less than 600 kg m^{-3} poor. In this case, all varieties had a density between 700 and 900 kg m^{-3}, thus, they were considered of good quality. (Villaseñor *et al.* 2012), reported a hectoliter weight of 77 Kg hL^{-1} with a grain protein content of 12% and a yield of 4,821 kg ha^{-1} in the Norteña F2007 variety; employing the same variety, we report a hectoliter weight of 68.5 kg hL^{-1} and a protein content of 11.7%, it is worth noting that due to its hectoliter weight, this genotype is considered quality 2, with a medium strong gluten classification. In this study, we obtained a hectoliter weight of 71.8 Kg hL^{-1} with the Luminaria variety, 5.2 points less than those reported by Villaseñor *et al.*, 2012. In a similar study to ours, (Hernandez *et al.*, 2007) determined that the wheat grain variety Anahuac F-75 was ranked as quality 1, in this study however, that same wheat variety was ranked as quality 3.

Seed quality

For the quality of the seed of the different varieties of wheat evaluated, they can be seen in the Table 4. (Vilchis, 2019) reports on studies carried out on the Rayon F-89 wheat variety, polar diameter 6.7 mm, equatorial diameter 4.0 mm, at grain moisture of 16%, for this work in the same grain variety it was 5.7 and 2.4 mm in polar and equatorial diameter. As for the weight of 1000 seeds (Karimi *et al.*, 2009), report weights of 1000 seeds of 18.3 grams at humidity of 8% in the grain, in this study the weight of 1000 seeds ranged between 22 to 31.6 grams in all varieties evaluated.

Table 4. Results obtained from the analysis of seeds of different varieties of wheat (*Triticum vulgare* sp.) used for sowing in the Autumn-Winter 2018 and 2019 cycle in Durango, Mexico.

	Rayón F89	**Norteña F2007**	**Durango**	**Luminaria F2012**	**Anáhuac F75**
Viable (%)	80.0	80.0	70.0	80.0	60.0
Vain (damaged embryo) %	5.0	6.0	10.0	5.0	6.0
Malformed (%)	13.0	25.0	0.0	20.0	20.0
Damaged by insects (%)	10.0	0.0	0.0	0.0	0.0
Varietal purity	ND	ND	ND	ND	ND
Moisture (%)	9.6	9.0	9.8	9.0	10.7
Weight of 1000 seeds (g)	28.6	31.6	22.0	24.0	25.5
Equatorial diameter (mm)	2.3	2.4	6.3	6.1	1.3
Polar diameter (mm)	6.0	5.7	6.3	1.7	1.7
Germination by flotation (%)	100	90	100	90	90
Germination by (Tetrazolium 2%) %	90	95	80	70	70
Apparent density (kg m^{-3})	780	740	680	780	750
Visible damage	Null	Null	Null	Null	Null
Fungal damage	Null	Null	Null	Null	Null
Mechanical damage (%)	0	0	0	0	0
Hectolitric weight (kg hL^{-1})	78.0	74.0	68.0	78.0	75.0

CONCLUSIONS

Based on these results, it is concluded that flour from the Luminaria variety can be used to produce tortillas and employed by the biscuit industry, the Norteña F2007 variety for the production of flour bread for biscuits, and none of the wheat varieties evaluated is recommended for planting in Durango to obtain flour for soup or semolina.

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