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Article

Nutritional value in grains of triticale as an alternative in the food industry

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Abstract

The objective of this research was to identify lines of triticale (X. *Triticosecale* Wittmack) of value in the food industry, based on their physical and chemical properties. Twenty elite lines of spring triticale from the CIMMYT research program were established under a completely randomized experimental design with six repetitions during 2018 in Celaya, Guanajuato, Mexico, where the following variables were evaluated: WTG, HW, moisture, ashes, fat, fiber, protein, and carbohydrates. The results showed differences ($p\leq 0.05$) between lines, the highest values of WTG, HW and the highest percentage in fat, fiber, proteins and carbohydrates were found in lines L-18, L-17 and L-14, in addition to L-20, L-10 and L-19. The AMMI model detected significant differences ($p\leq 0.05$) for the lines and their interactions with physicochemical variables; the biplot graph showed that lines L-18, L-7, L-10, L-17 and L-20 expressed greater association with WTG, HW, proteins, fats, fiber and carbohydrates, which allows them to be considered in the use of the food industry for obtaining higher averages.

Keywords: X. *Triticosecale* Wittmack, industrial quality, physicochemical properties.

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Introduction

Triticale (X. *Triticosecale* Wittmack), a cereal of wheat and rye hybridization, is mainly used as animal feed, in recent years the interest for its use in food production has increased (Zhu, 2018), due to its genetic variability and grain nutritional composition, which has allowed the development of food and beverage products, including bakery products such as biscuits, pasta, breads and malts. Little research has been done on the nutritional composition and various food uses of triticale due to the wide variation in the chemical composition of the grain, suggesting that it has potential as a cereal alternative for various food applications (Zhu, 2018).

Grain and flour are a source of vitamins and minerals (Pruska *et al*., 2017), it also has more lysine and protein than wheat varieties, which is valuable because it is an essential amino acid that the body does not synthesize, therefore, it is a product of interest for human diet, although its characteristics, such as texture and grain filling, are unfavorable during commercialization, since its flour yield is lower than wheat. Flour extraction from triticale grain can average 65% (Riasat *et al*., 2019), although it is highly variable depending on the variety, management and harvest conditions.

Triticale can be considered for human diet, but the yield and quality of flours should be increased (Oliete *et al*., 2010). In Mexico, the selection of genotypes for milling is scarce, because studies have focused on the production of forage and grain; however, Ammar *et al*. (2004) point out that yield, adaptation and industrial quality must be increased.

From the predictive point of view of selection, it is important to know if selecting a characteristic modifies another that is correlated with it since especially negative ones can neutralize the efforts of the breeder (Pattison *et al*., 2014). This reflects the importance of the crop in the food industry and the need for varieties of greater and better benefits that meet the needs and requirements of the industry. Therefore, the objective of this research was to identify triticale lines based on the physical and chemical properties of the grain with value for the food industry.

Materials and methods

Genetic material and location of experiments

The genotypes were 20 elite lines of spring habit triticale (Table 1), of F_8 generation selected at the CIMMYT experimental station, located in Ciudad Obregón, Sonora, of the nursery YTCL-2015, these excelled in grain yield, resistance to stem and leaf rust, as well as water stress. They were evaluated in the field during the autumn-winter 2017-2018 cycle at the Roque *Campus* of the National Technological Institute of Mexico (ITNM-Roque), in Celaya, Guanajuato, Mexico, whose climate is semi-warm BS1Hw (e), with a rainfall of 550 to 710 mm during the year and average annual temperature of 18.4 ºC, whose soils are of the Pelic Vertisol type, which are characterized by being clayey of dark coloration (García, 1973), specifically at 20º 31’ north latitude, 100º 45’ west longitude and with altitude of 1 765 masl.

Table 1. Genealogy of 20 elite lines of spring triticale evaluated in the state of Guanajuato.

Line	Genealogy
1	CTSS99Y00246S-1Y-0M-0Y-5B-1Y-0B
2	CTSS02B00380S-6Y-3M-4Y-2M-1Y-0M
3	CTSS02B00413S-22Y-2M-3Y-2M-1Y-0M
4	CTSS03Y00100T-050TOPY-49M-1Y-06Y-2M-4Y-0M
5	CTSS05Y00094S-020Y-8M-4Y-0M-1Y-0M
6	CTSS04B00008S-020Y-24M-2Y-0M-2Y-0M
7	CTSS04B00035S-020Y-29M-4Y-0M-2Y-0M
8	CTSS07Y00001S-17Y-010M-6Y-3M-3Y-0B
9	CTSS07Y00009S-26Y-010M-9Y-1M-3Y-0B
10	CTSS07Y00052S-3Y-010M-3Y-4M-2Y-0B
11	CTSS07Y00056S-27Y-010M-6Y-3M-1Y-0B
12	CTSS07Y00076S-12Y-010M-26Y-1M-4Y-0B
13	CTSS07Y00103S-23Y-010M-4Y-1M-2Y-0B
14	CTSS08Y00155T-099Y-016M-17Y-099M-4Y-4BMX-4Y
15	CTSS08Y00168T-099Y-024M-5Y-099M-1Y-4BMX-1Y
16	CTSS08Y00035S-099Y-026M-5Y-099M-5Y-2BMX-1Y
17	CTSS08Y00035S-099Y-026M-19Y-099M-2Y-2BMX-4Y
18	CTSS08Y00054S-099Y-021M-2Y-099M-9Y-2BMX-4Y
19	CTSS08Y00117S-099Y-032M-2Y-099M-15Y-1BMX-4Y
20	CTSS08Y00130S-099Y-037M-9Y-099M-5Y-3BMX-3Y

Genotype samples were obtained at harvest, to quantify their nutritional quality in the laboratory of food industries of ITNM-Roque, under a completely randomized experimental design with six repetitions where the variables evaluated were: weight of one thousand grains (WTG), hectoliter weight (HW), moisture, ashes, fat, fiber, protein and carbohydrates.

Physicochemical analyses

The hectoliter weight (HW) was determined with procedure 55-10 of the American Association of Cereal Chemists (AACC, 1995) and was obtained by dividing the weight of the grains by the volume of the container and related to the volume of 100 L, the measurements were made in 10 repetitions, while the weight of 1 000 grains (WTG) was determined in triplicate in 1 000 grains.

The percentage of moisture was evaluated with method 900.15 of the Association of Official Analytical Chemist (AOAC, 2012), with 10 g of each sample placed in crucibles, subjected to 105 °C in an oven for 16 h, which were introduced in a desiccator for 30 min until reaching room temperature to finally record the weight, the analysis was performed in duplicate and the moisture was determined with the following formula: $\% \text{ of moisture} = \frac{(B-A)-(C-A)}{B-A} * 100$. Where: A= is the weight of the crucible at constant weight (g); B= to the weight of the crucible with the sample (g); and C= to the weight of the crucible with the dry sample (g).

The crude protein content was calculated based on the total nitrogen using the Kjeldahl method, digestion was carried out with concentrated sulfuric acid and 40% sodium hydroxide was used in distillation, a standard solution of sulfuric acid was used for titration, official method of AOAC (2012). The determination of crude fat was carried out according to method 923.03 of AOAC (2000), where extractions were carried out in triplicate in samples of 1 g of flour that passed through a mesh 80 (0.18 mm), a Soxhlet System HT 1043 extraction Unit equipment (Tecator, Sweden) was used, with petroleum ether as solvent.

To value the ashes: method 923.03 of AOAC (2012) was used, 5 g of each sample was weighed, placed in a porcelain crucible, incinerated in a muffle at approximately 550 °C, until a luminous gray ash was produced, then allowed to cool in a desiccator and weighed when reaching room temperature; carbohydrates were determined by difference, subtracting from 100 the percentages calculated for each nutrient, the values were expressed in g kg^{-1}.

The fiber was assessed with the method of acid and alkaline digestion, fat was extracted from 2 g of sample, transferring it to a 600 ml glass to avoid contamination with paper fiber, 1 g of prepared asbestos and 200 ml of boiling 1.25% sulfuric acid were added, then the glass was turned periodically to prevent solids from adhering to the walls, then the glass was removed and it was filtered through paper, then the residue was washed several times until the washing waters had a pH equal to that of distilled water, in the end, it was calcined at 600 °C for 30 min to cool and determine its mass, the formula used was: % Fiber= $\left(\frac{A\text{-}B}{C}\right)$ *100. Where: A= to the weight of the crucible with the dry sample; B= to the weight of the crucible; and C= to the grams of dry sample. For protein: the Kjeldahl method (AOAC, 2012) was used, 0.1 g of sample was weighed in duplicate (dry samples from the moisture analysis) and its weight was recorded.

Statistical analysis

An analysis of variance (Anova) in a completely randomized design with six repetitions and a comparison of means with the least significant difference (LSD, $p \leq 0.05$) were performed. In the physicochemical characterization of the triticale lines, a matrix was generated, the data of WTG, HW, moisture, ashes, fiber, fat, protein and carbohydrates were averaged in six repetitions. The Upgma (unweighted metric mean) method was used to calculate distances and generate compact and homogeneous groups and thus differentiate the groups within the triticale lines (Núñez and Escobedo, 2011). For the biplot, the additive main effects and multiplicative interaction (AMMI) model and a principal component analysis for the genotype x environment interaction were used to know the relationship between the lines with the physicochemical variables (Crossa, 1990).

Results and discussion

The results of Anova (Table 2), show differences ($p < 0.01$) between lines for all variables, the effects that contributed to the total variation in HW were 61.29%, WTG (60.05%), because the expression of weight was mainly attributed to the genetic variation of the evaluated lines, as confirmed by the results of Jonnala *et al*. (2010), who found differences in WTG and HW in advanced triticale lines, which indicates that the genotypes provide different quality in the grain due to their genetic constitution; other effects that occurred in fiber, proteins and fat showed greater contributions with 77.05, 62.83 and 52.73%, respectively, which shows that the proportion of quality in the grain is influenced by genetic factors of the lines. These results are consistent with those obtained by Negash *et al*. (2013), who assessed quality in wheat grains and found that the most important effects were protein, carbohydrates and fiber.

Table 2. Mean squares of the analysis of variance of the physicochemical variables of 20 elite lines of spring triticale evaluated in 2018 in the state of Guanajuato.

SV	DF	WTG	HW	Moisture	Ashes	Fat	Fiber	Protein	Carbohydrates
Lines	19	32.56^{**}	20.52^{**}	1.04^{*}	0.1^{*}	8.01^{**}	0.19^{**}	33.6^{**}	135.82^{**}
Error	100	10.17	6.26	7.12	0.08	1.36	0.01	3.78	32.39
Total	119	17.45	10.78	6.14	0.08	2.42	0.04	8.53	48.9
CV (%)		7.98	3.33	16.07	14.03	12.45	2.9	15.17	9.09

SV= sources of variation; DF= degrees of freedom; WTG= weight of one thousand grains; HW= hectoliter weight, $^{*}=p\leq 0.05$, $^{**}=p\leq 0.01$ and CV= coefficient of variation.

Lines L-18, L-17, L-14, L-19 and L-20 showed numerically the highest averages in WTG and HW (Table 3); however, in WTG, L-18 only exceeded L-3 and L-5 and, in HW, L-20, L-17, L-1 only exceeded L-1 and L-5, so the grain weight and hectoliter weight are considered indicators of the grain yield potential of varieties or lines, in this case L-14, L-17 and L-20 also presented the lowest contents of moisture in grain; that is, a greater accumulation of dry matter and HW.

Table 3. Comparison of means (LSD) of 20 elite lines of spring triticale of physicochemical variables, evaluated in 2018 in the state of Guanajuato.

Line	WTG	HW	Moisture	Ashes	Fat	Fiber	Protein	Carbohydrates
1	38.13ab	68.36c	15.56a	2.24a	2.18bc	3.32k	9.15f	61.97abcde
2	39.01ab	73.96abc	15.85a	1.92c	2.34abc	3.51ghijk	15.54ab	54.16e
3	42.79b	75.36abc	14.78ab	1.93c	1.23c	3.57fghij	13.02abcdef	64.85abcde
4	36.23ab	73.26abc	13.67abc	1.92c	3.47abc	3.38jk	11.12cdef	66.13abcd
5	35.83b	69.53bc	13.24bc	1.90cd	3.15abc	3.61efghi	13.68abc	58.21abcde
6	42.92ab	75.82abc	12.73bc	2.14ab	2.31abc	3.39ijk	9.43def	63.83abcde
7	45.69ab	76.11abc	12.86bc	1.98abc	1.97c	3.84abc	13.49abcd	55.79cde
8	37.73ab	74.23abc	15.93a	1.95bc	1.39c	3.65defgh	13.32abcde	66.79abcd
9	37.64ab	74.46abc	14.84ab	2.07abc	4.53ab	3.45hijk	11.47bcdef	67.397abc
10	43.5ab	76.66ab	13.42bc	1.96bc	3.38abc	3.68bcdef	14.11abc	59.96abcde
11	42.07ab	76.03abc	12.61cd	2.27a	2.26abc	3.55fghij	9.27ef	63.14abcde
12	38.28ab	73.23abc	14.05ab	1.94bc	2.42abc	3.76abcdef	14.29abc	55.19de
13	39.16ab	76.56ab	13.25bc	1.96bc	1.31c	3.82abcde	13.19abcdef	66.08abcde
14	42.94ab	77.96a	12.03d	1.84d	2.05c	3.62defgh	11.26cdef	68.12ab
15	36.38ab	75.86abc	12.43cd	1.92c	3.24abc	3.84abcd	13.86abc	59.32abcde

Line	WTG	HW	Moisture	Ashes	Fat	Fiber	Protein	Carbohydrates
16	35.98ab	75.86abc	13.61abc	2.17ab	2.39abc	3.59fghij	9.55def	65.04abcde
17	43.05ab	78.06a	10.96d	1.82d	4.72a	3.86abc	16.61a	72.24a
18	45.84a	77.43a	12.1cd	1.84d	4.64a	3.91ab	16.39a	68.06ab
19	37.89ab	75.26abc	13.04bc	1.85d	1.47c	3.73bcdef	11.61bcdef	56.85bcde
20	37.81ab	78.8a	10.34d	1.98abc	4.59ab	3.94a	15.74a	61.1abcde
LSD	9.89	7.76	0.6	0.45	2.45	0.22	4.08	11.96

WTG= weight of one thousand grains; HW= hectoliter weight; LSD= least significant difference. Means with the same letter in the columns are not statistically different (LSD, 0.05).

Aisawi *et al*. (2015) mention that grain morphology is negatively altered by late sowings, nitrogen deficiency, deficiency in water supply and grain filling due to high or low temperatures. Therefore, the results obtained are based on the genetic differences of the lines, as well as the favorable environmental conditions in which the lines were sown in the field (December 18, 2017).

The results indicate a good grain filling during the cycle, which provides good flour yield during the milling process in the food industry. These results are consistent with what was reported by Pomortsev *et al*. (2019); Giunta *et al*. (2017) reported that higher grain weight is strongly affected by genetic and environmental factors; the results showed that, within the total variation of the values of these variables, it was due to the genotype-by-environment (GxE) interaction, which shows predicting the behavior of the lines when evaluated.

The moisture content is of great relevance because moisture contents greater than 13-14% favor the damage caused by the presence of microorganisms during temporary storage, consequently it affects the quality of flours in the production of food products. The moisture in lines L-20, L-17, L-14 and L-14 was satisfactory and reliable for processing in the production of biscuits because they were less than 13%, the content of minerals (ash) in the grain is important because, if their concentration is high, especially in grains with low hectoliter weight, it may not be favorable in the food and animal industry (Riasat *et al*., 2019).

Low ash levels are favorable because they can provide more minerals for the diet, on the other hand, when there are high levels of ash, they are particularly undesirable because they darken semolina and, to a greater degree, food pasta (Pattison *et al*., 2014). The concentration levels of ash in grain that are considered desirable should be less than 2% (Peña *et al*., 2007), the results showed that lines L-17, L-18, L-19 and L-14 presented values less than 2 in ashes, which makes them important for the contribution of minerals.

In relation to the fat content, variation was found between the lines, within the group with the best response, lines L-17, L-18 and L-20 showed higher values and were higher than L-1, L-3, L-7, L-8, L-13, L-14 and L-19; in general, cereals have low amounts of lipid compounds, triticale is between 1.5 fats (Peña *et al*., 2007), which are mainly present in the germ and aleurone layer of the grain. Therefore, only the lines of triticale L-3, L-8, L-13 and L-19 presented reduced values and the rest are within the range known for the fat content in the cereal, in turn Pruska *et al*. (2017) mentioned that those cereals with higher fat content should be considered to extend their use in human diet, at the same time increase crop yields and the quality of their flours, since fats represent the main source of energy from foods, as is the case of the concentration that some cereals, such as wheat and oats, have in the grain.

In the case of fiber, the highest numerical values were shown by lines L-18, L-20 and L-17, but the most important statistical group was also made up of L-15, L-13 and L7, the range of this variable is 3.1 in triticale (Peña *et al*., 2007), so the 20 lines represent a good source of fiber for humans, who are the ones that need the most for digestion (Moiraghi *et al*., 2011). The results showed values from 3.3 to 3.94, higher than the range established in triticale (3.1).

Lines L-17, L-18, L-20 and L-2 produced numerically the highest concentrations of proteins, but in the same group were L-12, L-10, L-15, L-5, L-7, L-8, L-13 and L-3; in this regard, Peña *et al*. (2007) report that triticale usually has a protein content of 14.3%, so only lines L-17, L-18, L-20 and L-2 are considered with desirable protein contents to make pasta and cookies due to their strong gluten, since they also exceeded by 4.61 the protein content of wheats (12%), Gulmezoglu *et al*. (2010) reported that triticale contains a good source of proteins, carbohydrates and fats that can be used in the animal diet and in processes for the food industry for the processing of pasta, biscuits or breads with own flours or mixtures with flours of other cereals.

In relation to the carbohydrate content in the grain, it was observed that in lines L-17, L-18, L-14, they presented higher numerical values of carbohydrates, but when considering the values obtained by Jonnala *et al*. (2010), lines L-9, L-8, L-4, L-13, L-16, L-13, L-6, L-11, L-1 and L-20, lines L-10, L-15, L-5, L-19, L-7, L-12 and L-2 were also higher; nevertheless, as they are classified within the group with the highest values, they are not considered desirable because they do not meet the necessary requirements. Pattison *et al*. (2014) establish that foods rich in carbohydrates are present in seeds, pasta, breads, cookies and tubers, among others, they are important since they represent 55% of the total foods in the diet of developed countries and more than 80% in underdeveloped countries, so the lines with higher percentages of proteins, carbohydrates and fibers have the potential to be used in the production of food formulas for humans and animals (Jonnala *et al*., 2010).

The cluster analysis classified the 20 lines of triticale into four groups with similarity based on the physicochemical characteristics of the grain (Figure 1), the first group was formed by lines L-17 and L-18, they provided higher WTG and HW and exceeded the general mean; however, for ashes, proteins, fiber and fat, their values were higher than what was reported by Peña *et al*. (2007), being acceptable for the milling industry, especially for the production of pasta, biscuits, macaroni and soups, Pattison *et al*. (2014) mentioned that a good quality in triticale grains should be when they present values higher than 14.3% in protein, less than 2% of ashes and greater than 1.5% of fat, the results of this research significantly exceeded that reported by Peña *et al*. (2007).

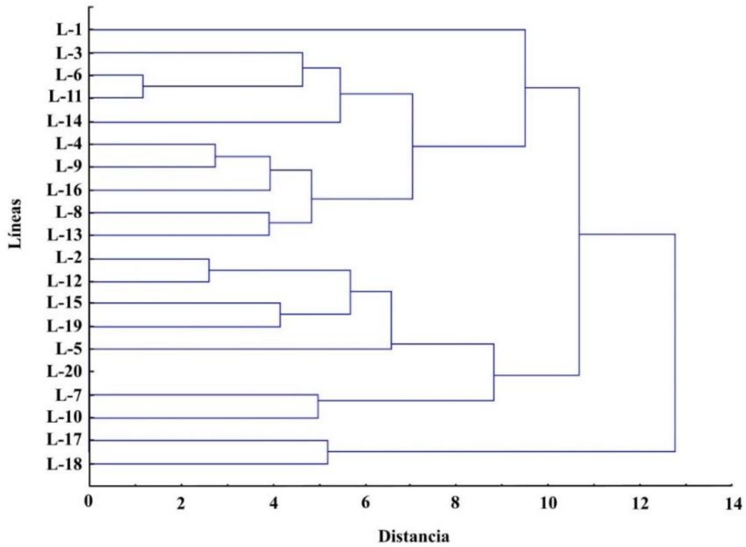

Figure 1. Dendrogram generated based on the contents of physicochemical parameters of 20 elite lines of spring triticale, Celaya, Guanajuato, Mexico.

The second group was formed by 40% of the lines, integrating L-10, L-7, L-20, L-5, L-19, L-15, L-12 and L-2, this group showed values lower than the general mean of WTG and HW, these parameters indicate the density and degree of filling of the grain, mainly for the morphology of the grain characteristic of the variety, normally, when the grain is not completely full, the hectoliter weight values are low, in this research the values presented in HW and WTG were 5.14 kg hl^{-1} higher than what is reported in wheat (70 kg hl^{-1}), which Peña *et al*. (2006) report.

It should be noted that the field experiment was carried out from December 2017 to April 2018, which favored grain filling, the third group contributed 25%, formed by lines L-13, L-8, L-16, L-9 and L-4, their characteristics are that they showed 0.26 kg hl^{-1} in HW, lower than the general average (75.14 kg hl^{-1}) and 2.6 g in WTG, these results are not significant for them to be used in the milling industry since they exceeded that reported in wheat by 4.8 kg hl^{-1}.

However, the average values of moisture, ashes, fat, and fiber were higher than those reported by Pattison *et al*. (2014) in wheat, with 13, 2, 2.62, and 3.58%, respectively. Castaño *et al*. (2015) report that the milling industry produces three grades of flour quality, related to their physicochemical properties: common or standard, fine and extrafine, which constitute the basis for the preparation of breads, tortillas, cookies and cakes, where semolinas may vary slightly in their grade of fineness due to the quality of flours of the genetic material to be used in the preparation of pasta (spaghetti, macaroni, soups), the results in this research are indicators that the lines in this group can be used in the preparation of cookies, pasta, cakes and macaroni due to the gluten, with the exception of the content of proteins and carbohydrates, which, despite having low values, are still favorable to consider them in the baking industry (Zhu, 2018).

The fourth group represented 25% and was made up of L-14, L-11, L-6, L-3 and L-1, whose WTG and HW values were 1.83 and 0.43 kg hl^{-1} higher than the average, in terms of moisture their values were less than 13.5%, in ashes only L-14 and L-3 showed values lower than 2%, so they are suitable for milling, in fat and fiber they had higher values, proteins and carbohydrates obtained slightly lower values than those reported by Peña *et al*. (2007), of the total food raw material generated by the milling industry, approximately 62% is destined to baking, 26% to biscuits, tortillas and others and 12% to the production of food pasta, these lines are promising for the production of the latter product, these results coincide with what was reported by Jing *et al*. (2016), who reported that the functional properties and structure in flours of cereals such as wheat and triticale are the fundamental basis for obtaining good milling quality.

The AMMI analysis (Figure 2), allowed dispersing the 20 lines in their physicochemical properties with greater and lesser association, forming three groups between the two components; the first contributed 60%, it was integrated by L-19, L-11, L-6, L-3, L-12, L-2, L-16, L-9, L-8, L-4 and L-13, these lines showed greater association with proteins, fats and fiber (Figure 2), L-20, L-2 and L-12 showed 1.2 to 1.5% more protein, in fiber and fat the 12 lines obtained on average between 1 and 3%, respectively, than reported by Peña *et al*. (2007).

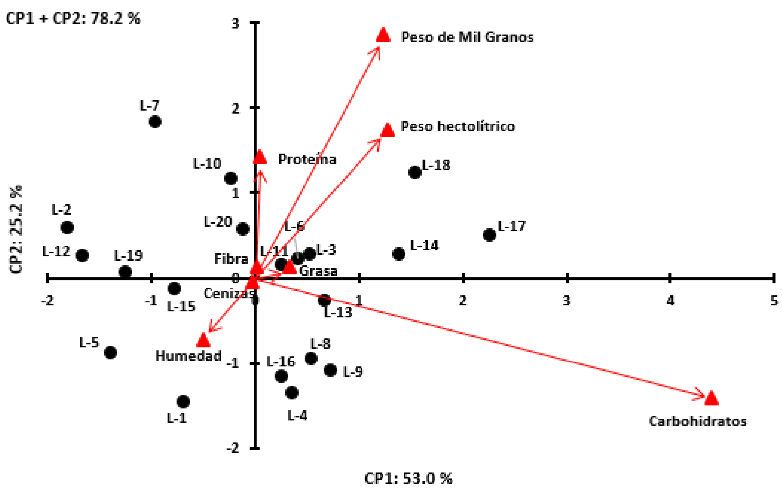

Figure 2. Biplot of the 20 lines of spring triticale with physicochemical variables, evaluated in Celaya, Guanajuato.

These lines have good availability of nitrogen in the grain and the levels of this component are acceptable for flours intended for baking, the production of tortillas, cookies and pasta, this is relevant because the gluten content is the most important factor when defining the quality of both cooking pasta (spaghetti and soups) and baking (Pattison *et al*., 2014). Therefore, the contents of these parameters could be an attributable factor of the climatic conditions in which the field grains were collected, the percentages of these parameters were between 1 to 3% higher than what was reported by Ferreira *et al*. (2015), who mentioned that the quality of protein present in grains such as wheat and triticale is decisive for use in the food industry; the second group contributed 25%, with lines L-7, L-18, L-17, L-14 and L-10 being associated with WTG, HW and carbohydrates, these parameters are important in the grain content, it is defined mainly by its morphology in each variety, this can be negatively altered by late sowings, nitrogen deficiency, deficiency in water supply, and grain filling due to high or low temperatures.

The hectoliter weight is considered an indicator of the yield potential in flours that a variety or line has during milling, in such a way that varieties with low hectoliter weight (less than 70 kg hl^{-1}) usually show low yields of flour, for this reason, during this research higher values were found in HW, the lowest value was in L-7 (76.10 kg hl^{-1}) and the highest in L-17 (78.07 kg hl^{-1}), these results indicate that the HW in this group is a decisive factor in determining the quality in flours in obtaining better yields (Jing *et al*., 2016).

The third group, formed by L-1, L-5 and L-15, showed a negative relationship with the content of minerals (ashes) and moisture in the grain, this result is important because, if their concentrations of ashes and moisture were greater than 2 and 14%, respectively, especially in grains with low hectoliter weight, it can significantly contaminate the semolina and flour from milling, the highest levels of ash contamination are particularly undesirable in hard or crystalline grains, because the particles darken the semolina and to a greater degree, food pasta, the range of ashes in triticale is 2%, for moisture the contents in the grain greater than 13-14% favor the damage, causing the presence of microorganisms (Fan, 2018).

The concentration levels of ashes in grain that are considered desirable should be less than 2% (Peña, 2007). The results indicate that this group, especially lines L-5 and L-15, showed ash values less than 2%, and moisture only line L-15 presented 12.43%, these results agree with those obtained by Pattison *et al*. (2014), who evaluated the quality of gluten in the grain of triticale varieties and found that values above 14% in moisture and above 2.1% in ashes contribute more to the quality in flours, therefore, the negative results in this research may present effects in having a quality of flours not suitable for the food industry.

Conclusions

The results obtained show that it is possible to use triticale as an alternative in the food industry for its nutritional quality of grain, suitable for processes of making pasta, breads, tortillas, macaroni, cakes and soups. It is necessary to modernize the diversity of triticale varieties that are grown in Mexico for their protein quality; it is recommended to use lines L-18, L-17, and L-14, in addition to L-20, L-10 and L-19 because they met the industrial quality ranges in this research, such as higher WTG and HW, higher percentages of fat, fiber, protein and carbohydrates, as well as lower values in moisture and ashes.

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