Nutritional evaluation of white corn grain for tortilla manufacturing

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ABSTRACT
Objective: Agronomic characteristics such as density, hectoliter weight, grain hardness and nutritional value of maize (*Zea mays* L.) grain in terms of protein, starch and oil content were evaluated.
Design/Methodology/Approach: Using the Dickey John INSTALAB 700® equipment, hybrid and native maize grains from different commercial houses that are planted in Durango, central region of northern Mexico. The seeds evaluated were of the certified type and evaluated in the Agricultural Biology laboratory of the Technological Institute of the Guadiana Valley. The grains were prepared following CIMMYT laboratory protocols in order to evaluate the nutritional and industrial quality of maize.
Findings/Conclusions: Ten genotypes exhibited soft grain hardness, one showed intermediate hardness and six showed hard hardness with values higher than a hectoliter weight of 74 kg hL^{-1}, the latter having the greatest potential to be planted extensively for use in the production of tortilla dough. Conclusions: The protein content in the corn evaluated was not statistically significant, but the starch content varied from 52 to 62% with an oil content of 3.5 to 6.9%.

Keywords: White grain corn, tortillas, starch and hardness

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INTRODUCTION

White grain corn has a per capita consumption of 196.4 kg in Mexico, its main use is in the production of tortillas, it represents 20.9% of the total food expenditure, much higher than other grains such as wheat and barley (FIRA, 2016). 7.5 million hectares of white and yellow corn were planted on an annual average from 2010 to 2020, with average yields of 3.5 tons ha^{-1} with an annual production of 26.3 million tons, with white grain corn being the one with the highest production, attaining yields above 21 million tons (SIAP, 2021). To satisfy the domestic demand for white and yellow grain corn, 15 million tons are imported annually (CIMMYT, 2019). In Mexico there are various forms of corn consumption, such as tortillas or processed flours, nonetheless, tortillas represent 64% of a total of 12 million tons per year, the color of the grain can be white, yellow or colored. Approximately, 36% of production is used by the flour industry (Salinas *et al.*, 2011). Corn grain that produces dough with a high degree of humidity, that can be extensible and of appropriate hardness is the best for tortilla production (Arámbula *et al.*, 2001).

(Rangel *et al.*, 2004) reported that creole white corn grain exhibits greater dough hardness and adhesion as well as a faster cooking speed when compared with other enhanced varieties. Tortillas elaborated with blue, red and orange corn are more antioxidant dense than tortillas elaborated with white corn grain (Salinas *et al.*, 2017).

Regarding the nutritional composition of corn, carbohydrates are within a range of 44 to 69%, 72% starch, 10% protein and 4% lipids (Urango, 2018). The commercial quality of corn grain for human consumption is declared in the MNX-034 (2002) standard, which includes the processes of nixtamalized flour fabrication and the elaboration of dough and tortilla.

In both cases, industries prefer corn with the following characteristics: hectoliter weight $\geq$74 kg hL^{-1}, nixtamal humidity between 36% and 42%, flotation index $\leq$40%, remaining pericarp $<$2% and solid loss $<$5%. The hectoliter weight is a factor related to the hardness of the grain, white corn that is intended to produce tortillas must have a minimum hectoliter weight of 74 kg hL^{-1}, if the value is greater than 75 it is considered hard grain, 74 to 75 is considered intermediate grain, and less than 74 is considered soft grain (Palacios, 2018). Generally, texture quality of tortillas decreases after being stored for more than 24 hours, this lapse can be increased by using corn with soft or intermediate hardness (Salinas y Aguilar, 2010). Corn grains generally contain an oil average of 3 to 5%, being oleic and inoleic acids the most representative (62%) and palmitic and stearic acids representing 12.8% on average (Corcuera *et al.*, 2013). The quality of tortillas as well as their shelf life is closely related to the endosperm in the corn; consumers prefer tortillas with a soft texture; this is achieved by using corn grain flours with floury endosperm and intermediate hardness (Osorio *et al.*, 2011). The determination of the nutritional analysis of corn grain can be achieved using the INSTALAB® 700 equipment, which uses NIR technology and a mathematical statistical treatment to predict the percentage concentration of a constituent within a sample. Certain constituents have been proven to absorb light energy at specific wavelengths. For example, moisture absorbs in the 1.94 μm (micrometer) band of near-infrared (NIR) light, protein absorbs in the 2.18 μm band, and oil in the 2.31 μm and 2.33 μm bands. By bombarding a sample with a very narrow band of light at a specific wavelength of NIR light, samples can be analyzed. Thus proteins, cellulose, starch, oil, fats and alcohol can be determined. NIR spectroscopy has been applied to predict some major components of grains, such as moisture, proteins, and lipids. It has demonstrated such a good performance, that it is currently preferred over traditional wet chemistry methods for routine analysis. Ferrari *et al.* (2004) mentions that the determination of the nutritional value of corn using near-infrared NIR spectroscopic techniques generate faster results and avoids the generation of dangerous residues. The objective of this work is to determine the nutritional value of white corn grain using NIR technology, the protein, oil and starch content in different commercial corn grains for use in the tortilla industry, as well as the agronomic variables of hardness and hectoliter weight.

MATERIALSAND METHODS

17 commercial white corn hybrids that are traditionally planted in Mexico were used (Table 1).

Table 1. Different white corn hybrids and creoles evaluated for tortilla production.

Items	Corn grain	Enterprise
1	Caribú	Asgrow
2	Cristiani 52	Cristiani
3	H 311	Agroferza
4	Creole VS 201	Nativo
5	Creole 3 1/2	Nativo
6	OSSO	Asgrow
7	308 Ángel	Asgrow
8	Ocelote	Asgrow
9	Tigre	Asgrow
10	Garañón	Asgrow
11	Dow 2358	Agroscienses
12	Novasem R 101	Novasem
13	Canelo	Semillas Rica
14	P3015 w	Pionner
15	P2361 w	Pionner
16	P3260 w	Pionner
17	P3057 w	Pionner

The methodology in this study consisted of: Classification of the grain by hybrid and variety, removal of impurities from the grains by passing them through No. 4 sieves (4.75 mm hole diameter), determination of humidity, determination of the hectoliter weight in kg hL^{-1}, weight of 100 seeds in grams, seed viability (additional) by the tetrazolium method in percentage grain hardness, calibration of the INSTALAB 700 equipment, calibration curves for white corn (one for each variety, 17 curves total), measurement of protein, starch and oil values within each variety and hybrid, statistical analysis.

Grain classification and cleaning. Dye was removed from each grain using a 70% alcohol-water mixture, seeds were submerged in the mixture for 45 min, after that, the grains were washed three times with tap water; lastly, the grains were dried for 24 h at room temperature.

Determination of humidity and hectoliter weight. To determine the humidity of the grain, the GAC 2100® equipment from Dickey John was used, grain humidity was determined in percentage directly. The hectoliter weight in kg hL^{-1} for each hybrid and corn creole was determined directly using the same equipment.

Weight of 1000 seeds, this step was carried out separating the impurities in sieves, 100 grains of each genotype were weighed on a digital weighing machine.

Viability of the embryo within the grain, 20 seeds were placed in Petri dishes, submerged with a 2% tetrazolium solution and covered with aluminum foil for 24 h, the result was reported as percentage of viable seeds.

Evaluation of the nutritional value of the corn grain, grains were grounded (the deck was removed leaving only the endosperm) until flour was obtained, this was carried out using a ROMER Series II® mill, each grind was labeled and stored in a polyethylene bag for later evaluation.

Evaluation of protein, oil and starch in corn genotypes, this procedure was conducted as follows: the INSTALB 700® equipment was turned on and allowed to heat up for 45 min until the color indicator turned from yellow to green, it was then calibrated with the corn curves previously loaded, each grain was filled with corn flour separately, grain type is selected, and the measurement is performed. Loading and data collection time takes approximately two minutes per sample.

Experimental design

The experimental design employed to evaluate the response variables of protein, starch and oil content is completely random and if minimal significant differences are detected, the results are subjected to the comparison of DMS means at a probability $p<0.05$. The mathematical model is as follows:

$$Y = U + T_{ij} + E_{ij}$$

Where: Y: dependent variable, U: is the population mean, T_{ij}: Treatments or hybrids evaluated, E_{ij}: Experimental error. The analysis of variance is conducted using the (Olivares, 1994) statistical software.

Table 2. Variables evaluated for density, hectoliter weight and grain hardness in corn hybrids and creoles.

	Corn grain	Enterprise	Density g cm^{3-1}	Hectoliter weight kg hL^{-1}	Grain hardness
1	Caribú	Asgrow	1.41	49.20	Soft
2	Cristiani 52	Cristiani	1.42	42.00	Soft
3	H 311	Agroferza	1.44	60.10	Soft
4	Creole VS 201	Native	1.43	62.20	Soft
5	Crole 3 1/2	Native	1.43	62.10	Soft
6	OSSO	Asgrow	1.42	69.30	Soft
7	308 Ángel	Asgrow	1.52	89.90	Hard
8	Ocelote	Asgrow	1.51	83.30	Hard
9	Tigre	Asgrow	1.42	83.20	Hard
10	Garañón	Asgrow	1.43	78.50	Hard
11	Dow 2358	Agrosciences	1.45	80.20	Hard
12	Novasem R 101	Novasem	1.40	74.60	Intermediate
13	Canelo	seeds Rica	1.43	77.20	Hard
14	P3015 w	Pionner	1.43	65.90	Soft
15	P2361 w	Pionner	1.50	57.50	Soft
16	P3260 w	Pionner	1.42	41.80	Soft
17	P3057 w	Pionner	1.41	41.60	Soft

RESULTS AND DISCUSSION

Calculated density, hectoliter weight and grain hardness in evaluated corn hybrids and creoles can be consulted in Table 2.

Density. All the genotypes evaluated exhibited homogeneous density with values between 1.40 and 1.53 g cm^{3-1}, the hectoliter weight ranged from values lower than 41.6, 41.8 for the hybrids P3057 w and P3260 from the Pioneer company (Ordoñez *et al.*, 2012) reported density values between 1.177 and 1.33 g cm^{3-1} in a chemical and physical study of red color hard corn.

Hardness. Regarding grain hardness, hybrids from the Asgrow commercial company were harder, while those from Pioneer were softer. The flour industry prefers grains that present hardness greater than 74 Kg hL^{-1}. In this study, the genotypes 308 Ángel, Ocelote, Tigre and Garañon from Asgrow met this requirement. Dow 2358 from Agroscienses and Novasem R 101 and Canelo from Rica seeds met these conditions. In an evaluation of white grain creole corn subjected to different thermal drying processes, (Garcia *et al.*, 2016) reported grain densities between 0.98 and 1.38 g cm^{3-1}, the hectoliter weight was lower in these corn grains at 74 Kg hL^{-1}, so its classification is soft type grain.

Hectoliter weight. Seven genotypes exhibited hectoliter weights greater than 74, so they are considered suitable for use by the nixtamal industry for the manufacture of tortillas. (Jimenez *et al.*, 2012) evaluated pre-improved white grain corn from the CIMMYT germplasm center and reported hectoliter weights of 82 to 89 Kg hL^{-1}, in this study the evaluated genotypes 308 Ángel, Ocelote, Tigre and Garañon exhibit similar values.

Protein, oil and starch

The analysis of variance for each variable revealed significant statistical differences at $p<0.05$ for protein, oil and starch content, the comparison of means by DMS can be seen in Table 3.

Protein. No significant statistical difference was found, but numerically, but the Cristiani 52 and P3015 w hybrids have the highest protein content, 2.23 and 2.26% respectively. (Mendez *et al.*, 2005) reported protein values between 8.8 and 11.3% in an evaluation of 20 corn suitable for tortilla production. (Martinez, 2022) reported protein content of 6.63% in white grain native corning a study of pigmented native corn with white grain color. In this work, protein content was lower in value, which is attributed to the fact that the majority of the grains were washed and rinsed with alcohol to remove the dye.

Starch. Obtained results indicate that hybrids 1, 2, 10 and 15,16 and 17 corresponding to the white grain corn Caribú, Cristiani 52, Garañón, P2361w, P3260w and P3057w, were the ones that contained the highest amount of starch with 61.5, 60.7, 60.0, 60.6, 60.1, and 60.0% respectively, with Asgrow's Caribú being the one that exhibited the highest amount of starch (61.5%) (Mendez *et al.*, 2005) reported starch percentage values ranging from 55.3 to 70.4, the results obtained in this study coincide, since evaluated hybrids concentrated a greater amount of starch compared to the native creoles (Agama *et al.*, 2013) reported values between 70.9 and 76.2% of starch in white corn grains, they found a relationship that indicates that the higher the starch content in the grain, the lower the protein content,

Table 3. Comparison of means for protein, oil and starch content in 17 white corn grains evaluated for use in the tortilla industry.

	Corn grain	Enterprise	Protein %	Oil %	Starch %
1	Caribú	Asgrow	1.41	4.30 i	61.5 a
2	Cristiani 52	Cristiani	2.23	4.10 j	60.7 ab
3	H 311	Agroferza	1.44	4.50 h	59.4 bc
4	Creole VS 201	Native	1.06	5.20 e	54.6 e
5	Creole3 1/2	Native	0.26	5.00 f	57.2 d
6	OSSO	Asgrow	1.60	6.90a	52.1 f
7	308 Ángel	Asgrow	0.53	6.50 b	54.8 e
8	Ocelote	Asgrow	0.66	5.60 d	56.3 de
9	Tigre	Asgrow	0.86	5.50 d	57.2 d
10	Garañón	Asgrow	2.00	4.70 g	60.0 ab
11	Dow 2358	Agroscienses	1.93	4.90 f	59.7bc
12	Novasem R 101	Novasem	1.80	6.00 c	57.8 cd
13	Canelo	Seeds Rica	1.86	3.50 l	60.00 ab
14	P3015 w	Pionner	2.26	3.50 l	61.70 a
15	P2361 w	Pionner	1.20	3.20 m	60.60 ab
16	P3260 w	Pionner	1.60	4.30 i	60.10 ab
17	P3057 w	Pionner	1.20	3.80 k	60.00 ab
DMS			NS	0.169	1.840

NS: Not significant. Means with different letters are statistically different at $p<0.05$.

for this study the highest value in starch was observed in Asgrow's Caribú corn with 61.5, no genotype exceeded 62%.

Oil. Torres *et al.*, 2010, reported values ranging from 4.3 to 4.7% of oil in Comiteco corn grains, in this study, Asgrow's OSSO hybrid presented the highest oil content with 6.90%, (Guzmán *et al.*, 2015) reported oil contents from 4.11 to 6.29% in cónico Norteño creole corn, in the present work, the two-creole evaluated exhibited oil values between 5.0 and 5.20%.

CONCLUSIONS

The density of the evaluated corn types presented homogeneous densities, most corn types exhibited soft hardness, with only a few presenting hard hardness of interest for the dough and tortilla industries, being the hybrids from Asgrow the ones with the highest hardness and hectoliter weight values. Regarding the use of creole white grain corn in the dough and tortilla industries, it is limited to only being used in the communities of origin due to the steep costs of transport to production centers of high demand. The starch content was acceptable, with the greatest amount being concentrated on the endosperm; the corn hybrids evaluated had a higher starch content compared to the native corn. All genotypes displayed uniform values in oil content. These results allow farmers to identify and plant the types of white corn that the industry requires in order to provide higher quality tortillas and longer shelf life.

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REFERENCES

Agama A. E., Juárez G. E., Evangelista L. S., Rosales R. S., Rosales R. O. L., Bello P. L. A. 2013. Características del almidón de maíz y relación con las enzimas de su biosíntesis. *Agrociencia, 47*(1), 01-12. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-31952013000100001&lng=es&tlng=es.

Arámbula V.G., González H. J., Ordorica F. C. A. 2001. Physicochemical structural and textural properties of tortillas from extrused instant corn fluor supplemented with various types of corn lipids. *J. Cereal Sci.* 33:245-252. https://www.academia.edu/101510062/

Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT). Maíz para México, plan estratégico 2030: 25-35, CIMMYT, El Batán, Estado de México, 2019. https://repository.cimmyt.org/server/api/core/bitstreams/308853f3-18bd-4d84-8421-97fd2306bcf5/content

Corcuera, V.R., Salmoral, E.M, Pennisi, M., Kandus, M., Moreno-Ferrero, V., Salerno, J.C. (2013). Análisis Proximal del Grano de Maíces de Uso Especial. II. Determinación de la Calidad Proteica, del Aceite y Almidón. En CD-ROM del XIV Congreso Argentino de Ciencia y Tecnología de Alimentos, 5° Simposio Internacional de Nuevas Tecnologías/III Simposio Latinoamericano sobre Higiene y Calidad de Alimentos, Rosario-Sta. Fe, Argentina.http://wwww.publitec.com.ar/contenido/objetos/Granodemaices.pdf

Ferrari, M., Mottola. L., Quaresima. V. (2004) Principles, techniques, and limitations of near infrared spectroscopy. *Canadian Journal of Applied Physiology*. http://www.humankinetics.com/acucustom/sitename/Documents/DocumentItem/3960.pdf

FIRA .2016. Panorama agroalimentario. Maíz 2016. Dirección de Investigación y Evaluación Económica y sectorial. https://www.gob.mx/cms/uploads/attachment/file/200637/Panorama_Agroalimentario_Ma_z_2016.pdf

García J.A. y Vázquez C. L. 2016. Secado de maíz propiedades del grano. *Revista en Investigación y Desarrollo en Ciencia y Tecnología de Alimentos*. Vol. 1, No. 2. pág. 73-77. http://www.fcb.uanl.mx/IDCyTA/files/volume1/2/1/14.pdf

Guzmán M., Salvador H., Vázquez C., Aguirre G. M. G., Serrano F. I. 2015. Contenido de ácidos grasos, compuestos fenólicos y calidad industrial de maíces nativos de Guanajuato. *Revista fitotecnia mexicana, 38*(2), 213-222. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0187-73802015000200012&lng=es&tlng=es.

Jiménez J. A, Arámbula V. G., Cruz L. E., Aparicio T. M. A. 2012. Característica del grano, masa y tortilla producida con diferentes genotipos de maíz del trópico mexicano. *Universidad y ciencia, 28*(2), 145-152. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0186-29792012000200004&lng=es&tlng=es.

Martínez R. P. 2022. Caracterización física, química, nutracéutica y propiedades tecno funcionales de tres variedades de maíz (*Zea mays* L.) Criollo pigmentado (blanco, amarillo y negro). Tesis profesional. Universidad Autónoma de Querétaro. 112 pág. http://ri-ng.uaq.mx/handle/123456789/4340

Méndez M. G., Solorza F. J., Velázquez V. M., Gómez M. N., Paredes L. O., Bello P. L. A. 2005. Composición química y caracterización calorimétrica de híbridos y variedades de maíz cultivadas en México. *Agrociencia, 39*(3), 267-274. https://www.redalyc.org/articulo.oa?id=30239303

NMX-FF-034/1-SCFI-2002. Productos alimenticios no industrializados para consumo humano - cereales – parte i: maíz blanco para proceso alcalino para tortillas de maíz y productos de maíz nixtamalizado - especificaciones y métodos de prueba. https://sitios1.dif.gob.mx/alimentacion/docs/NMX-FF-034-1-SCFI-2002_MAIZ_blanco.pdf

Olivares S.E. 1994. Software de diseños experimentales versión 2.1. Facultad de Agronomía de la Universidad Autónoma de Nuevo León. https://www.scielo.sa.cr/scieloOrg/php/reflinks.php?refpid=S1659-321201300010001100023&pid=S1659-13212013000100011&lng=es

Ordóñez M. R., Gely, M. C., Pagano A. M. 2012. Estudio de las propiedades físicas y de la cinética de secado de granos de maíz colorado duro. *Avances en Ciencias e Ingeniería, 3*(3),153-171. [fecha de Consulta 7 de Julio de 2024]. ISSN: Recuperado de: https://www.redalyc.org/articulo.oa?id=323627687015

Osorio D P. E., Agama A. L. A., Bello P. J. J., Islas H.N. O., Gómez M., and Paredes L. O. 2011. Effect of endosperm type on texture and *in vitro* starch digestibility of maize tortillas. *LWT-Food Sci. Technol.* 44: 611-615. DOI:10.1016/j.lwt.2010.09.011

Palacios R. N. 2018. Calidad nutricional e industrial de Maíz: Laboratorio de Calidad Nutricional de Maíz "Evangelina Villegas" CDMX, México: CIMMYT. https://repository.cimmyt.org/server/api/core/bitstreams/1768d9d2-7abb-4519-9bf3-1cc984534137/content

Rangel Meza, E., Muñoz Orozco, A., Vázquez Carrillo, G., Cuevas Sánchez, J., Merino Castillo, J., & Miranda Colín, S. 2004. Nixtamalización, elaboración y calidad de tortilla de maíces de Ecatlán, Puebla, México. *Agrociencia, 38*(1), 53-61. https://www.redalyc.org/articulo.oa?id=30238106

Salinas M Y., Castillo L E.B. Vázquez C.M.G., Buendía G.M.O. 2011. Mezclas de maíz normal con maíz ceroso y su efecto en la calidad de la tortilla. *Revista Mexicana de Ciencias Agrícolas* 2: 689-702. https://www.redalyc.org/articulo.oa?id=263121118005

Salinas M. Y., Aguilar M. L. 2010. Effect of maize (*Zea mays* l.) grain hardness on yield and quality of tortilla. *Ingeniería Agricola y Biosistemas 2*(1): 5-11. doi: 10.5154/r.inagbi.2010.08.009.

Salinas M. Y., Hernández M. V., Trejo T. L., Ramírez D. J L., & Iñiguez G. O. 2017. Composición nutricional y de compuestos bioactivos en tortillas de poblaciones nativas de maíz con grano azul/morado. *Revista mexicana de ciencias agrícolas, 8*(7), 1483-1496. Recuperado en 07 de julio de 2024, de http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-09342017000701483&lng=es&tlng=es.

Servicio de Información Agroalimentaria y Pesquera (SIAP). 2021. Producción agrícola. Gobierno de México. https://www.gob.mx/siap/acciones-y-programas/produccion-agricola-33119

Sierra M. M., Palafox C. A., Vázquez C. G., Rodríguez M. F., & Espinosa C. A. 2009. Caracterización agronómica, calidad industrial y nutricional de maíz para el trópico mexicano. *Agronomía Mesoamericana, 21*(1), 21-29. https://doi.org/10.15517/am.v21i1.4908

Torres M. B., Coutiño E. B., Muñoz O. A., Santa cruz V. A. Mejía C. A., Serna S. Sergio O., García L.S., & Palacios R. N. 2010. Selección para contenido de aceite en el grano de variedades de maíz de la raza comiteco de Chiapas, México. *Agrociencia, 44*(6), 679-689. Recuperado en 15 de junio de 2024, de http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-31952010000600007&lng=es&tlng=es.

Urango M. L.A. 2018. Componentes del maíz en la nutrición humana. Fondo Editorial Biogénesis: Algunos componentes generales, particulares y singulares del maíz en Colombia y México. https://revistas.udea.edu.co/index.php/biogenesis/article/view/336229/20791758