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Mixolab Profile of Wheat Flour and Their Correlation with Textural Properties of Hot-Press Tortilla

Esther Perez-Carrillo[1] --- Ana A. Chew-Guevara[2] --- Erick Heredia-Olea[3] --- Hector H. Velázquez-Reyes[4] --- Sergio O. Serna-Saldivar[5]*

[1,2,3,5]Centro de Biotecnología-FEMSA, Escuela de Ingeniería y Ciencias, Tecnológico de Monterrey, Av. Eugenio Garza Sada, Monterrey, N.L,. Mexico
[4]Universidad Autónoma Agraria Antonio Narro, Calzada Antonio Narro, col. Buenavista, Saltillo, Coahuila, México

Abstract

Refined wheat flours commercially milled from the same red winter wheat under 10 different commercial conditions were tested for quality with a Mixolab and then processed into tortillas using the hot-press forming procedure. Tortilla making qualities of the flour samples were evaluated during dough handling, hot-pressing, baking, and the first five days on the shelf at room temperature. The most dominating Mixolab variables that were correlated with flour tortilla performance and textural shelf stability were C3 related to starch gelatinization (1.93-2.18), C4 related to amylase activity (1.46-1.78) and C5 related to starch retrogradation (2.82-3.41). These mixolab parameters influenced tortilla texture after one day storage whereas parameters C3 and C4 influenced tortillas stored for two and five days. Hot-press tortillas produced from 03 flour, which had the highest C3, C4 and C5 values, had the worst textural shelf-life (Force 12.41 N) and rollability. On the other hand, tortillas produced from 07 flour, that had the lowest C3, C4 and C5 values, exhibited the best textural shelf life (Force 6.73 N). Mixolab parameters C3, C4 and C5 proved to be useful in predicting the quality of wheat flours intended for hot-press tortilla production.

Keywords: Hot-press tortillas, Mixolab, Refined wheat flour, Wheat flour tortillas.

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Contents

** Corresponding Author*

1. Introduction

Wheat flour tortillas are unleavened, flat, circular bakery items commonly leavened with baking powder. Historically, tortillas have been produced for several centuries practically since the Spaniards conquered Mexico and introduced wheat to the Americas. Nowadays, tortillas are consumed practically all over the globe because most fast food chain restaurants offer burritos and tacos in their menus. In the USA, tortillas are considered as the second most popular bakery item after yeast-leavened breads mainly due to their convenience as wraps that suit an on-the-go lifestyle. The key quality attributes that provide the desired functionality in tortillas are extensibility during pressing (diameter) and retention of flexibility over time (shelf stability). Most flour tortillas are produced with all-purpose flours with intermediate protein content (10 to 11%). These flours yield rollable tortillas that do not crack and break when reheated and folded [1-3]. However, no wheat cultivars have been identified or bred for this particular use. Generally, hard red winter wheats with relatively low protein content are selected and supplemented with various types of additives (i.e. oxidizing and reducing agents, hydrocolloids, emulsifiers or dough conditioners) to achieve the required functionality [4]. The protein of the flour and the rate of starch retrogradation are primary factors affecting tortilla textural shelf-life. It is recognized that tortillas obtained from low protein flour crack and split apart when folded after one day of storage whereas counterparts that contain more protein yield tortillas with improved textural stability [5].

Koksel, et al. [6] concluded that the Mixolab data could be related with Farinograph and Alveograph parameters, the Zeleny sedimentation test and bread volume. Therefore this instrument can be effectively used for flour screening especially in terms of dough strength. Hrušková, et al. [7] observed a link among parameters of farinograph, amylograph and mixolab tests, and a principal component analysis confirmed these relationships. A tight associations between farinograph dough development time or stability and mixolab C1 (behavior during mixing), and between mixing tolerance index and the difference C1-C2 (protein quality) were observed. Maximum amylograph peak viscosity was connected with C3 (starch gelatinization), C4 (amylase activity) and C5 (starch retrogradation) torque points as well with the differences of C3-C2, C3-C4, and C5-C4. Levels of torque points C3, C4, and C5 corresponded to dough consistency changes (i.e., resistance against mixing) and the farinograph dough development time and stability whereas differences C3-C2, C3-C4, and C5-C4 are highly linked to amylase activity and starch gel properties during heating and cooling.

Despite their popularity, there are no established methods to predict the most suitable flours for tortilla quality and predict their textural shelf life [1]. The Mixolab is a rheological instrument recently developed suited to evaluate the quality of wheat flours for different end uses. The instrument introduced in 2004 by Chopin Technologies measures the consistency of dough over time with a gradual increase in the applied temperature. It is designed to test both protein and starch characteristics of the flour and also provide information about rheological properties of dough [8]. The computerized analysis of the curve yields the Mixolab Profiler. The Mixolab has been successfully used to evaluate flour for bread and cookie making qualities. Except for a recent report of Posner, et al. [9] there is no information on the use of Mixolab to determine the quality characteristics of flours intended for hot-press wheat flour tortillas. Therefore this research was undertaken to assess the optimal mixolab parameters for hot-press wheat flour tortillas and their textural shelf-life.

2. Materials and Methods

2.1. Flour Samples

Ten untreated flour samples milled from the same blend of wheats in different commercial Mexican mills were donated by the US Wheat Associates, Mexico City, Mexico. These flours differed in particle size distribution, color and damaged starch.

2.2. Flour Characterization and Dough Tests

Particle size distribution was determined with the sieving to an end point method [10] on a set of flour sieves (US meshes No. 80, 100, 120 and 140). 100 g sample was placed on the top sieve and rotapped and sieved for 1 min. Then, the overs of each sieve were weighed and sieved again. The procedure was repeated until the weight difference between consecutive weights was less than 1 g.

Flour moisture and Falling Number were determined using AACC Methods 44-15A and 56-81B, respectively [11]. The dough rheological properties dough especially in terms of strength, extensibility and resistance to extension were determined with the Alveograph (Chopin Instruments, Villeneuve-La-Garenne, France) Approved Method 54 30A and Brabender Farinograph following the Method 54-21 [11]. Starch damage was conducted according to AACC method 76-33.01. The Mixolab (Chopin, France) was used to analyze the flour samples according to AACC method 54-60.01 [11] and ICC 173. The starch gelatinization was followed during the increase of temperature from 35° to 90°C at a rate of 2°C/min. Protein properties related to water absorption, stability, elasticity and weakening were determined. The enzymatic activities and retrogradation as affected by mixing and the temperature increase were also monitored. A Mixolab wheat tortilla profile was generated based on these parameters [8].

2.3. Preliminary Tortilla Trials

Tortillas were prepared by methods described by Bello, et al. [12] and Serna Saldivar [13] with slight modifications. 200 g flour (14% mb) plus 30 g vegetable shortening (Productos Lirio, Monterrey, NL, Mexico), 3 g refined iodized salt (La Fina, Sales del Istmo, Coatzacoalcos, Ver., Mexico), 4 g double acting baking powder (Rexal, Productos Mexicanos, Monterrey, NL, Mexico), 2 g whole dry milk (Nido, Nestlé, Querétaro, Qro, México), 0.4 g calcium propionate (TECSA, Monterrey, NL, Mexico), 0.4 g fumaric acid (PRIMAK, Monterrey, NL, Mexico), 0.4 g carboxymethyl cellulose (PIASA, Monterrey, NL, México), 0.4 g sodium stearoyl-2-lactylate (TECSA, Monterrey, NL, Mexico), and distilled water were mixed with a predetermined volume of warm water (40°C) in a 100-200 g dough mixer (National Manufacturing Co., Lincoln, NE). Optimum water absorption and mix times were subjectively determined by observing dough handling properties. Dough texture was subjectively evaluated using a 1 to 5 rating. A subjective score of 1 meant that the dough was slack or soft and needed less force to extend whereas a score of 5 was assigned to very rough or firm dough that needed high force to extend. Water absorption was varied in order to obtain a dough with intermediate properties (2.5 in the subjective score of 1 to 5) suited for hot-press tortillas. Experimental doughs were divided into 30 ± 0.25 g pieces, manually rounded and allowed to rest in a proof cabinet (National Manufacturing Co., Lincoln, NE) adjusted to 29°C and 85% RH for 30 min. Each dough ball was flattened using a commercial inclined hot press for 3.13 sec. The temperature of the plates was set at 187°C and the gap between the hot plates adjusted to 1.75 mm. The resulting flattened tortilla discs were baked on a four-pass circular moving griddle set at different temperatures (Manufacturas C&D Industriales, Monterrey, NL, Mexico). The raw tortilla was baked on one side for 10.79 sec at 200°C, turned over and baked for another 11.01 s at 260°C, turned over again and baked for 11.04 s at 265°C and finally turned over again and baked at 230°C for 13.60 s [13].

2.4. Pilot Plant Tortilla Trials

Tortillas were prepared by methods delineated by Serna Saldivar [13]. 2 kg flour (14% mb) plus 300 g vegetable shortening (Productos Lirio, Monterrey, NL, Mexico), 30 g refined iodized salt (La Fina, Sales del Istmo, Coatzacoalcos, Ver., Mexico), 40 g double acting baking powder (Rexal, Productos Mexicanos, Monterrey, NL, Mexico), 20 g whole dry milk (Nido, Nestlé, Querétaro, Qro, México), 4 g calcium propionate (TECSA, Monterrey, NL, Mexico), 4 g fumaric acid (PRIMAK, Monterrey, NL, Mexico), 4 g carboxymethyl cellulose (PIASA, Monterrey, NL, México) and 4 g sodium stearoyl-2-lactylate (TECSA, Monterrey, NL, Mexico) were mixed with a volume of warm water determined according to preliminary tortilla trials. The dough mixing protocol consisted of first blending dry ingredients with the shortening at slow speed with a hook attachment for 1 min. Then, distilled water tempered to 40°C was added and the blend mixed at slow speed for 1 min and then at medium speed until gluten development. Resulting doughs were placed in the hopper of an automatic dough cutter and rounder (Manufacturas C&D Industriales, Monterrey, NL, Mexico). The speed of the blade was adjusted to yield 30 g pieces and rounded mechanically and immediately placed in the proof cabinet set at 29°C and 85% RH for 30 min. Then, the relaxed dough balls were hot-pressed into tortilla discs and baked as explained above. The baked tortillas were cooled on a wire rack to room temperature (25±2°C) for about 30 min, placed inside sealed polyethylene bags and kept at room temperature for further evaluations [13].

2.5. Evaluation of Tortilla Properties

Ten tortillas from each treatment were randomly selected and measured for diameter and thickness. The diameter of tortillas was the average of two diagonal measurements. Likewise, two tortillas from each batch were randomly selected and measured for color using the Minolta chromameter (model CR-300, Minolta Camera Co., Ltd., Chuo-Ku, Osaka, Japan). Values for L* (brightness or whiteness), a*(redness and greenness), and b*(yellowness and blueness) were measured. Surface color was measured from four different randomly selected spots of each tortilla. Tortilla moisture and protein were determined using the AACC Methods 44-15A, and 08-03, respectively [11]. Texture analyses were conducted after 0, 1, 2 and 5 days of storage at room temperature using a TA.XT2i Texture Analyzer (Stable Micro Systems, Godalming, England) and rollability or dowel technique [13, 14]. A tortilla was rolled around a 1 cm wooden dowel and rated from 1 (no cracks; very flexible) to 5 (break immediately; cannot be rolled). Tortillas were considered unacceptable when the rollability score was lower than 3. To assess the reheating functionality after 7 days storage at room temperature, a griddle was heated in an oven to a surface temperature of 232°C. Five tortillas from each lot were reheated for 15 sec on one side, turned over and heated for 15 sec on the other side and finally an additional 15 sec on the initial side. Immediately after the reheating schedule, the rollability was evaluated using a dowel [13] and a subjective scale of 1 to 5 where 1 was excellent and 5 very poor.

2.6. Statistical Analysis

Flour characteristics and tortilla data were analyzed using a randomized experimental design using analysis of variance procedures. Tortilla texture and rollability measurements were analyzed with non-parametric tests (Friedman). Minimum significant differences and Tukey tests were applied to determine differences among means ($P<0.05$).

3. Results and Discussion

3.1. Functional Properties of Flours

The wheat flour milling process involves a series of breaking, middling reduction, and sifting operations. Particle size is a relevant concept in flour milling [15] and a critical factor in determining the flour usefulness and functionality. In this study, particle size analysis results were compared for the ten flours produced from the same wheat blend (Fig. 1). Flours 01 and 04 had a more uniform particle size distribution whereas flours 08 and 10 have higher proportion of fine particles. Interestingly, coarser flours had lower water absorptions whereas finer flours had higher water absorptions and starch damage and lower dough stability (Table 1). These observations agree with Wang and Flores [15]. Kuakpetoon, et al. [16] observed that in the same type of wheat the particle of fine flours were highly uniform in shape with a spherical form. In contrast, the particles of coarse flours were irregularly shaped and had a rougher surface. Fine flours had higher mixolab C2 and C3-C4 values and lower C3, C4, C5, C1-C2, C2-C3 and C4-C5 values compared to counterparts with coarser particles (Table 2).

Flours parameters clearly differed despite that all originated from the same wheat blend (Table 1). Results indicate that none of the mills processed wheat using the same method and procedures so the refined flours had different functional and rheological properties. Falling Number (FN) values indicated that flours were adequate for bread making. The 01 and 07 flours showed the highest and lowest FN values, respectively. The difference between these flours were approximately 30%. The 07 flour had the highest farinograph water absorption and UCDc value. The flour 01 showed the highest Alveograph W value and Farinograph dough stability, this particular flour had the lowest end point percentage at Sieve No. 140. The lowest W value was observed in flour 06 which had the highest P/G and P/L values. Furthermore, this flour had the highest Farinograph water absorption. The lowest P/G and P/L values were observed in the 03 flour which also had the lowest Farinograph absorption value. The lowest Farinograph stability was associated to flours 03 and 09 which also had the lowest UCDc values. Differences in FN indicate that flours differed due to the milling procedures. According to Rani, et al. [17] the settings of the milling rolls and combination of different flour streams affect functionality of flours obtained from the same lot of wheat kernels. None of the commercial mills followed methodical grinding rolls adjustment and the operation was based only on the head millers' experience [9]. The higher alveograph W and P/G values and farinograph stability observed in flour 01 indicated that this flour was capable of forming a stronger gluten network. The starch damage value is the one of the best parameters to evaluate mill grinding adjustments. Millers evaluate continuously the starch damage in their flour streams and adjust milling rolls to the optimum required in the final product. Typically the starch damage after the break stages should be in the range of 4 to 5% and in the sizing and reduction stages in the range of 5-6% and 8-10%, respectively. Waniska, et al. [18] studied 61 wheat flour properties and their effects on tortilla quality and observed that starch damage values for a good tortilla flour should be between 4 and 12 with average of 7.6%.

3.2. Mixolab Profile

The Mixolab allows the measurement of dough consistency over time and evaluate in the same assay both the mixing and pasting properties of flour during a gradual increase in temperature [8]. Table 2 depicts Mixolab parameters of the ten commercial flours obtained from the same wheat blend. The combined effect of the mechanical shear stress and the temperature in the second stage of the Mixolab curve produced a decrease in the C2 torque, which is attributed to the weakening of the gluten network. Protein weakening is also represented by the difference between points C1 and C2 (C1-C2). Codină, et al. [19] observed that the C2 parameter was positively correlated with alveograph W value. The correlation between alveograph W and C2 values was not significant in this study; however, a negative correlation between C1-C2 and W values was observed. The Mixolab C3, C4 and C5 parameters are commonly affected by the starch condition and characteristics. Water absorption values were similar to the ones obtained from the Farinograph; however, in case of higher absorption the Mixolab has better precision. The highest dough development was reported for 04 flour and the lowest for 07 and 09 flours. The highest stability and C5-C4 parameter were reported for the 02 flour which also had the highest FN (Table 1). However, Mixolab stability values did not correlate with farinograph dough stability. The lowest C2 and UCDs values were reported for the 04 flour (Table 1). The 07 flour had the highest UCD and the lowest C3, C4 C5 and C3-C4 parameters. However, there were not significant correlations among alveograph, farinograph and mixolab parameters.

3.3. Plant Pilot Tortilla Trials

Table 3 summarizes mixing data of dough for tortilla production during tortilla trials. As expected and according to functional tests, the 03 and 04 flours absorbed the lowest water to produce optimum dough. In contrast, flour produced with the 08 flour absorbed higher water than the recommended for hot-press tortillas (Tables 1 and 2). Mixing properties indicated that the dough rheological properties and gluten content values did not necessarily correlate to practical tortilla dough mixing requirements (Tables 1 and 3) probably due to the high shortening addition to the typical formulation. Differences in absorption and mixing time coincide with C3, C4, C5, C1-C2 and C3-C2 Mixolab parameters (Table 2).

All types of tortillas produced from 30 g dough balls weighed approximately 26 g after baking and cooling. The 10 flour had the highest protein content and C2 Mixolab value related to gluten weakening after achieving dough development time. Tortilla diameter is one of the key quality attributes because a tortilla is primarily meant to function as a wrap. Diameter, thickness and color parameters differed among the different types of tortillas (Table 4). The 08 tortillas had the highest diameter and lowest thickness. The rest of the tortillas did not differ in diameter. In the case of tortilla color, the highest L, a, b values were observed in tortillas produced with the 05, 10 or 03 flours, respectively. The rest of the tortillas had similar color values. Waniska, et al. [18] reported similar physical tortilla values whereas Ramirez-Wong, et al. [20], reported higher diameter (19.93 cm) and lower thickness (0.90 mm) with tortillas weighing 32 g. Tortilla color parameters "a" and "b" were similar to data reported by Barros, et al. [21] and Ramirez-Wong, et al. [20]. However, L was lower compared to Barros, et al. [21] and higher compared to tortillas obtained by Ramirez-Wong, et al. [20].

3.4. Tortilla Texture

The textural shelf-life of tortillas plays a critical role in terms of quality and acceptance. Most flour tortillas are expected to last on the shelf at room temperature for at least one week and up to three weeks. Staling of flour tortillas is mainly due to the gradual transformation of amorphous starch to a partially crystalline, retrograded state. The reassociation of starch molecules during storage corresponds to loss of freshness and increased structure or firmness of tortilla [22]. The 07 tortillas had the lowest force value throughout five days of storage at room temperature whereas counterparts manufactured from the 03 flour exhibited the toughest texture or highest force values (Table 5). These flours absorbed the lowest and highest water during dough mixing and showed important differences in their Mixolab profiles. Correlation coefficients between tortilla texture (force) and Mixolab parameters are presented in Table 7. Results showed that the C3, C4 and C5 parameters influenced tortilla texture of fresh tortillas (day 1); however, the Mixolab parameters C3 and C4 influenced texture of tortillas stored for 2 to 5 days. As expected, fresh tortillas (day 0) had the lowest force and largest extension values (Table 5) and the best rollability properties (Table 6). Most of the loss of texture in all tortillas occurred during the first day of storage. This agrees with a previous research conducted by Bejosano, et al. [23] which indicated that most of the changes in flour tortilla texture also occurred during the first day of storage although a progressive hardening occurred during the subsequent 4 days of storage. These authors also concluded that tortilla staling is best estimated by subjective rollability and 2-dimensional extensibility tests. Cracking and breaking of tortillas during rolling can be delayed by using flour with higher protein quality or adding vital gluten, hydrocolloids and/or emulsifiers [24]. The force values related to tortilla firmness almost doubled after 24 h of storage. Likewise, the tortilla extension values after one day of storage were approximately one half to one third of the values originally observed in fresh tortillas. The higher force and lower extension values are typically observed in bakery products and is mainly attributed to starch retrogradation. A comparison of the 5-day stored tortillas indicated that tortillas made with the 08 flour had the best textural properties. These tortillas had 50% less force compared to counterparts produced from the 03 flour. In terms of extension, there were not differences among tortillas at the same day. It is well known that the optimum protein for tortillas is intermediate because soft wheats usually yield tortillas with limited textural shelf-life and are more prone to lose texture with less reheating capacity. On the other hand, the use of hard wheat flours yields doughs that require more proofing and result in doughy and firmer tortillas [2, 18]. Tortilla rupture was also correlated to total flour starch damage. Accordingly, one of the major variables that need to be controlled during the milling process is the level of starch damage in flour and the stages where they are generated. A high wet gluten content in relation to starch damage, and optimal water distribution in the flour as affected by particle size apparently had positive effects on final tortilla quality. Tortillas from the different mills were tested for rollability 5 days after baking. Data shows significant differences in the rollability of the different baked tortillas. The 5-day old tortillas of three of the mills showed rollability values above 4. Rollability tortilla values were negatively correlated to total flour starch damage as well as that in the reduction stages, -0.828 and -0.946 respectively. Accordingly, an increase and controlled starch damage that affects water absorption and falling number values will guarantee good rollability of the final tortilla.

4. Conclusions

Wheat flours with the highest C3, C4 and C5 parameters produced the best textured tortillas. These Mixolab parameters proved to be indicative of the quality of wheat flours intended for hot-press tortilla production.

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References

[1] J. N. Alviola and J. M. Awika, "Relationship between objective and subjective wheat flour tortilla quality evaluation methods," *Cereal Chem.*, vol. 87, pp. 481-485, 2010.

[2] S. O. Serna-Saldivar, L. W. Rooney, and R. D. Waniska, "Wheat flour tortilla production," *Cereal Foods World*, vol. 33, pp. 855-864, 1988.

[3] L. Wang and R. A. Flores, "Effect of different wheat classes and their flour milling streams on textural properties of flour tortillas," *Cereal Chemistry*, vol. 76, pp. 496-502, 1999.

[4] T. O. Jondiko, N. J. Alviola, D. B. Hays, A. Ibrahim, M. Tilley, and J. M. Awika, "Effect of high-molecular-weight glutenin subunit allelic composition on wheat flour tortilla quality," *Cereal Chem.*, vol. 89, pp. 155-160, 2012.

[5] N. N. Kelekci, S. Pascut, and R. D. Waniska, "The effects of storage temperature on the staling of wheat flour tortillas," *J. Cereal Sci.*, vol. 37, pp. 377-380, 2003.

[6] H. Koksel, K. Kahraman, T. Sanal, D. S. Ozay, and A. Dubat, "Potential utilization of Mixolab for quality evaluation of bread wheat genotypes," *Cereal Chem.*, vol. 86, pp. 522-526, 2009.

[7] M. Hrušková, I. Švec, and I. Jurinová, "Chemometrics of wheat composites with hemp, teff, and chia flour: Comparison of rheological features," *Int. J. Food Sci.*, vol. 2013, p. 6. Doi: 10.1155/2013/968020, 2013.

[8] A. Dubat, "A new AACC International approved method to measure rheological properties of a dough sample," *Cereal Foods World*, vol. 55, pp. 150-153, 2010.

[9] E. S. Posner, A. A. Chew-Guevara, M. Mitre-Dieste, E. Perez-Carrillo, E. Heredia-Olea, J. D. Wilson, and S. O. Serna-Saldívar, "Generation of a mixolab profile after the evaluation of the functionality of different commercial wheat flours for hot-press tortilla production," *Cereal Chem.*, vol. 91, pp. 139-145, 2014.

[10] E. S. Posner and N. A. Hibbs, *Wheat flour milling*. MN, USA: Pub. AACC -International, St. Paul, 2005.

[11] AACC International, *Approved methods of the American association of cereal chemists. Methods 08-03, 38-11, 44-40, 46-13, 54-21, 54-30A, 56-60, 56-62, 56-81B, and 76-30*, 10th ed. MN: The Association: St. Paul, 2000.

[12] A. B. Bello, S. O. Serna-Saldivar, R. D. Waniska, and L. W. Rooney, "Methods to prepare and evaluate wheat tortilla," *Cereal Foods World*, vol. 36, pp. 315-322, 1991.

[13] S. O. Serna Saldivar, *Production of chemical-leavened products: Crackers, cookies, cakes and related products, donuts and wheat flour tortillas. Chapter 10 In: Cereal grains: Laboratory reference and procedures manual*. Boca Raton, FL: CRC Press Taylor & Francis Group, 2012.

[14] C. P. Friend, S. O. Serna-Saldivar, R. D. Waniska, and L. W. Rooney, "Increasing the fiber content of wheat tortilla," *Cereal Foods World*, vol. 37, pp. 325-328, 1992.

[15] L. Wang and R. A. Flores, "Effect of flour particle size on the textural properties of flour tortillas," *J. Cereal Sci.*, vol. 31, pp. 263-272, 2000.

[16] D. Kuakpetoon, R. A. Flores, and G. A. Milliken, "Dry mixing of wheat flours: Effect of particle properties and blending ratio," *LWT-Food Sci. and Techn.*, vol. 34, pp. 183-193, 2001.

[17] K. U. Rani, J. S. U. Prasada Rao, K. Leelavathi, and P. Haridas Rao, "Distribution of enzymes in wheat flour mill streams," *J. Cereal Sci.*, vol. 34, pp. 233-242, 2001.

[18] R. D. Waniska, M. Cepeda, B. Sullins King, J. L. Adams, L. W. Rooney, P. I. Torres, G. L. Lookhart, S. R. Bean, J. D. Wilson, and D. B. Betchel, "Effects of flour properties on tortilla qualities," *Cereal Foods World*, vol. 49, pp. 237-244, 2004.

[19] G. Codină, S. Mironeasa, C. Mironeasa, C. N. Popa, and R. Tamba-Berehoiu, "Wheat flour dough alveograph characteristics predicted by mixolab regression models," *J. Sci. Food Agric.*, vol. 92, pp. 638-644, 2011.

[20] B. Ramirez-Wong, C. E. B. Walker, A. I. Ledesma-Osuna, P. I. Torres, C. L. Medina-Rodríguez, G. A. López-Ahumada, M. G. Salazar-García, R. Ortega-Ramírez, A. M. Johnson, and R. A. Flores, "Effect of flour extraction rate on white and red winter wheat flour compositions and tortilla texture," *Cereal Chem.*, vol. 84, pp. 207-213, 2007.

[21] F. Barros, J. N. Alviola, and L. W. Rooney, "Comparison of quality of refined and whole wheat tortillas," *J. Cereal Sci.*, vol. 51, pp. 50-56, 2010.

[22] K. Seetheraman, N. Chinnapha, D. Waniska, and P. White, "Changes in textural, pasting and thermal properties of wheat buns and tortillas during storage," *J. Cereal Sci.*, vol. 35, pp. 215-223, 2002.

[23] F. P. Bejosano, J. Suman, R. Miranda Lopez, N. N. Kelekci, and R. D. Waniska, "Rheological and sensory evaluation of wheat flour tortillas during storage," *Cereal Chem.*, vol. 82, pp. 256–263, 2005.
[24] C. P. Friend, R. D. Waniska, and L. W. Rooney, "Effects of hydrocolloids on processing and qualities of wheat tortillas," *Cereal Chemistry*, vol. 70, pp. 252-256, 1993.

Table-1. Functional characteristics of refined wheat flours milled from the same wheat blend by ten different types of commercial mills.

	Wheat Flour									
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**
Moisture, %	14.40	13.90	13.30	13.10	12.70	12.40	13.10	13.30	13.00	14.20
Falling Number, (sec.)	483	524	416	415	423	421	403	436	441	440
Alveograph										
W	271	269	216	201	203	174	211	215	185	228
P/G	3.52	3.45	2.48	2.58	2.92	3.88	3.54	2.89	3.63	3.17
P/L	0.77	0.74	0.50	0.54	0.64	0.97	0.80	0.59	0.86	0.67
Farinograph										
Absorption 500, %	55.70	56.50	54.80	55.30	56.90	60.30	60.70	60.40	60.20	55.70
Absorption 14 %	56.20	56.40	54.00	54.20	55.40	58.50	59.90	59.60	59.00	56.20
Stability, min	14.30	13.40	10.50	10.00	8.60	8.50	6.20	8.00	5.60	14.30
Starch Damage Values										
UCDc (Units Chopin Dubois converted)	15.90	15.00	15.10	12.50	16.00	18.40	19.10	19.20	18.70	15.90

Table-2. Mixolab parameters of refined wheat flours milled from the same wheat blend by ten different types of commercial mills

Wheat Flour	**Water Absorption (% 14)**	**Dough Development Time (min)**	**Primary Parameters**					**Secondary Parameters**			
			Stability (min)	**C2 (Nm)**	**C3 (Nm)**	**C4 (Nm)**	**C5 (Nm)**	**C1-C2 (Nm)**	**C3-C2 (Nm)**	**C3-C4 (Nm)**	**C5-C4 (Nm)**
01	55.0	1.43	9.67	0.49	2.16	1.75	3.36	0.63	1.67	0.41	1.61
02	55.0	1.83	9.82	0.50	2.14	1.73	3.41	0.64	1.64	0.41	1.68
03	53.6	1.48	8.58	0.46	2.18	1.78	3.36	0.65	1.72	0.40	1.58
04	54.5	1.62	9.32	0.45	2.14	1.75	3.30	0.63	1.69	0.39	1.55
05	55.0	1.32	9.42	0.45	2.04	1.71	3.12	0.64	1.59	0.33	1.41
06	56.9	1.53	9.20	0.53	2.06	1.70	3.30	0.57	1.53	0.36	1.60
07	57.6	4.68	9.10	0.53	1.94	1.46	2.82	0.58	1.41	0.48	1.36
08	57.1	5.30	9.83	0.53	1.93	1.52	2.95	0.56	1.40	0.41	1.43
09	57.2	4.68	8.53	0.54	2.02	1.55	2.87	0.56	1.48	0.47	1.32
10	56.0	5.02	9.85	0.56	1.98	1.56	3.10	0.59	1.42	0.42	1.54

[a] Each value is the average of at least three observations. Data on 14% mb flour.

Table-3. Mixing water absorption and dough development time of refined wheat flours milled from the same wheat blend by ten different types of commercial mills for tortilla production[1].

Wheat Flour	**Water Absorption[2,3], %**	**Optimum Mix Time (min)**
01	49.85	12:20
02	47.79	13:00
03	47.39	11:42
04	47.25	12:00
05	48.85	11:00
06	52.27	10:30
07	53.07	10:42
08	52.20	11:00
09	51.71	10:50
10	53.83	11:00

[1] Each value is the average of at least three observations. Data on 14% mb flour.
[2] Subjectively determined using a 1 to 7 scale where 7 meant that dough was extremely firm and 1 extremely slack. The optimum consistency was rated as 4.
[3] Water was tempered to 40°C before dough mixing.

Table-4. Protein content and physical characteristics of tortillas produced from 10 different refined flours obtained from different commercial mills[1].

Tortilla	**Moisture**	**Protein[2]**	**Diameter cm**	**Thickness Mm**	**Color Parameters**		
					L	**a**	**b**
01	25.17dc	11.60ab	12.34ef	2.00c	46.58ab	-0.76f	14.49ab
02	27.98ab	11.50 ab	12.92bcde	2.04bc	53.99ab	-0.62ef	12.34ab
03	24.10de	9.73b	12.33ef	2.00c	45.76ab	0.29b	**15.40a**
04	26.23bcd	10.85ab	12.16f	2.04bc	50.39ab	-0.31de	12.62ab
05	24.09 de	10.25ab	12.36def	2.02c	**59.13a**	0.07bcd	14.25ab
06	**29.05a**	10.59ab	12.97bcd	2.31bc	48.91ab	-0.33de	12.28ab
07	27.40abc	11.97ab	13.49b	2.37ab	43.21b	0.25b	11.27b
08	22.10 e	10.60ab	14.64a	1.54d	39.15b	0.20bc	13.52ab
09	25.50bcd	11.99ab	12.63cdef	2.71a	45.96ab	-0.18cd	13.24ab
10	26.63abc	12.46a	13.01b	2.08bc	47.66ab	0.83a	13.40ab

[1] Each value is the average of at least three observations. Means with different letter(s) in each column are statistically different (P<0.05).
[2] Values are expressed on dry matter basis.

Table-5. Textural properties of hot-press tortillas stored for 5 days at room temperature produced form flours produced by ten different types of commercial mills.

Day of Storage	Wheat Flour									
	01	02	03	04	05	06	07	08	09	10
Force (N)										
0	11.39±1.08	5.52±0.87	6.34±1.05	5.34±0.54	4.80±0.48	5.86±0.75	4.08±0.65	4.13±0.80	6.39±0.89	5.78±0.57
1	9.06±0.81	7.68±1.09	9.58±1.38	7.68±1.10	7.83±0.74	7.34±0.94	5.36±1.04	6.16±1.42	7.12±1.34	7.22±1.06
2	10.90±1.42	8.36±0.90	11.29±1.05	9.53±1.16	8.54±2.06	7.82±0.87	6.23±0.98	6.47±1.84	10.23±1.83	8.61±1.34
5	11.56±2.54	9.38±1.43	12.41±1.37	10.54±1.19	10.94±1.42	9.32±1.18	6.73±0.66	7.95±1.21	11.26±2.84	9.24±0.92
Extension (mm)										
0	8.23±2.44	6.80±1.75	5.95±1.56	10.07±2.90	11.25±2.69	4.44±1.12	6.03±1.61	3.42±1.76	7.15±1.85	10.94±2.08
1	1.78±0.50	2.70±0.61	1.06±0.92	1.33±0.84	1.72±0.54	1.56±0.65	1.84±0.71	0.67±1.45	1.72±0.34	2.14±0.68
2	1.63±0.48	1.67±0.37	0.25±0.59	0.12±0.40	0.34±0.34	1.04±0.73	1.45±0.73	0.41±1.31	1.68±3.65	1.72±0.98
5	0.05±0.26	0.26±0.57	0	0.09±0.30	0.10±0.33	0.04±0.21	0.63±0.67	0.001±0.002	0.06±0.28	0.71±0.76

[a] Each value is the average of at least three observations. Data on 14% mb flour.

Table-6. Rollability of hot-press tortillas kept at room temperature for five days or reheated produced from different types of flours[1]

Wheat Flour	Rollability of Tortillas at Room Temperature[2]				Rollability of Reheated Tortillas[3]
	Day 0	Day 1	Day 2	Day 5	Day 7
01	1.0^{a}±0	1.3^{a,b}±0.2	2.5^{a}±0.3	3.4^{a,b}±1	1.7^{b,c}±0.3
02	1.0^{a}±0	1.5^{a,b}±0.2	2.2^{a,b}±0.1	2.5^{b,c}±0	3.4^{a}±0
03	1.0^{a}±0	1.4^{a,b}±0.2	2.2^{a,b}±0.1	2.4^{b,c}±0	2.0^{b,c}±0
04	1.0^{a}±0	1.1^{b}±0	N/A	N/A	1.5^{c}±0.4
05	1.0^{a}±0	1.2^{a,b}±0.1	2.2^{a,b}±0.1	4.4^{a}±03	1.8^{b,c}±0.2
06	1.0^{a}±0	1.6^{a}±0.2	1.7^{b}±0.3	2.2^{c}±0.1	2.2^{b,c}±0.4
07	1.0^{a}±0	1.4^{a,b}±0.1	1.5^{b}±0.1	2.1^{c}±0.1	1.9^{b,c}±0.3
08	N/A	N/A	N/A	N/A	N/A
09	1.0^{a}±0	1.4^{a,b}±0.2	2.1^{a,b}±0.6	2.7^{b,c}±0.6	2.4^{a,b,c}±0.7
10	1.0^{a}±0	1.3^{a,b}±0.1	2.0^{a,b}±0	2.6^{b,c}±0.1	2.9^{a}±0.7

[1] Each value is the average of at least three observations. 1 (breaks immediately; cannot be rolled) and 5 (no cracks; very flexible).
[2]Means with different letter(s) in each row or mill of "Rollability of tortillas at room temperature" are statistically different ($P<0.05$).
[3]Means with different letter(s) in the column of "Rollability of reheated tortillas" are statistically different ($P<0.05$).

Table-7. Correlation coefficients between wheat flour Mixolab parameters and force (texture parameter) of hot-press tortillas produced from ten different types of flours

Force at Day of Storage	Mixolab Parameters			
	C2	C3	C4	C5
0	-	-	-	-
1	-	0.878	0.872	0.786
2	-	0.775	0.656	-
5	-	0.120	0.732	-

(-) not significant.

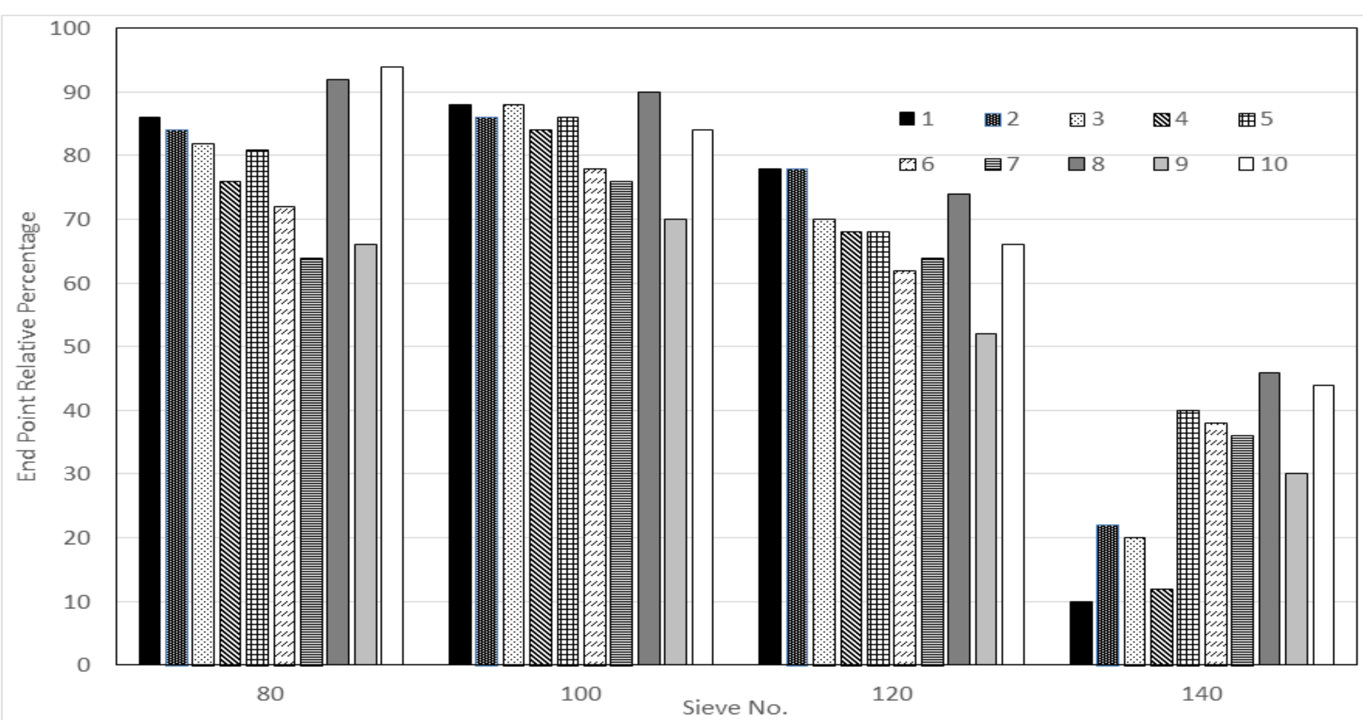

Fig-1. Particle size distribution of ten flours obtained from at the same wheat blend according to sieving to an end point method.

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