International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 16, Number 1 (2023), pp. 14-20

Effect of a Maltogenic Amylase and High-Performing Maltogenic Amylase on Freshness and Other Quality Attributes of Corn Tortillas Made with a Griddle Process

Amber N. Montes[1], Sophia Leung[2*], Malissa Keo[3], Assad Al-Ammar[4], Dipak Roda[5], and Vic Rathi[6]

[1] Associate Food Scientist, Enzyme Innovation (a division of Specialty Enzymes & Probiotics), USA (during the time that research was conducted for this study).
[2] Corresponding Author; Food Science Lab Manager, Enzyme Innovation (a division of Specialty Enzymes & Probiotics), USA.*
[3] Research & Development Chef, Enzyme Innovation (a division of Specialty Enzymes & Probiotics), USA.
[4] Quality Control Laboratory Manager, Specialty Enzymes & Probiotics, USA.
[5] VP of Marketing & Business Development, Enzyme Innovation (a division of Specialty Enzymes & Probiotics), USA.
[6] President & CEO, Specialty Enzymes & Probiotics, USA.

Abstract
The effects of a maltogenic amylase and a high-performing maltogenic amylase were evaluated for extending freshness of corn tortillas, compared to a control (no enzyme added) using a griddle cooking process. The maltogenic amylase and high-performing maltogenic amylase were tested at 0.0025%, 0.0050%, 0.0075%, and 0.0100% of the flour weight. Tortillas were evaluated by pH, moisture, color, rollability, foldability, texture analyzer, and sensory. Tortillas with both enzymes were significantly softer and better in rollability and foldability than control tortillas after 35 days without altering pH, color, or moisture. Overall, the high-performing maltogenic amylase was found to be more effective than the maltogenic amylase in extending freshness of the corn tortillas. The high performing maltogenic amylase offers a promising solution for further extending the shelf life of corn tortillas.

Keywords: Extended Shelf Life, Staling, Tortillas, Enzymes, Maltogenic Amylase, Retrogradation.

I. INTRODUCTION

Staling can cause undesirable effects such as decreased resilience, increased firmness, and a loss of a pleasant taste and smell [1,2]. Consumers look for baked goods that are similar in taste and texture to fresh baked goods [2]. For corn tortillas, consumers look for tortillas that are soft, taste pleasant, and stay intact when rolled or folded. During staling, corn tortillas become harder and tend to break when folded or rolled, which is unacceptable for shelf life [3]. During the staling process, there is a gradual retrogradation (recrystallization) of branched starch chains (amylopectin) [4].

The food industry has been moving towards products with further extended shelf life, prolonged softness, and fresher taste. Maltogenic amylases are enzymes that can extend the shelf life of baked goods by delaying staling [5,6]. Maltogenic amylases delay staling by shortening the amylopectin chains, which slows the retrogradation or reassociation of amylopectin chains [3].

Maltogenic amylases continue to be developed to further extend the shelf life of baked goods. A high performing maltogenic amylase was developed to have better water binding properties to further delay staling in baked goods.

The aim of this study was to evaluate this high-performing maltogenic amylase and a maltogenic amylase for delaying staling in corn tortillas and their effect on other quality attributes, compared to a control (no enzyme added), using a griddle cooking process.

II. METHOD

The high performing maltogenic amylase and maltogenic amylase were tested in corn tortillas made with a griddle cooking process at 25, 50, and 100ppm of the flour weight, and these tortillas were compared with a control, over a shelf life of 35 days at room temperature.

II.I Preparation of Tortilla

Corn tortillas were made using a method adapted from Bueso-Ucles [4] with modifications. Corn tortillas were made using the formulas shown in Table 1. The maltogenic amylase (SEBake Fresh 10P) and high-performing maltogenic amylase (SEBake Fresh Ultra) were provided by Enzyme Innovation (Chino, CA) and were added along with the dry ingredients at varied dosages. Dry ingredients were pre-mixed for 5 minutes. Water was added and mixed with a dough hook for 30 seconds on speed 1 (60 rpm) and 90 seconds on speed 2 (90rpm). Dough was divided into 31g dough balls. A tortilla press was used to press tortillas for 5 seconds. The tortillas were then cooked on a griddle at 135ºC for 45 seconds each side. Tortillas were cooled to 23-24ºC on a cooling rack and then packaged in polyethylene bags to simulate storage conditions similar to retail tortillas.

Table 1. Corn tortilla formulas (on a flour weight basis)

Ingredients	C1	C2	C3	C4	C5	C6	C7	C8	C9
Corn Flour	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Fumaric Acid	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Potassium Sorbate	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
CMC	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Guar gum	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Water	144.2%	144.2%	144.2%	144.2%	144.2%	144.2%	144.2%	144.2%	144.2%
Maltogenic amylase	---	0.0025%	0.0050%	0.0075%	0.0100%	---	---	---	---
High-performing maltogenic amylase	---	---	---	---	---	0.0025%	0.0050%	0.0075%	0.0100%

II.II Evaluation of Tortilla

A digital caliper was used to determine the thickness of tortillas. An analytical balance measured the weight, and a ruler was used to measure the diameter of baked tortillas. pH was prepared according to AACC method 02-52 [7] with modifications using a wireless pH meter (HALO FC2022). A tortilla was ground up using a coffee grinder, until the tortilla was finely ground. 10g of ground tortilla and 90g of distilled water were blended for 1 minute [8]. Moisture by loss on drying was evaluated using a halogen moisture analyzer at 135^{o}C in auto mode. Color of tortilla was measured using a colorimeter with a 2^{o} observer and C illuminant. Color values were reported as CIELAB L*a*b* values. L* value is the measurable lightness (higher values indicate a lighter color), a* positive value indicates redness and negative value indicates greenness, and b* positive value indicates yellow and negative value indicates blue [9]. For the color test, two tortillas were layered directly on top of each other and were measured for average color at three different sections of the tortilla.

II.III Rollability, Foldability, and Pliability

Rollability was tested using a method by Suhendro [10] to monitor texture changes of tortillas during a 35-day storage timeframe. The rollability test is a simple method that reflects the way tortillas are handled prior to consumption [11]. A tortilla was wrapped around a 1 cm wooden dowel to test the rollability of each tortilla. By observation, the tortilla was rated on how it rolled. Tortillas were evaluated using a 5-point scale (1=unrollable, 5=rollable without cracking or breaking) [12].

Methods by Wang and Flores [11] and Suhendro [10] were modified to measure foldability of corn tortillas, using a 5-point scale (1=unfoldable, 5=foldable without cracking or breaking). A tortilla was folded in half to mimic a taco form and was rated on how the tortilla folded from the center.

Pliability evaluated the flexibility of a tortilla (1=complete crumbling, 5=completely pliable). A tortilla was placed in the palm of the hand, closed all the way, held with a closed palm for two seconds, and then released. After the tortilla was released and placed down flat, it was rated for any visible cracks or breaks [10].

II.IV Texture Analysis

Tortilla firmness by puncture method was evaluated using a texture analyzer (TMS-Pro). Using the method provided by the Mecmesin Texture Analysis Guide [13], a single tortilla was punctured with a ball probe at a speed of 150 mm/min and distance of 35 mm. The rupture force (the force required to puncture through the tortilla) was measured in Newtons (N). Rupture force is a measure of the firmness of a tortilla. A higher rupture force value represents a firmer tortilla. A lower rupture force value represents a softer tortilla.

II.V Sensory

Sensory analysis was conducted on tortillas that were 1 and 14 days old. Panelists were asked to evaluate the aroma, softness, rollability, tear strength, tenderness, and overall taste of each sample. A 9-point scale was used to describe these tortilla characteristics (see Table 2). All samples were re-heated using typical store brand tortilla recommended conditions. Tortillas were wrapped in a damp paper towel and were re-heated in a 700-watt microwave for 45 seconds. Heated tortillas were stored in individual tortilla warmers for sensory analysis.

Table 2. Sensory attributes and methods used for corn tortillas

Attribute	Method	Scoring
Aroma	By smell	1=strong off-aromas, 5=neutral, 9=pleasant
Softness	By eating	1=very hard, 5=not soft/not hard, 9=very soft
Rollability	By rolling tortilla into taquito form	1=unrollable, 5=rolls with some breaking, 9=rollable, no breaks or cracks
Tear strength	By tearing the sample with teeth	1=very rubbery/ hard to tear, 9=very soft, easy to tear
Tenderness	By eating	1=very brittle and dry, 5=neutral, 9=very soft
Taste	By taste	1=strong off-flavors, 5=neutral, 9=pleasant

II.VI Data Analysis

A one-way ANOVA was used to analyze the data, and a Tukey's t-test was used for comparing the values using a program from Assaad et al. [14]. Differences were considered statistically significant at a p value < 0.05.

III. RESULTS & DISCUSSION

The corn tortillas were similar in visual appearance (Fig. 1).

III.I Evaluation of Corn Tortillas

As seen in Table 3, overall, corn tortillas with maltogenic amylase (C2-C5) and high-performing maltogenic amylase (C6-C9) were similar to control (C1) in pH, moisture, thickness, diameter, weight and color characteristics.

Fig. 1. Corn tortilla top view (C1-C9) from left to right

Table 3. Corn tortilla pH, moisture, dimensions, weight, and color

Charac-teristic	C1	C2	C3	C4	C5	C6	C7	C8	C9
pH	5.12 ± 0.07^{a}	5.04 ± 0.16^{a}	5.18 ± 0.04^{a}	5.03 ± 0.21^{a}	5.11 ± 0.13^{a}	5.07 ± 0.17^{a}	5.09 ± 0.11^{a}	5.08 ± 0.11^{a}	5.17 ± 0.07^{a}
Moisture (%)	45.90 ± 0.70^{a}	44.60 ± 2.20^{a}	45.10 ± 0.40^{a}	46.60 ± 1.00^{a}	44.80 ± 1.10^{a}	45.80 ± 0.70^{a}	43.80 ± 0.70^{a}	48.30 ± 0.10^{a}	48.40 ± 2.00^{a}
Diameter (cm)	14.0 ± 0.1^{a}	13.8 ± 0.1^{a}	13.9 ± 0.0^{a}	13.7 ± 0.1^{a}	13.7 ± 0.1^{a}	14.0 ± 0.0^{a}	13.6 ± 0.3^{a}	13.8 ± 0.0^{a}	13.8 ± 0.3^{a}
Thickness (mm)	1.4 ± 0.0^{a}	1.4 ± 0.0^{a}	1.2 ± 0.0^{a}	1.3 ± 0.1^{a}	1.3 ± 0.1^{a}	1.2 ± 0.0^{a}	1.3 ± 0.0^{a}	1.4 ± 0.0^{a}	1.4 ± 0.1^{a}
Weight (g)	24.4 ± 0.1^{a}	24.2 ± 0.1^{a}	24.8 ± 0.1^{a}	24.1 ± 0.3^{a}	24.3 ± 0.2^{a}	24.5 ± 0.2^{a}	24.2 ± 0.2^{a}	24.0 ± 0.2^{a}	24.4 ± 0.1^{a}
Color (L*)	73.50 ± 0.01^{a}	73.40 ± 0.22^{a}	73.70 ± 0.13^{a}	73.70 ± 0.07^{a}	73.60 ± 0.01^{a}	73.60 ± 0.00^{a}	73.70 ± 0.11^{a}	73.80 ± 0.09^{a}	73.60 ± 0.15^{a}
Color (a*)	-0.24 ± 0.09^{a}	-0.24 ± 0.03^{a}	-0.18 ± 0.12^{a}	-0.22 ± 0.19^{a}	-0.17 ± 0.16^{a}	-0.17 ± 0.13^{a}	-0.19 ± 0.03^{a}	-0.27 ± 0.02^{a}	-0.27 ± 0.04^{a}
Color (b*)	21.20 ± 0.03^{a}	21.10 ± 0.01^{a}	21.10 ± 0.13^{a}	20.90 ± 0.01^{a}	20.70 ± 0.33^{a}	20.90 ± 0.50^{a}	20.90 ± 0.07^{a}	20.80 ± 0.22^{a}	21.00 ± 0.06^{a}

Values are means ± SEM, n = 2 per treatment group.
Means in a row without a common superscript letter differ (P<0.05) as analyzed by one-way ANOVA and the TUKEY test.

III.II Rollability, Foldability, and Pliability

Table 4 shows the rollability data for the corn tortillas. On day 1, there was no significant difference in rollability between all tests (C1-C9). On day 7, a difference was observed between control (C1) and tests with added enzyme (C2-C9). Control tortillas with no enzyme (C1) at day 7 were significantly less rollable than tortillas with enzyme (C2-C9). Tortillas with high-performing maltogenic amylase at (C6-C9) were similar in rollability to tortillas with maltogenic amylase (C2-C5), when compared at the same dosage. At the end of the 35-day storage period, tests with high-performing maltogenic amylase and maltogenic amylase (C2-C9) rated significantly better in rollability than control (C1).

Table 4. Rollability of corn tortillas

Day	C1	C2	C3	C4	C5	C6	C7	C8	C9
Day 1	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}
Day 7	4.0 ± 0.0^{b}	4.8 ± 0.2^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	4.9 ± 0.0^{a}
Day 14	3.0 ± 0.0^{a}	4.2 ± 0.7^{b}	4.5 ± 0.5^{bc}	4.8 ± 0.2^{bc}	5.0 ± 0.0^{bc}	4.0 ± 0.0^{ab}	4.5 ± 0.5^{bc}	4.5 ± 0.5^{bc}	5.0 ± 0.0^{bc}
Day 21	2.5 ± 0.5^{b}	4.0 ± 1.0^{a}	4.5 ± 0.5^{a}	4.5 ± 0.5^{a}	4.7 ± 0.2^{a}	4.0 ± 0.0^{a}	4.5 ± 0.5^{a}	4.7 ± 0.2^{a}	4.7 ± 0.2^{a}
Day 35	2.0 ± 0.0^{c}	3.0 ± 0.0^{bc}	4.0 ± 0.0^{ab}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	4.0 ± 0.0^{ab}	4.5 ± 0.5^{a}	4.8 ± 0.2^{a}	4.8 ± 0.2^{a}

Values are means ± SEM, n = 2 per treatment group.
Means in a row without a common superscript letter differ (P<0.05) as analyzed by one-way ANOVA and the TUKEY test.

Fig. 2 shows a comparison of 0.0100% high-performing maltogenic amylase (C9) and the control (C1) in the rollability test on day 35. The control tortillas broke up during rolling, while the tortillas with 0.0100% high-performing maltogenic amylase stayed intact when rolled.

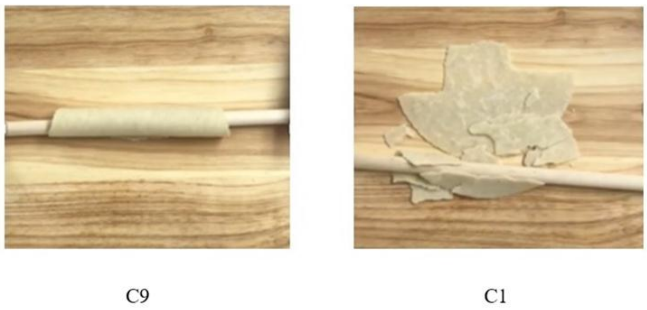

Fig. 2. Day 35 rollability for C9 (0.0100% high-performing maltogenic amylase) on the left and C1 (control) on the right

From Table 5, there were no significant differences in foldability between all tests (C1-C9) from day 1 to day 7. On day 14, the tortillas with added enzyme (C2-C9) were rated significantly better in foldability than the control tortillas (C1). On days 21 and 35, corn tortillas with maltogenic amylase (C2-C5) were similar in foldability to tortillas with high-performing maltogenic amylase (C6-C9). On day 35, tortillas with 0.0100% maltogenic amylase (C5) and 0.0050%-0.0100% high-performing maltogenic amylase (C7-C9) rated significantly better in foldability than the control (C1). The results suggest that the high-performing maltogenic amylase was two times more effective than the maltogenic amylase in prolonging foldability, since half the dosage of high-performing maltogenic amylase (0.0050%) could be used to achieve similar foldability results as 0.0100% maltogenic amylase, for achieving significantly better foldability ratings than the control.

Table 5. Foldability of corn tortillas

Day	C1	C2	C3	C4	C5	C6	C7	C8	C9
Day 1	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}
Day 7	4.0 ± 1.0^{a}	4.5 ± 0.5^{a}	4.9 ± 0.0^{a}	4.9 ± 0.0^{a}	5.0 ± 0.0^{a}	4.9 ± 0.0^{a}	5.0 ± 0.0^{a}	4.6 ± 0.1^{a}	4.5 ± 0.5^{a}
Day 14	2.5 ± 0.5^{b}	4.7 ± 0.2^{a}	5.0 ± 0.0^{a}	4.9 ± 0.0^{a}	5.0 ± 0.0^{a}	4.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}
Day 21	2.0 ± 0.0^{b}	4.0 ± 0.0^{a}	4.7 ± 0.2^{a}	4.7 ± 0.2^{a}	4.7 ± 0.2^{a}	3.0 ± 0.0^{ab}	3.5 ± 0.5^{ab}	4.5 ± 0.5^{a}	4.5 ± 0.5^{a}
Day 35	1.5 ± 0.5^{b}	3.0 ± 0.0^{ab}	4.0 ± 1.0^{ab}	4.0 ± 0.0^{ab}	4.5 ± 0.5^{a}	2.0 ± 0.0^{ab}	4.5 ± 0.5^{a}	4.5 ± 0.5^{a}	4.5 ± 0.5^{a}

Values are means ± SEM, n = 2 per treatment group.
Means in a row without a common superscript letter differ (P<0.05) as analyzed by one-way ANOVA and the TUKEY test.

Fig. 3. Day 35 foldability for C9 (0.0100% high-performing maltogenic amylase) on the left and C1 (control) on the right

Fig. 3 shows a comparison of 0.0100% high-performing maltogenic amylase (C9) and the control (C1) in the foldability test on day 35. The control tortillas broke during folding while the tortillas with 0.0100% high-performing maltogenic amylase stayed intact when folded.

Table 6 shows the pliability data for the corn tortillas. On day 1, there were no differences in pliability between the tests (C1-C9). On day 7, tortillas with maltogenic amylase (C2-C9) were significantly more pliable than the control tortillas (C1). Tortillas with maltogenic amylase and high-performing maltogenic amylase (C2-C9) had higher pliability values than control tortillas without enzyme (C1) from day 7 to day 35. On day 35, tortillas with 0.0075%-0.0100% high performing maltogenic amylase (C8-C9) rated significantly better in pliability than control (C1), and the difference in pliability between the high performing maltogenic amylase and maltogenic amylase was not statistically significant.

Table 6. Pliability of corn tortillas

Day	C1	C2	C3	C4	C5	C6	C7	C8	C9
Day 1	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}
Day 7	4.0 ± 0.0^{d}	4.5 ± 0.0^{c}	4.8 ± 0.0^{b}	4.9 ± 0.0^{a}	4.9 ± 0.0^{a}	4.8 ± 0.0^{b}	4.9 ± 0.0^{a}	4.9 ± 0.0^{a}	4.5 ± 0.0^{c}
Day 14	3.5 ± 0.4^{c}	4.0 ± 0.0^{bc}	4.0 ± 0.0^{bc}	4.5 ± 0.0^{ab}	4.9 ± 0.0^{a}	4.0 ± 0.0^{bc}	4.0 ± 0.0^{bc}	4.9 ± 0.0^{a}	5.0 ± 0.0^{a}
Day 21	3.5 ± 0.5^{ab}	4.0 ± 0.0^{a}	4.0 ± 0.0^{a}	4.5 ± 0.5^{a}	4.5 ± 0.5^{a}	4.0 ± 0.0^{a}	4.0 ± 0.0^{a}	4.0 ± 0.0^{a}	4.0 ± 0.0^{a}
Day 35	3.5 ± 0.4^{b}	4.0 ± 0.0^{ab}	4.0 ± 0.0^{ab}	4.0 ± 0.0^{ab}	4.0 ± 0.0^{ab}	4.0 ± 0.0^{ab}	4.0 ± 0.0^{ab}	4.5 ± 0.0^{a}	4.5 ± 0.0^{a}

Values are means ± SEM, n = 2 per treatment group.
Means in a row without a common superscript letter differ (P<0.05) as analyzed by one-way ANOVA and the TUKEY test.

III.III Texture Analysis

Fig. 4 and Table 7 show the firmness by rupture force of the tortillas over 35 days of shelf life. All tortillas on day 1 were similar in rupture force. However, at day 7, tortillas with enzymes (C2-C9) were significantly softer (lower rupture force values) than the control (no enzyme) (C1). Differences in firmness between the maltogenic amylase and high-performing maltogenic amylase tests (C2-C9) were detected on day 14. Tortillas with lower levels of maltogenic amylase (C2-C3) were significantly firmer (higher rupture force values) than tortillas with lower levels of high-performing maltogenic amylase (C6-C7). Overlap was seen between maltogenic amylase at 0.0100% (C5) and high-performing maltogenic amylase in firmness at all doses (C6-C9) from day 14 through 35.

Tortillas with either enzyme staled more slowly than the control tortillas. Control (C1) was 2 times firmer on day 35 than it was on day 1. Tortillas with 0.0025%-0.0075% maltogenic amylase (C2-C4) were 1.2-1.7 times firmer on day 35 when compared to day 1. Day 35 tortillas with highest dose of maltogenic amylase (C5) and all high-performing maltogenic amylase tests (C6-C9) were similar in firmness to their respective day 1 firmness readings. This suggests that the high-performing maltogenic amylase was more effective in delaying staling and prolonging softness than the maltogenic amylase. Overall, tortillas with both enzymes (C2-C9) were significantly softer (lower rupture force values) than the control (C1) at 35 days of storage.

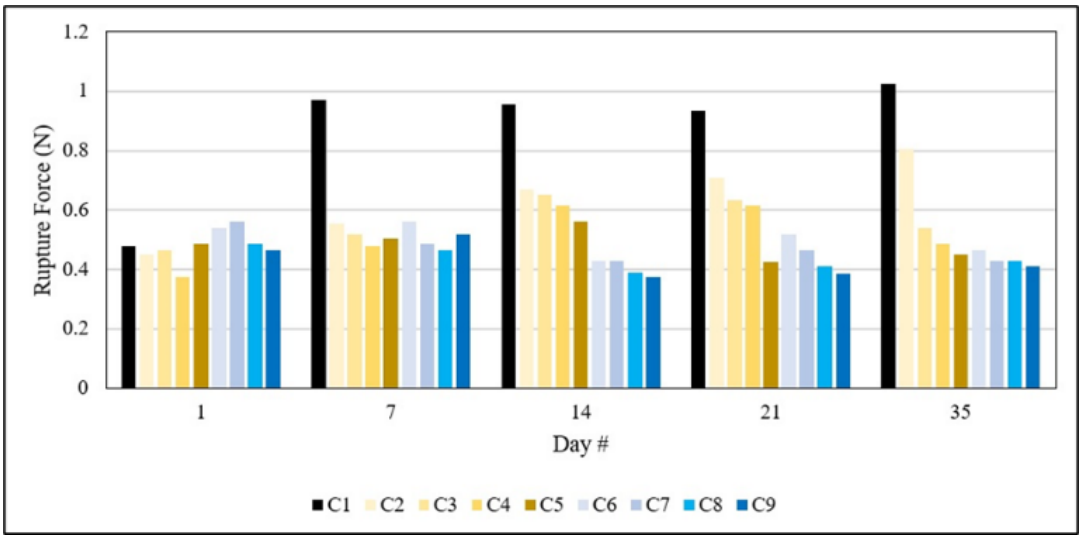

Fig. 4. Corn tortilla firmness by puncture method

Table 7. Firmness data

Day	C1	C2	C3	C4	C5	C6	C7	C8	C9
Day 1	0.48 ± 0.00^{a}	0.45 ± 0.00^{a}	0.47 ± 0.01^{a}	0.38 ± 0.05^{a}	0.49 ± 0.05^{a}	0.54 ± 0.06^{a}	0.56 ± 0.07^{a}	0.49 ± 0.05^{a}	0.47 ± 0.04^{a}
Day 7	0.97 ± 0.05^{a}	0.56 ± 0.05^{b}	0.52 ± 0.03^{b}	0.48 ± 0.00^{b}	0.51 ± 0.07^{b}	0.56 ± 0.03^{b}	0.49 ± 0.02^{b}	0.47 ± 0.01^{b}	0.52 ± 0.07^{b}
Day 14	0.96 ± 0.04^{a}	0.67 ± 0.03^{b}	0.65 ± 0.01^{b}	0.62 ± 0.01^{bc}	0.56 ± 0.07^{bd}	0.43 ± 0.01^{cd}	0.43 ± 0.01^{cd}	0.39 ± 0.01^{d}	0.38 ± 0.02^{d}
Day 21	0.94 ± 0.05^{a}	0.71 ± 0.03^{b}	0.64 ± 0.02^{bc}	0.62 ± 0.01^{bd}	0.43 ± 0.04^{de}	0.52 ± 0.00^{be}	0.47 ± 0.01^{cde}	0.41 ± 0.08^{de}	0.39 ± 0.01^{e}
Day 35	1.02 ± 0.01^{a}	0.81 ± 0.04^{b}	0.54 ± 0.01^{c}	0.49 ± 0.02^{cd}	0.45 ± 0.00^{cd}	0.47 ± 0.01^{cd}	0.43 ± 0.01^{cd}	0.43 ± 0.01^{cd}	0.41 ± 0.03^{d}

Values are means ± SEM, n = 2 per treatment group.
Means in a row without a common superscript letter differ (P<0.05) as analyzed by one-way ANOVA and the TUKEY test.

III.IV Sensory

Table 8 shows the sensory data on day 1 for the corn tortillas. The control tortillas (C1) rated significantly lower in aroma than tortillas with added enzyme (C2-C9). All tests with high-performing maltogenic amylase (C6-C9) were rated significantly softer than the control tortillas (C1), while some of the tortillas with maltogenic amylase had softness ratings which were not statistically different from the control tortillas. Tortillas with maltogenic amylase at all doses (C2-C5) had significantly higher rollability ratings than the control (C1). Tortillas with high-performing maltogenic amylase had higher rollability ratings than the control tortillas, but this difference was not statistically significant. Tortillas with maltogenic amylase at 0.0025%-0.0050% (C2-C3) and high-performing maltogenic amylase at 0.0050-0.0100% (C7-C9) rated significantly more tender than the control (C1) on day 1. On day 1 lowest doses of maltogenic amylase 0.0025-0.0075% (C2-C4) and the highest doses of high-performing maltogenic amylase 0.0050-0.0100% (C7-C9) rated significantly better in taste than the control (C1).

Table 9 shows the sensory data on day 14 for the corn tortillas. Tortillas with enzyme generally had higher ratings than control tortillas (C1) for softness, rollability, and taste. However, the tortillas with enzyme were statistically similar to control for these attributes. This may be due to the variation in scoring by different panelists, since the rating system was subjective. Tortillas with 0.0050%-0.0100% maltogenic amylase and 0.0025%-0.0100% high-performing maltogenic amylase were rated significantly more tender (higher tenderness ratings) than the control. Although the sensory ratings for softness and rollability were not statistically different between the tortillas with and without enzyme, significant differences were observed in the subjective rollability test and objective texture test (on the same day of evaluation), which were performed by an expert in tortillas and had less variation in scoring. The rollability test and texture test (puncture force) both indicated that tortillas with maltogenic amylase and high-performing maltogenic amylase at all doses (C2-C9) were significantly softer and had significantly better rollability than the control tortillas (see day 14 in Tables 4 and 7).

Table 10 shows the overall sensory scores and average texture results during testing. These results show that corn tortillas with maltogenic amylase and high-performing maltogenic amylase (C2-C9) had higher overall sensory scores, were softer (had lower firmness values), and rated better in rollability, foldability, and pliability than the control (C1). In addition, corn tortillas with high performing maltogenic amylase (C6-C9) were the softest (had the lowest firmness values), compared to corn tortillas with maltogenic amylase (C2-C5) at the same dosage.

Table 8. Corn tortilla sensory data on day 1

Attribute	C1	C2	C3	C4	C5	C6	C7	C8	C9
Aroma	1.6 ± 0.8^{b}	8.0 ± 0.8^{a}	6.2 ± 0.7^{a}	6.5 ± 0.7^{a}	6.7 ± 0.7^{a}	6.5 ± 0.8^{a}	7.5 ± 1.0^{a}	5.8 ± 1.0^{a}	6.5 ± 1.0^{a}
Softness	1.9 ± 1.0^{b}	7.2 ± 1.1^{a}	7.2 ± 1.1^{a}	5.2 ± 1.6^{ab}	5.5 ± 1.6^{ab}	7.5 ± 0.7^{a}	7.5 ± 0.9^{a}	7.5 ± 0.9^{a}	7.7 ± 0.9^{a}
Rollability	1.5 ± 0.7^{b}	7.5 ± 0.7^{a}	8.5 ± 0.2^{a}	7.5 ± 0.8^{a}	7.7 ± 1.1^{a}	7.0 ± 1.0^{ab}	7.0 ± 1.1^{ab}	6.7 ± 1.3^{ab}	5.7 ± 2.0^{ab}
Tear Strength	1.8 ± 0.9^{c}	7.2 ± 0.8^{a}	6.2 ± 0.6^{ac}	8.0 ± 1.6^{a}	5.2 ± 1.4^{ac}	4.5 ± 0.2^{ac}	6.5 ± 0.9^{ab}	6.0 ± 1.1^{ac}	6.0 ± 1.1^{ac}
Tenderness	1.5 ± 0.7^{c}	7.2 ± 0.8^{a}	6.2 ± 1.2^{ab}	5.2 ± 1.2^{ac}	5.0 ± 1.5^{ac}	5.7 ± 0.4^{ac}	6.7 ± 0.7^{a}	7.0 ± 0.9^{a}	6.7 ± 0.8^{a}
Taste	2.1 ± 1.0^{b}	8.0 ± 0.7^{a}	7.0 ± 0.6^{a}	6.7 ± 1.3^{a}	5.2 ± 1.4^{ab}	6.5 ± 0.8^{ab}	8.5 ± 0.9^{a}	7.5 ± 0.9^{a}	7.5 ± 0.9^{a}

Values are means ± SEM, n = 4 per treatment group.
Means in a row without a common superscript letter differ (P<0.05) as analyzed by one-way ANOVA and the TUKEY test.

Table 9. Corn tortilla sensory data on day 14

Attribute	C1	C2	C3	C4	C5	C6	C7	C8	C9
Aroma	6.5 ± 0.7^{a}	6.2 ± 0.8^{a}	7.5 ± 0.7^{a}	7.7 ± 0.6^{a}	7.5 ± 0.7^{a}	7.7 ± 0.6^{a}	7.2 ± 0.5^{a}	7.5 ± 0.6^{a}	6.5 ± 0.3^{a}
Softness	4.0 ± 1.3^{ab}	6.7 ± 0.7^{ab}	6.5 ± 0.8^{ab}	7.7 ± 0.6^{a}	7.0 ± 0.8^{a}	7.7 ± 0.2^{a}	7.2 ± 0.2^{a}	7.5 ± 0.3^{a}	7.0 ± 0.7^{a}
Rollability	5.0 ± 0.6^{ab}	5.2 ± 1.4^{ab}	6.2 ± 1.6^{ab}	7.5 ± 0.8^{a}	7.2 ± 0.7^{a}	7.0 ± 0.6^{ab}	5.5 ± 1.3^{ab}	6.0 ± 0.9^{ab}	7.7 ± 0.6^{a}
Tear Strength	2.2 ± 0.4^{bc}	6.2 ± 1.0^{ac}	7.7 ± 0.6^{a}	8.2 ± 0.4^{a}	8.5 ± 0.4^{a}	7.7 ± 0.2^{a}	6.7 ± 1.1^{ab}	7.7 ± 0.5^{a}	6.5 ± 1.2^{ab}
Tenderness	2.0 ± 0.5^{bc}	5.2 ± 0.5^{ac}	6.5 ± 0.9^{a}	7.0 ± 0.7^{a}	8.5 ± 0.4^{a}	7.7 ± 0.2^{a}	7.2 ± 1.1^{a}	7.7 ± 0.5^{a}	7.0 ± 0.7^{a}
Taste	5.5 ± 1.1^{ab}	6.5 ± 0.8^{ab}	7.7 ± 0.6^{a}	8.0 ± 0.5^{a}	7.5 ± 0.8^{a}	7.5 ± 0.8^{a}	7.7 ± 0.7^{a}	8.0 ± 0.6^{a}	7.2 ± 0.6^{a}

Values are means ± SEM, n = 4 per treatment group.
Means in a row without a common superscript letter differ (P<0.05) as analyzed by one-way ANOVA and the TUKEY test.

Table 10. Overall sensory and average texture data

Attribute	C1	C2	C3	C4	C5	C6	C7	C8	C9
Overall Sensory Score	65.0	81.0	85.0	87.0	84.0	87.0	88.0	88.0	85.0
Rollability	3.3	4.2	4.6	4.9	5.0	4.4	4.7	4.8	4.9
Foldability	3.0	4.3	4.7	4.7	4.9	3.8	4.6	4.7	4.7
Pliability	3.7	4.0	4.1	4.2	4.3	4.4	4.4	4.7	4.6
Firmness (N)	0.87	0.64	0.56	0.51	0.49	0.50	0.47	0.44	0.43

**Overall sensory score data is a sum of the totals from day 1 and 14 sensory testing. Other attributes are average of all testing days from day 1 to 35.*

IV. CONCLUSION

The addition of maltogenic amylase and high-performing maltogenic amylase significantly extended the shelf life of corn tortillas made with a griddle cooking process. Both enzymes made tortillas significantly softer and significantly better in rollability and foldability than control tortillas after 35 days of storage without altering pH, color, or moisture of original product. Overall, the high-performing maltogenic amylase was more effective than the maltogenic amylase in prolonging softness in corn tortillas. The high-performing maltogenic amylase offers a promising solution for further extending the shelf life of corn tortillas.

REFERENCES

[1] Kwasniewska-Karolak I, Mostowski R. The influence of storage conditions on the staling rate and starch retrogradation in wheat rolls packaged in a modified atmosphere. J Microbiol, Biotechnol Food Sci 2019;8(5):1188-1193.

[2] Chinachoti P, Vodovotz, Y, editors. Bread staling. Boca Raton, FL: CRC Press, 2018.

[3] Hoseney RC, editor. Principles of cereal science and technology, first edition. St. Paul, MN: AACC; 1996.

[4] Bueso-Ucles FJ. Antistaling properties of amylases, wheat gluten and CMC on corn tortilla [Ph.D. dissertation]. Austin, TX: Texas A&M University; 2003.

[5] Grewal, NK. Structural changes induced in waxy maize starch and normal wheat starch by maltogenic amylases [Ph.D. thesis]. Manhattan, KS: Kansas State University; 2008.

[6] Iturbe-Chinas FA, Lucio-Aguerreber RM, Lopez-Munguia A. Shelf life of tortilla extended with fungal amylases. Int J Food Sci Technol 1996;31(6):505-509.

[7] American Association of Cereal Chemists. Approved methods of the American Association of Cereal Chemists, 10th edition. AACC Method 02-52. Hydrogen-Ion Activity (pH)—Electrometric Method. St. Paul, MN: AACC, 2000.

[8] Ting L, Gary GH, Book SL, Marquart L. Effects of chemical leavening system and processing condition son the opacity and other quality characteristics of whole-wheat flour tortillas. LWT-Food Science and Technology 2016;73:123-130.

[9] Hunter Associates Laboratory Inc. (2012). Measuring color using Hunter L, a, b versus CIE 1976 L*a*b*. Application Note AN 1005.00, 1-4. Reston, VA: Hunter Associates Laboratory Inc.. https://support.hunterlab.com/hc/en-us/article_attachments/201450469/an-1005b.pdf

[10] Suhendro E. Instrumental methods for the evaluation of corn tortilla texture [Ph.D. dissertation]. College Station, TX: Texas A&M University; 1997.

[11] Wang L, Flores RA. Effects of wheat starch and gluten on tortilla texture. Cereal Chem 1999;76(5):807-810.

[12] Cepeda M, Waniska RD, Rooney LW, Bejosano FP. Effects of leavening acids and dough temperatures in wheats flour tortillas. Cereal Chem 2000;77(4):489-494.

[13] Mecmesin Ltd. Texture Analysis Solutions: Tortilla Tear Strength [Online]. Available from: https://www.textureanalyzers.com/publications/tortilla-tear-strength [Accessed July 2020].

[14] Assaad H, Zhou L, Carroll RJ, Wu G. Rapid publication-ready MS-Word tables for one-way ANOVA. SpringerPlus 2014; 3:474.