

Research and Professional Briefs

Fortification of All-Purpose Wheat-Flour Tortillas with Calcium Lactate, Calcium Carbonate, or Calcium Citrate Is Acceptable

JOELLE E. ROMANCHIK-CERPOVICZ, PhD, RD; REBECCA J. MCKEMIE

ABSTRACT

Fortification helps provide adequate nutrients for individuals not meeting daily needs. Foods may be fortified with calcium to assist individuals with lactose intolerance and others preferring not to consume traditional forms of dairy. This study examined the quality of all-purpose wheat-flour tortillas fortified with calcium lactate, calcium carbonate, or calcium citrate. These tortillas were compared to similarly prepared nonfortified flour tortillas (control) and commercial nonfortified flour tortillas. Calcium-fortified tortillas contained 114 mg elemental calcium per standard serving (48 g tortilla), an 8.6-fold increase compared to nonfortified tortillas. Moisture contents and rollabilities of all tortillas were similar. Consumers (N=87) evaluated each tortilla in duplicate using a hedonic scale and reported liking the appearance, texture, flavor, aftertaste, and overall acceptability of all tortillas. However, the appearance of control tortillas was preferred over commercial tortillas ($P<0.01$), whereas the aftertaste of commercial tortillas or those fortified with calcium carbonate was preferred over the control ($P<0.05$). Despite these differences, consumers were equally willing to purchase both fortified and nonfortified tortillas, suggesting that appearance and aftertaste may not influence willingness to purchase. Overall, this study shows that fortification of flour tortillas with various forms of calcium is a feasible alternative calcium source. *J Am Diet Assoc.* 2007;107:506-509.

J. E. Romanchik-Cerpovicz is an associate professor of Nutrition and Food Science, Department of Health and Kinesiology, Georgia Southern University, Statesboro.

R. J. McKemie is a graduate student, Department of Foods and Nutrition, University of Georgia, Athens; at the time of the study, she was an undergraduate student, Department of Health and Kinesiology, Georgia Southern University, Statesboro.

Address correspondence to: Joelle E. Romanchik-Cerpovicz, PhD, RD, Associate Professor of Nutrition and Food Science, Georgia Southern University, Department of Health and Kinesiology, PO Box 8076, Statesboro, GA 30460-8076. E-mail: jromchik@georgiasouthern.edu

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Dairy products are the major source of calcium for the US population (1,2). However, for individuals who do not prefer dairy products or those who are lactose-intolerant, including greater than 50% of Mexican Americans, approximately 75% of African Americans, and 100% of Native Americans (3), alternative sources of calcium should be consumed for adequate intake. Reliance on nondairy foods, such as plant foods, often helps individuals with lactose intolerance obtain adequate calcium. However, bioavailability of calcium from these sources is often compromised by the presence of fiber, such as phytates.

Recently, tortillas have been modified by researchers, such as Hambidge and colleagues (4), who increased the bioavailability of calcium in corn tortillas by preparation with low-phytate maize. Unlike corn tortillas, flour tortillas traditionally contain all-purpose wheat flour (4). These tortillas have also been modified recently by Friend and colleagues (5) to extend their shelf life by adding calcium propionate.

Calcium intake by people in the United States is less than adequate (6,7), which can contribute to an increased risk of developing osteoporosis (8). Fortification of foods such as orange juice, carbonated beverages, yeast breads, and breakfast cereals has been used to help improve calcium intake (9-11).

Calcium-fortified foods should have similar physical and sensory characteristics as their nonfortified counterparts (9). This study determined moisture contents, rollabilities, and sensory attributes of all-purpose wheat flour tortillas fortified with calcium lactate, calcium carbonate, or calcium citrate. Fortified tortillas were compared to nonfortified control tortillas and to commercially manufactured nonfortified tortillas.

METHODS

Preparation of Tortillas

Nonfortified tortillas (control) were prepared according to the methods described by Holt and colleagues (12). To be comparable to commercial tortillas, a serving was determined to be 48 g. Tortillas were fortified with powdered calcium lactate, calcium carbonate, or calcium citrate to contain 114 mg elemental calcium per serving. Preliminary tests indicated this amount of calcium was the maximum that could be added while retaining acceptable sensory texture attributes. According to the US Food and Drug Administration Food Labeling Guide, each fortified tortilla provides 11.4% of the Daily Value for calcium, classifying it as a Good Source for healthy, 19- to 50-year old adults (13). Tortilla formulas are presented in Table 1.

Table 1. Formulas and preparation procedures for flour tortillas

| Ingredient ^a | Control nonfortified ^{bc} (g) | Calcium lactate–fortified ^{bd} (g) | Calcium carbonate–fortified ^{be} (g) | Calcium citrate–fortified ^{bf} (g) |
|--------------------------------------|--|---|---|---|
| All-purpose wheat flour | 87.30 | 87.30 | 87.30 | 87.30 |
| Salt | 2.00 | 2.00 | 2.00 | 2.00 |
| Shortening | 11.70 | 11.70 | 11.70 | 11.70 |
| Water | 47.30 | — | — | — |
| Calcium-fortified, lactose-free milk | — | 47.30 | 47.30 | 47.30 |
| Calcium lactate | — | 1.11 | — | — |
| Calcium carbonate | — | — | 0.50 | — |
| Calcium citrate | — | — | — | 0.86 |

^aIngredients for tortillas, including unbleached enriched all-purpose wheat flour (Pillsbury Best, J.M. Smucker Co, Orrville, OH), salt, shortening, and distilled water (Great Value, Wal-Mart Inc, Bentonville, AK), calcium-fortified lactose-free milk (Lactaid, McNeil Nutritionals LLC, Ft Washington, PA), and calcium lactate, calcium carbonate, and calcium citrate powders (NOW Foods, Bloomingdale, IL), were obtained from a local supermarket. A KitchenAid Mixer (model KSM90, KitchenAid USA, St Joseph, MI) equipped with a flat beater or dough hook attachment was used for mixing ingredients. Tortillas were frozen in a Kenmore Refrigerator/Freezer (model 363.9738517, Sears Roebuck and Co, Chicago, IL) and were cooked using a West Bend nonstick electric skillet (No. 72017-001, The West Bend Co, West Bend, WI).

^bProcedure: Nonfortified tortillas were prepared using the previously published formula of Holt and colleagues (5) and calcium was added to this recipe to fortify the other tortillas. Sift together flour, salt, and calcium (fortified). In mixer equipped with the flat beater attachment, cut shortening into flour, salt, and calcium (fortified) mixture. Add water (nonfortified) or calcium-fortified lactose-free milk (fortified), a little at a time, while mixing on speed 3 for 2.5 min. Using the dough hook attachment, continue mixing the tortilla dough on speed 6 for 7 min to develop gluten. Remove and cover dough with plastic wrap and let rest on counter for 20 min. Divide dough into 15-g balls. Using a rolling pin, roll each ball between two pieces of waxed paper to 13 cm diameter. Place each waxed-paper-wrapped tortilla in the freezer for 3 min. Remove waxed paper and cook tortilla on electric skillet heated to 375°F (190°C). Cook tortilla 20 sec on one side, 25 sec on the second, and then another 5 sec on first side to cook thoroughly, while pressing with plastic spatula to remove air pockets. Remove tortilla from pan and cool on a wire rack. Wrap in plastic wrap when cool and store in an airtight container.

^cMacronutrient content per 100 g: 332.4 kcal, 53.3 g carbohydrate, 10.0 g fat, 7.3 g protein, 28 mg calcium; serving size 48 g.

^dMacronutrient content per 100 g: 354.8 kcal, 55.0 g carbohydrate, 11.2 g fat, 8.5 g protein, 238 mg calcium; serving size 48 g.

^eMacronutrient content per 100 g: 354.8 kcal, 55.0 g carbohydrate, 11.2 g fat, 8.5 g protein, 238 mg calcium; serving size 48 g.

^fMacronutrient content per 100 g: 354.8 kcal, 55.0 g carbohydrate, 11.2 g fat, 8.5 g protein, 238 mg calcium; serving size 48 g.

Objective Evaluation of Tortillas

Three batches of each type of tortilla were prepared during a single session. Each recipe produced approximately 10 tortillas. On the same day as preparation, a random tortilla sample was removed from each batch for moisture content determination. For moisture analysis, freshly prepared tortillas as well as three samples of commercially manufactured tortillas were dried to a constant mass (64°C, 3 days). Moisture content was determined as $(\text{initial mass} - \text{dried mass}) / \text{initial mass} \times 100$.

For textural quality analysis, a random tortilla sample was also removed from each batch and stored in airtight containers for 24 hours. Each tortilla, as well as three samples of commercial tortillas, were analyzed using the rollability scale of Friend and colleagues (14).

Sensory Evaluation of Tortillas

Ninety-three untrained volunteers were recruited from faculty, staff, and students at Georgia Southern University to evaluate tortillas during two test sessions conducted 2 weeks apart. Panelists signed consent forms and indicated food allergies before participation. Panelists allergic to ingredients used in the tortillas were excluded from this study. This study was approved by the Institutional Review Board at Georgia Southern University.

During test sessions, panelists were seated at individual tables to evaluate one set of five plain tortillas that were coded and randomized previously. The final randomized order presented to panelists was nonfortified plain tortilla; calcium-lactate fortified tortilla; calcium-

carbonate fortified tortilla; calcium-citrate fortified tortilla; and, finally, nonfortified, commercially manufactured tortilla. A hedonic scale (9=like extremely, 5=neither like nor dislike, and 1=dislike extremely) was used by panelists to evaluate each tortilla for appearance, texture, flavor, aftertaste, overall acceptability, and willingness to purchase. Panelists cleansed their palates with distilled water (25°C) between samples according to Lawless and Heymann (15). As previously published (16), each panelist's duplicate responses for each tortilla's attribute were averaged before further statistical analysis to obtain a more accurate indication of a panelist's true feelings about each product. Test-retest reliability, determined as percent agreement of each panelist's evaluation ratings within two points on the nine-point hedonic scale, was 80%.

Statistical Analysis

Objective data and sensory evaluation scores were analyzed for significance using repeated measures analysis of variance with post hoc testing by Tukey-Kramer multiple comparisons using InStat Instant Biostatistics (version 3.0 for Windows, 1998-1999, Graph Pad Software, Inc, San Diego, CA); $P < 0.05$ was considered significant.

RESULTS AND DISCUSSION

Table 2 shows that moisture content of nonfortified tortillas averaged 21.2%, consistent with Holt and colleagues (21.58%) (12) using the same recipe. Moisture

Table 2. Physical characteristics^a and consumer perceptions^b of flour tortillas

| Characteristic | Control nonfortified | Calcium lactate-fortified | Calcium carbonate-fortified | Calcium citrate-fortified | Commercially manufactured nonfortified ^c |
|---------------------------------------|--------------------------------|---------------------------|-----------------------------|---------------------------|---|
| | ←————— <i>mean ± SD</i> —————→ | | | | |
| Moisture content (%) | 21.2±2.5 | 23.2±1.8 | 22.2±1.3 | 21.3±1.0 | 21.5±2.3 |
| Rollability ^e | 1.0±0.0 | 1.0±0.0 | 1.0±0.0 | 1.0±0.0 | 1.0±0.0 |
| Sensory attributes^g | | | | | |
| Appearance | 6.1±1.3 | 6.3±1.5 | 6.2±1.6 | 6.2±1.6 | 5.5±2.1** |
| Texture | 5.6±2.0 | 5.7±1.6 | 5.7±1.7 | 5.7±1.5 | 5.6±2.0 |
| Flavor | 5.6±2.0 | 5.6±1.5 | 5.8±1.7 | 5.8±1.7 | 6.0±2.0 |
| Aftertaste | 5.1±1.6 | 5.3±1.5 | 5.7±1.6* | 5.6±1.7 | 5.9±2.0** |
| Overall acceptability | 5.7±1.5 | 5.7±1.5 | 5.9±1.6 | 5.9±1.7 | 6.0±2.0 |
| Willingness to purchase | 5.4±1.8 | 5.4±1.7 | 5.8±1.8 | 5.7±1.9 | 5.9±2.3 |

^aMean±standard deviation based on the preparation and analysis of three samples of each type of tortilla.
^bMean±standard deviation based on 87 untrained consumer panelists.
^cCommercially manufactured 15.2 cm (6-in) flour tortillas (Azteca Foods, Inc, Summit-Argo, IL) were purchased from a local supermarket.
^dSD=standard deviation.
^eRollability was evaluated using the five-point scale of Friend and colleagues (7): 1=no cracking (best); 2=signs of cracking, but no breaking; 3=cracking and breaking beginning on one surface; 4=cracking and breaking imminent on both sides; and 5=unrollable, breaks easily.
^fTortillas were evaluated using a nine-point hedonic scale: 1=dislike extremely, 5=neither like nor dislike, and 9=like extremely.
^gTortillas (24 h after preparation) were evaluated for consumer sensory acceptability on characteristics of appearance, texture, flavor, aftertaste, overall acceptability, and willingness to purchase.
*Indicates significant ($P<0.05$) difference, compared to control.
**Indicates significant ($P<0.01$) difference, compared to control.

contents of tortillas fortified with calcium lactate (23.2%), calcium carbonate (22.2%), and calcium citrate (21.3%) did not significantly differ from one another or nonfortified control tortillas. Commercial tortillas in this study also contained 21.5% moisture, which did not significantly differ from either fortified or nonfortified tortillas. These results suggest that products produced in this study are similar in moisture content to tortillas in the marketplace.

The rollability of each tortilla was consistently rated “1,” indicating “no cracking” of tortillas. These results are consistent with Friend and colleagues (5), where the addition of calcium propionate, as an antimicrobial agent, did not alter the rollability of flour tortillas.

Eighty-seven panelists completed the sensory evaluations of tortillas. Sixty-five of these panelists (75%) reported consuming tortillas at least monthly, and 41 panelists (47%) reported consuming tortillas two to four times per month. Seventy-six panelists (87%) reported consuming calcium-fortified products at least monthly and 47 panelists (54%) reported consuming calcium-fortified products at least once a week. Orange juice (32%) and bread (25%) were the most widely consumed calcium-fortified products on a weekly basis.

Table 2 shows that mean ratings for all sensory attributes of tortillas ranged from neutral to like moderately. Specifically, ratings for appearance, texture, flavor, and overall acceptability of fortified tortillas did not significantly differ from the nonfortified control. Aftertastes of calcium lactate- and calcium citrate-fortified tortillas also did not significantly differ from the control. However, the aftertaste of calcium carbonate-fortified tortillas was preferred over the control ($P<0.05$), suggesting some forms of calcium impart more desirable characteristics on the aftertaste of products.

Preliminary testing in this laboratory precluded the use of calcium ascorbate for fortification of tortillas due to undesirable aftertaste ratings. Others concur that flavor and texture characteristics of calcium-fortified food products, such as hamburger and orange-flavored beverage, do not significantly differ from nonfortified counterparts (17,18).

Table 2 shows that all characteristics of commercial tortillas were also liked (mean ratings >5.0). All tortillas received moderate sensory ratings similar to those of the commercial tortillas. However, the appearance of commercial tortillas was less liked ($P<0.01$), although their aftertaste was preferred ($P<0.01$) over control tortillas. Because flour tortillas are a bland product intended to be served with other foods, such as meats and sauces, it is not surprising that mean ratings for plain tortillas were not higher.

Whereas differences in appearance and aftertaste existed among commercial and control tortillas, panelists' willingness to purchase ratings were similar for these, as well as calcium-fortified tortillas. These data suggest that calcium-fortified tortillas may be viable competitors among tortillas currently in the marketplace.

Calcium fortification is often targeted at commonly consumed foods such as orange juice, carbonated beverages, and breakfast cereals in the United States (9) and staple foods, such as rice, in developing countries (19). Although the present study did not examine the influence of calcium-fortified tortillas on overall calcium intake, mandatory fortification of white wheat flour with calcium carbonate in the United Kingdom has been shown to contribute to approximately 14% of total calcium consumption, which, if removed, may result in significantly increased numbers of adolescents with inadequate calcium intake (9).

One limitation of this study is that the bioavailability of calcium from these tortillas was not determined. In addition, because certain ethnic groups, such as Mexican Americans, may consume tortillas to a greater extent than others, additional studies could examine sensory evaluation ratings of flour tortillas by various ethnic groups. Altering these recipes in the future to exclude all forms of dairy could also make these products desirable for individuals whose culture excludes dairy consumption.

CONCLUSIONS

This is the first study showing that flour tortillas can be successfully fortified with calcium lactate, calcium carbonate, or calcium citrate, which may provide consumers with more nutritious alternatives to plain flour tortillas. Because calcium salts used in this study are readily available, preparation of tortillas at home and at onsite food-service operations is feasible. It is also important for food and nutrition professionals to be aware that these fortified tortillas are a lactose-free product, which may help individuals with lactose intolerance obtain adequate calcium.

This study produced tortillas fortified with calcium at levels of 10% of the Adequate Intake for adults. Although this level may appear modest, increased fortification may lead some individuals to exceed their Upper Limit for calcium because calcium fortification is fairly widespread in foods (20). To avoid exceeding this limit, calcium-fortified tortillas should be consumed as part of a well-balanced diet.

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References

- Lanou AJ, Berkow SE, Barnard ND. Calcium, dairy products, and bone health in children and young adults: A re-evaluation of the evidence. *Pediatrics*. 2005;115:736-743.
- Rajeshwari R, Nicklas TA, Yang S, Berenson GS. Longitudinal changes in intake and food sources of calcium from childhood to young adulthood: The Bogalusa heart study. *J Am Coll Nutr*. 2004;23:341-350.
- Jackson KA, Savaiano DA. Lactose maldigestion, calcium intake and osteoporosis in African, Asian, and Hispanic Americans. *J Am Coll Nutr*. 2001;20(suppl 2):198S-207S.
- Hambidge KM, Krebs NF, Westcott JL, Sian L, Miller LV, Peterson KL, Raboy V. Absorption of calcium from tortilla meals prepared from low-phytate maize. *Am J Clin Nutr*. 2005;82:84-87.
- Friend CP, Ross RG, Waniska RD, Rooney LW. Effects of additives in wheat flour tortillas. *Cereal Foods World*. 1995;40:494-497.
- Heaney RP, Rafferty K, Dowell MS, Bierman J. Calcium fortification systems differ in bioavailability. *J Am Diet Assoc*. 2005;105:807-809.
- Bell RA, Quandt SA, Spangler JG, Case LD. Dietary calcium intake and supplement use among older African American, white, and Native American women in a rural southeastern community. *J Am Diet Assoc*. 2002;102:844-846.
- Mahan LK, Escott-Stump S. *Krause's Food, Nutrition, and Diet Therapy*. 11th ed. Philadelphia, PA: Saunders Publishing Co; 2004.
- Fairweather-Tait SJ, Teucher B. Iron and calcium bioavailability of fortified foods and dietary supplements. *Nutr Rev*. 2002;60:360-367.
- Cerklewski FL. Calcium fortification of food can add unneeded dietary phosphorus. *J Food Comp Anal*. 2005;18:595-598.
- Babarykin D, Adamsone I, Amerika D, Spudass A, Moisejev V, Berzina N, Michule L, Rozental R. Calcium-enriched bread for treatment of uremic hyperphosphatemia. *J Renal Nutr*. 2004;14:149-156.
- Holt SD, Resurreccion AVA, McWatters KH. Formulation, evaluation and optimization of tortillas containing wheat, cowpea, and peanut flours using mixture response surface methodology. *J Food Sci*. 1992;57:121-127.
- US Food and Drug Administration, Center for Food Safety and Applied Nutrition. Claims that can be made for conventional foods and dietary supplements: A food labeling guide—Appendix A. Available at: <http://www.cfsan.fda.gov/~dms/flg-6a.html>. Accessed January 13, 2006.
- Friend CP, Serna-Saldivar SO, Waniska RD, Rooney LW. Increasing the fiber content of wheat tortillas. *Cereal Foods World*. 1992;37:325-328.
- Lawless HT, Heymann H. *Sensory Evaluation of Food Principles and Practices*. Gaithersburg, MD: Aspen Publishers; 1999.
- Romanchik-Cerpovicz JE, Tilmon RW, Baldree KA. Moisture retention and consumer acceptability of chocolate bar cookies prepared with okra gum as a fat ingredient substitute. *J Am Diet Assoc*. 2002;102:1301-1303.
- Kilgore LT, Watson K, Wren N. Fortification of hamburger with calcium, vitamin A and ascorbic acid. *J Am Diet Assoc*. 1977;71:135-139.
- Assmann S, Medeiros DM, Chambers E. Fortification with calcium citrate malate may not influence the sensory properties of an orange flavored beverage. *J Food Qual*. 2003;26:395-407.
- Hettiarachchy NS, Gnanasambandam R, Lee MH. Calcium fortification of rice: Distribution and retention. *J Food Sci*. 1996;61:195-197.
- Johnson-Down L, L'Abbe MR, Lee NS, Gray-Donald K. Appropriate calcium fortification of the food supply presents a challenge. *J Nutr*. 2003;133:2232-2238.