Effects of Added Proteins in Wheat Tortillas[1]

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ABSTRACT

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Functionality of proteins in wheat tortillas was evaluated by adding milk, oilseed, and hydrolyzed plant and wheat proteins. Many proteins decreased dough mixing and resting times and machinability by weakening the dough structure. Heat-denatured milk and soy proteins maintained gluten functionality and rollability of tortillas better than the corresponding native proteins did. Adding wheat gluten improved dough properties and tortilla rollability. Improved gluten functionality corresponded to a longer shelf-stability of tortillas. The viscoelastic character of gluten was partially retained after baking wheat tortillas. Adding milk and oilseed proteins improved the nutritional value of tortillas.

Wheat tortillas are chemically leavened, flat breads that are increasing in popularity in the United States (Serna-Saldivar et al 1988). Wheat tortillas are a staple food and provide most of the calories and protein in parts of Mexico and Central America. Hence, the health status of many people could be improved by increasing protein nutritional value of wheat tortillas. However, functional characteristics, such as dough machinability, pliability, and tortilla rollability, must be retained in nutritionally improved tortillas.

Soybean flour and milk proteins have been used in the baking industry to improve protein nutritional value of bread and other baked products (Kinsella 1971, Gonzales-Agramon and Serna-Saldivar 1988). Many oilseed flours have been evaluated to fortify cereal-based foods (Dalby 1969, Rooney et al 1972).

The objective of this study was to determine the functionality of milk, oilseed, and hydrolyzed plant and wheat proteins in wheat tortillas.

MATERIALS AND METHODS

Tortilla Formulation

Hot-press wheat tortillas were prepared with a standard formula: 1.0 kg of wheat flour (Rio Blanco, hard white winter, 10.8% protein); 120 g of shortening (Tri-Co, Bunge Foods, Bradley, IL); 15 g of salt (United Salt Corp., Houston, TX); 17 g of baking powder (ADM Arkady, Decatur, IL); 5 g of sodium stearoyl-2-lactylate (SSL, Breddo, Kansas City, KS); 2.3 g of fumaric acid (Denka Chem. Co., Houston, TX); and 2.8 g of potassium sorbate (Sorbistat-K, Pfizer, New York, NY) (Bello et al 1991). Wheat flour was replaced with commercially available proteins (Table I): high-heat, nonfat, dry milk (HHNFDM, DMW Ridgeview, Inc., La Crosse, WI); calcium caseinate (DMW Ridgeview); native whey protein (Alacen 855, New Zealand Milk Products, Inc., Petaluma, CA); denatured whey protein (Alatal 812, New Zealand Milk Products); native soy flour, 70% water-soluble protein (WSP) (Soyafluff 200W, Central Soya, Fort Wayne, IN); denatured soy flour (WSP < 1) (Bakers Nutrisoy, ADM); soy protein concentrate (5% WSP) (Promosoy, Central Soya); cottonseed flour, defatted with hexane (glandless cottonseed [91% WSP Choi et al 1984)], Food Protein Research and Development Center, Texas A&M University); hydrolyzed soy protein (N-Z-Soy BL, Sheffield Products, Norwich, NY); hydrolyzed corn gluten protein (Sheffield); and vital wheat gluten (Supra Vital, Roquette Co., Gurnee, IL).

Processing

Optimum dough water-absorption levels were estimated for control tortilla dough, and for doughs containing HHNFDM, native soy flour, denatured soy flour, and 2 and 3% wheat gluten, using a modified farinograph (type 3350, C. W. Brabender, South Hackensack, NJ) method (AACC 1983, Bello et al 1991). Water-absorption level and mixing time for each treatment were confirmed or adjusted in preliminary trials. Tortillas were prepared according to Bello and coworkers (1991) with the following modifications. The dough was mixed at low speed for 1 min and then at medium speed until a soft and pliable dough developed. The dough balls (44 g) were rested for 25–40 min before hot-pressing.

Analysis

Dough was analyzed subjectively for mixing characteristics and machinability (Bello et al 1991) and objectively for pH. Tortillas were evaluated for mass (g) by stacking and measuring 10 cooled tortillas. The diameter of tortillas (mm) was measured at two places on each of five baked tortillas, and the mean was calculated. Moisture and protein contents of tortillas were determined in duplicate on the day of baking (AACC 1983).

Tortillas were subjectively analyzed for baking characteristics and puffing, sensory properties of one-day-old tortillas, and storage stability (rollability) (Bello et al 1991; Friend et al, *unpublished*). Untrained panelists (30) evaluated the color, texture, flavor, acceptability, and overall ranking of preference of selected tortillas. A sensory evaluation scale of 1 (dislike) to 9 (like) and a rank of preference scale of 1 (worst) to 5 (best) were utilized. Storage stability (rollability) of tortillas was evaluated every two days by wrapping a tortilla around a dowel (1.0 cm diameter) and rating the cracking and breakage of both sides of the tortilla. The rollability scale was: 1 (no cracking), 2 (signs of cracking), 3 (cracking and breaking beginning on one surface), 4 (cracking

TABLE I
Protein Contents (%) of Additives in Commercial Samples, Wheat Tortilla Formulas, and Tortillas

Protein	Commercial Sample[a]	Formula Addition[b]	Tortilla[a]
Wheat tortilla (control)	. . .	. . .	6.2[c]
Calcium caseinate	89.5[d]	3.5	9.3
High-heat nonfat dry milk	34.5	3.5[d]	7.4
Native whey	79.7[e]	3.9	9.3
Denatured whey	90.5[e]	3.4	9.3
Native soy flour	51.0[f]	7.6	10.1
Denatured soy flour	52.0[g]	7.5	10.1
Cottonseed flour	52.0[h]	7.5	10.1
Soy concentrate	70.0[f]	5.5	10.1
Hydrolized soy	89.6[i]	1.0	7.1
Hydrolized corn gluten	66.4[i]	1.3	7.1
Vital gluten	75.0[j]	1.0, 2.0, 3.0	7.0, 7.7, 8.5

[a] Dry weight basis.
[b] Baker's percent.
[c] Gonzalez-Agramon and Serna-Saldivar, 1988.
[d] DMW Ridgeview, Inc., La Crosse, WI.
[e] Technical Bulletin, New Zealand Milk Products, Inc., Petaluma, CA.
[f] Central Soya, Fort Wayne, IN.
[g] ADM Co., Decatur, IL.
[h] Zarins and Marshall, 1988.
[i] Sheffield Products Technical Bulletin, Norwich, NY.
[j] Roquette Co., Gurnee, IL.

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TABLE II
Amino Acid Profiles[a] and Calculated Protein Efficiency Ratio (C-PER)[b] of Tortillas Containing Added Protein

Protein	Lys	Iso	Leu	Met + Cys	Phe + Tyr	Trp	Thr	Val	C-PER
Control[c]	35	74	71	85	103	74	53	65	1.20
Caseinate[b,e]	62	85	83	83	118	78	64	79	2.17
HHNFDM[d,e]	48	81	77	83	107	80	59	71	1.74
Native whey[f]	69	85	93	96	99	103	79	70	2.32
Denatured whey[f]	75	83	101	96	104	110	74	70	2.33
Native soy[g]	58	83	79	78	110	80	65	72	2.05
Denatured soy[h]	58	83	79	78	110	83	65	72	2.04
Cottonseed[i]	50	69	69	59	92	87	54	70	1.68
Soy concentrate[g]	58	84	80	77	110	88	65	72	2.06
Hydrolyzed soy[j]	42	74	71	79	100	74	55	65	1.54
Hydrolyzed corn[j]	32	71	76	77	101	68	51	62	1.12
Gluten, 1%[k]	34	76	73	85	104	76	53	66	1.17
Gluten, 2%[k]	33	77	74	85	105	77	52	67	1.15
Gluten, 3%[k]	32	79	75	85	106	78	52	67	1.13

[a] Percentage of the FAO WHO (1973) Standard for individual amino acids.
[b] Calculated according to Hsu et al 1978.
[c] Gonzales-Agramon and Serna-Saldiar, 1988.
[d] High-heat, nonfat, dry milk.
[e] DMW Ridgeview, Inc., La Crosse, WI.
[f] Technical Bulletin, New Zealand Milk Products, Inc., Petaluma, CA.
[g] Central Soya, Fort Wayne, IN.
[h] ADM Co., Decatur, IL.
[i] Zarins and Marshall, 1988.
[j] Sheffield Products Technical Bulletin.
[k] Hoseney, 1990.

and breaking imminent on both sides), and 5 (unrollable, breaks easily) (Friend et al, *unpublished*). Two tortillas per treatment were sampled.

Calculated protein efficiency ratio (C-PER) of tortillas was estimated according to Hsu et al (1978).

Statistical Analysis

Treatment effects were evaluated by analysis of variance using a completely randomized design. Treatment means from two replicates were compared using least significant difference (SAS 1990).

RESULTS AND DISCUSSION

Amount of Proteins Added to Wheat Tortillas

Wheat tortillas contained 6.2 ± 0.12% protein (Gonzalez-Agramon and Serna-Saldivar 1988) (Table I). Proteins from various sources were added to the control tortilla dough to increase protein content by 3.1% and to improve amino acid composition of tortillas.

The complementary effect of proteins from wheat and other sources improved the protein quality of tortillas (Table II). Lysine is the first limiting amino acid in wheat tortillas (Gonzales-Agramon and Serna-Saldivar 1988). Addition of milk proteins or oilseed proteins improved the lysine content and C-PER of tortillas (Table II). However, lysine was still the first limiting amino acid in the protein-fortified tortillas. Adding wheat gluten decreased C-PER of tortillas because wheat gluten contains very little lysine (Hoseney 1990).

Tortilla dough containing 9% HHNFDM, the amount needed to increase in protein content by 3.1%, had poor machinability and was sticky and difficult to handle. Therefore, less HHNFDM (3.5%) was incorporated into tortillas to facilitate processing with a machinable dough.

Rheological Properties of Tortilla Dough.

The modified farinogram of control tortilla dough (Fig. 1) had a continuous rise in viscosity to 750 farinogram units (FU), followed by a slow decrease in viscosity. All modified farinograms, except those containing HHNFDM and native whey protein, were similar to the control. Modified farinograms of doughs containing HHNFDM and native whey protein had a rapid increase of initial viscosity followed by a small decrease and then a slow rise in viscosity to 750 FU. This is similar to farinograms of tortilla dough containing hydrocolloids (Friend et al 1993).

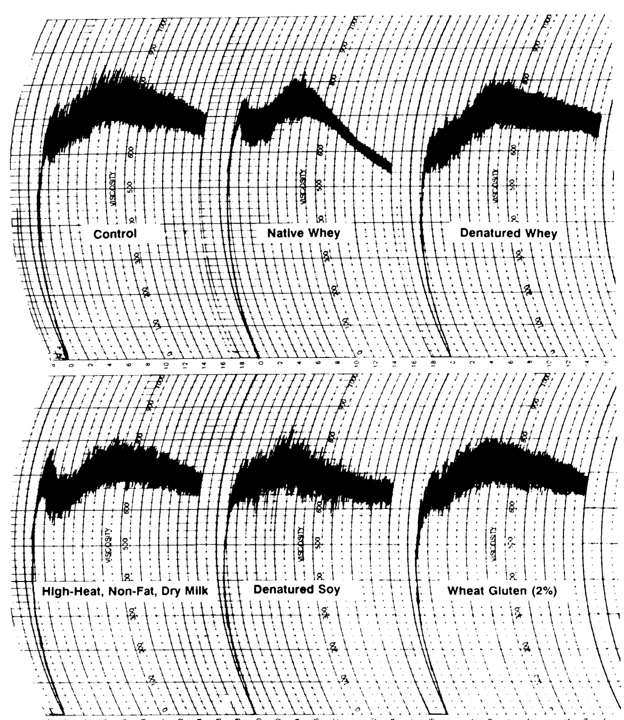

Fig. 1. Modified farinograms of tortilla doughs with added proteins.

Water-absorption levels of tortilla doughs containing added proteins were higher than that of the control dough, except for doughs containing HHNFDM and native whey protein (Tables III and IV). Slightly higher water-absorption levels and longer mixing times were required for tortilla doughs than had been estimated by the farinograph procedure. Water-absorption levels determined using the farinograph or during the preparation of tortilla dough were positively correlated ($r = 0.89$, $\alpha = 0.05$). Similar results were reported by Bello and coworkers (1991).

Dough Machinability

Control tortilla dough was pliable, had good machinability, and yielded tortillas with good characteristics (smooth surfaces with good puffing). Tortilla dough containing HHNFDM was slightly less viscous, less elastic, and softer than the control dough, but it was still a machinable dough (Tables III and IV). In contrast, dough containing calcium caseinate was stiffer and less elastic than the control dough (Table IV).

Tortilla dough with native whey proteins contained less water and was softer, less elastic, and stickier than the control dough (Tables III and IV). During hot-pressing, the weak and sticky doughs flattened more than the control dough did and tended to stick on the hot-press platen. To prevent this problem, precise mixing and resting time requirements of doughs containing native whey protein were needed to obtain the best dough and tortillas.

Whey protein contains small compounds with free sulfhydryl (SH) groups that catalyze disulfide (SS) interchange reactions in gluten (Kinsella 1971). Because only a few SH groups are required during dough mixing (Khan and Bushuk 1979, Mecham 1968), the extra SH groups in native whey protein caused excessive SH-SS interchange during dough mixing. Thus, native whey protein weakens wheat dough structures. Tortilla dough containing native whey protein had characteristics similar to that of dough containing cysteine (Friend et al, *unpublished*).

Tortilla dough prepared with denatured whey protein had higher water-absorption levels than the control dough (Table III). It had better machinability than the dough prepared from native whey but was not as good as the control dough (Table IV). Heat treatment appears to denature proteins that interfere with proper gluten formation. This was also noted by Kinsella (1971) and Rooney et al (1972).

Tortilla doughs containing native soy flour, denatured soy flour, or soy protein concentrate were stiffer and less elastic than control tortilla dough, but they were still machinable (Table IV). Similar results were reported by Gonzales-Agramon and Serna-Saldivar (1988). Adding cottonseed flour decreased mixing time of tortilla dough and produced a weak dough that was less machinable than control tortilla dough. Similar results were obtained by Rooney et al (1972) in bread doughs.

Incorporating hydrolyzed soy or corn proteins to increase protein content of tortillas to 9.1% yielded tortilla doughs that were sticky and had poor machinability. Therefore, only 1.0–1.3% hydrolyzed protein was incorporated into tortillas. At these levels, hydrolyzed plant proteins did not alter water-absorption level of tortilla dough, but they did decrease dough mixing time and machinability (Table IV).

TABLE III
Rheological Properties of Tortilla Doughs Containing Added Protein

Treatment	Water Absorption (%)	Mixing Time (min)	Mixing Stability (min)
Control	47.0	3.6	5.0
High-heat nonfat dry milk	47.0	3.7	4.5
Native whey	44.6	3.5	2.4
Denatured whey	48.0	3.7	4.3
Native soy flour	50.0	3.5	4.1
Denatured soy flour	50.0	3.3	4.2
Gluten, 2%	49.2	3.5	5.0
Gluten, 3%	49.8	3.5	5.8
LSD ($\alpha = 0.05$)	0.35	0.20	0.76

TABLE IV
Effects of Added Protein on pH, Water-Absorption Levels, and Tortilla Dough Characteristics

Treatment	pH	Water Absorption Level (%)	Mixing Time (min)	Dough Characteristics	Machinability
Control	5.9	48.0	6.0	Pliable	Good
Calcium caseinate	5.9	50.5	5.5	Soft	Moderate
High-heat, nonfat, dry milk	5.9	48.0	5.5	Soft	Good
Native whey	5.9	47.5	4.8	Soft	Moderate
Denatured whey	5.8	50.0	5.5	Soft	Good
Native soy	6.0	50.0	5.8	Stiff	Good
Denatured soy	5.8	50.0	5.8	Stiff	Good
Concentrated soy	5.9	51.0	5.8	Stiff	Moderate
Cottonseed flour	6.0	49.7	5.0	Soft	Moderate
Hydrolized soy	5.8	47.9	4.7	Soft	Poor
Hydrolized corn gluten	5.8	48.0	4.7	Soft	Poor
Gluten, 1%	5.9	50.0	6.0	Pliable	Good
Gluten, 2%	5.9	50.5	6.0	Pliable	Good
Gluten, 3%	5.9	50.7	6.1	Pliable	Good

TABLE V
Effects of Added Protein on Tortilla Characteristics

Treatment	Diameter (mm)	Weight (g)	Moisture (%)	Appearance	Puffing
Control	161	41.0	30.4	Smooth	Good
Calcium caseinate	163	42.1	32.1	Rough	Low
High-heat, nonfat, dry milk	157	41.4	30.7	Smooth	Good
Native whey	168	39.0	27.7	Smooth	Low
Denatured whey	168	41.0	30.3	Smooth	Good
Native soy flour	164	42.1	30.8	Smooth	Good
Denatured soy flour	164	40.3	31.3	Smooth	Good
Concentrated soy flour	161	41.3	30.8	Smooth	Good
Cottonseed flour	172	38.9	29.5	Rough	Good
Hydrolized soy	174	40.1	30.0	Smooth	Medium
Hydrolized corn gluten	148	40.8	30.2	Rough	Low
Gluten, 1%	157	41.2	31.1	Smooth	Good
Gluten, 2%	156	41.3	31.3	Smooth	Good
Gluten, 3%	156	41.3	31.7	Smooth	Medium
LSD ($\alpha = 0.05$)	5	0.9	0.7		

Adding 2% wheat gluten increased dough water-absorption level but did not alter mixing time (Tables III and IV). However, mixing stability was increased by adding 3% wheat gluten. Tortilla doughs containing wheat gluten were stronger and more viscoelastic than the control. Longer resting times (up to 40 min) were required for these treatments to produce pliable and machinable dough. Resting time was determined by measuring the diameter of tortillas. Underrested dough produced smaller diameter tortillas and overrested dough produced larger diameter tortillas.

Tortilla Characteristics and Rollability

Control tortillas, prepared from the standard formula, were well puffed and had smooth surfaces (Table V). Physical measurements were: diameter, 161 mm; weight, 41.0 g; and moisture, 30.4%. Control tortillas could be rolled easily up to eight days of storage (Fig. 2).

Tortillas prepared with calcium caseinate had rough surfaces, low puffing, more mass, and more moisture (Table V). These tortillas tended to have more translucent areas than the control tortillas. Storage stability of these tortillas was the same as that of control tortillas (Fig. 2).

Casein absorbs more water during mixing and releases some of the water during baking (Kinsella 1971). This could result in increased weight and good storage stability of tortillas because casein continues to retain water in baked products.

Tortillas containing HHNFDM had good appearance, puffing, physical properties, weight, moisture, and storage stability (rollability) (Table V, Fig. 2). These values were similar to those of control tortillas. Tortillas containing native whey protein had smooth surfaces but low puffing, larger diameter (168 mm), lower weight (39.0 g), and lower moisture content (27.7%) (Table V). Tortillas prepared with native whey protein were less rollable during storage than were control tortillas or those produced from denatured whey (Fig. 2). The poor water-holding capacity of native whey protein in baked products (deVilbiss et al 1947) probably contributed to the increased water loss in the oven.

Denatured whey protein produced tortillas that had characteristics similar to those of control tortillas. However, the diameter of tortillas prepared with denatured whey protein (168 mm) was larger than that of control tortillas.

Tortillas prepared from native and denatured soy flours had smooth surfaces and good puffing (Table V). Slightly less puffing and more translucent areas were noticed in tortillas prepared with soy concentrate. Tortillas containing cottonseed flour had rough surfaces, a larger diameter (172 mm), and less moisture (29.5%) than that of control tortillas (Table V).

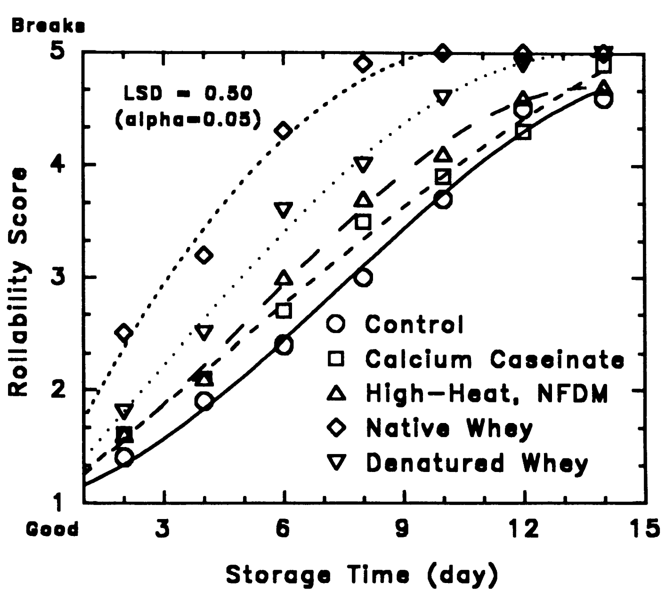

Fig. 2. Effect of storage time on rollability of tortillas containing milk proteins. NFDM = nonfat dry milk.

Tortillas containing oilseed flours were less rollable than the control tortillas (Fig. 3). Tortillas containing heat-denatured soy flour or concentrated soy proteins had better storage stability than those prepared with native soy or cottonseed proteins. Apparently, as reported earlier (Rooney et al 1972), native oilseed proteins adversely affect functionality of wheat gluten.

Tortillas containing hydrolyzed proteins had rough surfaces and poor overall quality (Table V). Storage stability of these tortillas was not evaluated because of poor characteristics, including bad odor and taste and rough surfaces (data not presented).

Tortillas prepared with added wheat gluten tended to have smaller diameters (156–157 mm), medium-to-good puffing, similar weights, and higher moisture contents (Table V). Storage stability of tortillas containing 1% wheat gluten was similar to that of control tortillas (Fig. 4). However, tortillas prepared with 2 and 3% wheat gluten had better storage stability.

The added vital wheat gluten increased the water-absorption level and elasticity and strength of the dough. Functionality of wheat gluten increases when more gliadin and glutenin proteins interact through hydrogen bonding, ionic and hydrophobic association, and secondary structures (Khan and Bushuk 1979). Improved tortilla rollability appears to correspond with increased gluten functionality.

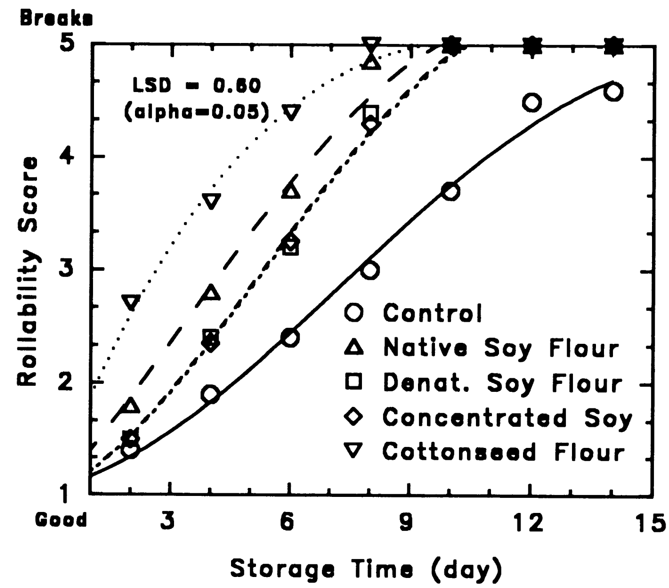

Fig. 3. Effect of storage time on rollability of tortillas containing oilseed proteins.

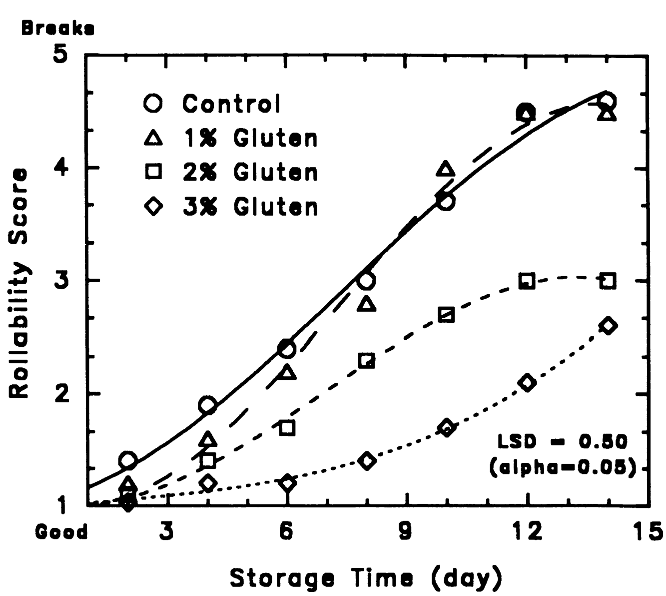

Fig. 4. Effect of storage time on rollability of tortillas containing added vital wheat gluten.

TABLE VI
Taste Panel Evaluation[a] of Wheat Tortillas with Good or Improved Storage Stability

Treatment	Color	Texture	Flavor	Acceptability	Rank[b]
Control	7.2	7.0	7.2	7.3	3.7
High-heat, nonfat, dry milk	6.6	6.1	6.5	6.4	2.8
Denatured whey	6.9	6.6	6.7	6.9	2.9
Denatured soy flour	6.4	6.4	6.4	6.3	2.5
Gluten, 2%	6.8	6.5	7.1	7.0	3.3
LSD ($\alpha = 0.05$)	0.8	0.8	0.8	0.7	0.7

[a] Sensory scale: 1 = dislike, 9 = like.
[b] Ranking: 1 = worst, 5 = best.

Sensory Evaluation

Tortillas containing 2% wheat gluten and control tortillas were consistently evaluated as having good organoleptic properties and were ranked higher than the other treatments (Table VI). The color of tortillas prepared from denatured soy flour was less preferred than that of control tortillas. Texture of tortillas prepared from HHNFDM had a lower score than that of control tortillas. Acceptability of tortillas prepared from HHNFDM and denatured soy flour scored lower than that of the control.

CONCLUSIONS

Most proteins, except native whey and HHNFDM, increased dough water absorption. Doughs containing native whey needed precise mixing time. Denatured whey and soybean proteins in tortilla doughs improved machinability and yielded better tortillas than did native proteins. Wheat gluten significantly enhanced storage stability (rollability) of wheat tortillas, whereas the other proteins decreased storage stability. The viscoelastic character of gluten appears to be partially retained after baking. Thus, gluten can be added to improve the storage stability of protein-fortified wheat tortillas. Adding milk and oilseed proteins improved the nutritional value of wheat tortillas.

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