TORTILLAS: A STUDY OF DEHYDRATED MASAS, TEMPERING TIME AND FATS USED IN TORTILLA CHIP MANUFACTURE

by

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INTRODUCTION

In the United States, the popularity of Mexican food is increasing (Bedolla and Rooney, 1982; Kostecka, 1984). The Mexican restaurant segment has been growing at the rate of 16-19% over the last few years, and now franchised stores are growing at an accelerated rate (Kostecka, 1984). Taco Bell, owned by PepsiCo, Inc., claims to be the fastest growing fast food restaurant chain in America, projecting $4 billion in sales by the year 1990. As of June 1986, Taco Bell operated over 2200 restaurants in 47 states and several foreign countries (Anon., 1986a).

The increasing demand for Mexican cuisine also is reflected by the many corn (maize) and tortilla chips found in today's market (Vandaveer, 1984a). One of the snack food giants, Frito-Lay, now carries four basic corn or tortilla chip products -- Fritos, introduced in 1932; Doritos, introduced in 1961; Tostitos, introduced in 1981; and Santitas, introduced in 1986 (Anon., 1986b). Each is available in several different varieties, ranging from Cool Ranch Doritos to Jalepeno Cheese Santitas.

Traditionally, tortillas have been a Mexican staple and the basis for many Mexican dishes. By the traditional method tortillas were handmade from maize that had been soaked in lime water (a source of alkali). Bressani and co-workers (1958) describe the traditional method for tortilla preparation. This unleavened bread was developed by Central and South American Indians during the prehistoric period. Whole corn kernels were cooked with ashes (a source of alkali) and water to produce nixtamal, and then hand ground into a paste (masa) (Matz, 1984). Today tortillas remain a staple food in Mexico and other Latin American countries. From this basic food a cook can roll or cut, then fry to obtain tacos, tortilla chips, and other similar Mexican type items (Kennedy, 1975; Ortiz, 1979).

A private company that recently has become a dehydrated masa supplier, engaged the Department of Foods and Nutrition at Kansas State University to develop a project to test a new masa flour. The company agreed to fund research comparing their dehydrated masa to other similar masas currently on the market. Early studies for the company involved comparison of masa flours, masa doughs, and soft tortillas.

Several reports dealing with corn tortillas were found; however, the literature concerning fried tortillas and tortilla chips was scarce. The objectives of this study were:

1. To compare the lipid content, moisture content, color, texture (resistance to puncture), and consumer preference of fried tortillas made from three dehydrated masas that are manufactured in the United States.

2. To investigate the effect of tempering on the lipid content, moisture, height, texture (resistance to shear), and color of fried tortillas.

3. To compare the lipid content, moisture content, texture (resistance to shear), color, and flavor of tortillas fried in four types of cooking lipid (fat).

REVIEW OF LITERATURE

Corn for Masa

The response of the corn kernel to masa processing is affected by endosperm texture, endosperm type, and the soundness of the kernels. Method of drying and storing the corn also affects behavior. Kernels that are more horny will take up less water and be less sticky than floury corn kernels. Corn with a very soft endosperm texture, the result of a high starch-to-protein ratio, produces masa that is sticky. Corn with more than 4% cracked kernels will produce sticky masa unless cooking time is changed significantly (Matz, 1984). According to Bedolla and Rooney (1982) there seems to be a relationship between the amount of enzyme-susceptable starch and cooking time.

Because the assessment of the time required for the alkaline treatment is so variable, Martinez-Herrera and Lachance (1979) attempted to develop: 1) a reliable procedure for characterizing different varieties of corn based on their physical characteristics, and 2) a formula to predict time needed for the lime treatment. Within variety, kernal size was evaluated for 20 randomly selected kernels. Two methods were used to determine hardness, a subjective and an objective method. The cooking times at the terminal point of cooking for the different varities of corn were experimentally determined. The scientists found a linear relationship existed between raw corn kernel hardness and time at the terminal point of cooking. They concluded the instrumental measurement of corn kernel hardness could replace the highly variable sensory method when determining the terminal point of cooking in the alkaline treatment of corn.

Producing Masa

Masa can be produced by several methods such as traditional cooking, steam cooking, pressure cooking, and extrusion cooking (Khan et al., 1982; Bedolla et al.,1983). The choice of a processing method affects the characteristics of the tortilla and the cost of production. The corn snack industry has been able to expand because of the wide acceptance of the traditional aroma and texture of alkaline-cooked corn products. In general, corn tortillas and tortilla chips are processed using the traditional method (Matz, 1984; Anon, 1985).

The traditional method for tortilla preparation involves the addition of one part whole corn to two parts of approximately 1% lime solution (Bressani et al.,1958). The alkaline cooking process aids in separating the pericarp from the kernel leaving endosperm and germ together (MacDonald, 1984). The lime treatment operation has a critical effect in tortilla quality (Martinez-Herrera and LaChance, 1979). The mixture is heated to 80 °C for

20 to 45 min, depending on the exact nature of the corn used. The cooked corn is removed from heat and allowed to steep for 8-16 hours. This steeping time allows water to penetrate the kernel and soften the endosperm (Stauffer, 1983). The following day the cooking liquor is decanted, and the corn, now referred to as "Nixtamal", is washed two or three times with water without removing the epicarp or germ. The nixtamal is ground with a stone into a fine dough called "masa", which has a moisture content of approximately 50-60% (Stauffer, 1983). Some of the starch granules have been gelatinized, but if the extent is too great, the masa will be too sticky to process. A dry, crumbly masa could result if not enough starch has been gelatinized because of inadequate cooking. After grinding, masa is formed into pancake shapes and cooked on a hot griddle for 1-2 min on each side (Katz et al., 1974; Bressani et al., 1958).

The optimization of the entire process used to produce masa is controlled using subjective measurements in most cases. The producer must rely on skilled personel to 1) determine the correct amount of cooking for the various corn varieties used, and 2) assess the rheological properties of masa such as plasticity, cohesiveness, and stickiness. Work by Bedolla and Rooney (1982) attempted to predict optimum cooking time of corn using objective measurements. They concluded the optimum cooking time for a particular lot of corn could be predicted by cooking the corn for 70 min and measuring the nixtamal shear force (NSF).

Methods of Production

Until recently, manufacturers have purchased raw corn and produced masa as a step in the production line. New technology has given manufacturers another choice--they can purchase a dehydrated masa from a supplier. This dehydrated masa is a relatively new development which takes the manufacturer out of the corn cooking business (Anon., 1983b; Del Valle et al, 1976). The supplier processes the corn into masa, grinds, dehydrates, and ships the dehydrated masa to the manufacturer. At the manufacturing level, water is added and the masa is ready for cooking. By mixing dehydrated masa flour with water and flattening the dough, fresh tortillas can be prepared within a few minutes -- in contrast to the traditional method which requires up to 12 hrs (Anon., 1985).

The key issue in a consumers' acceptance of tortillas made from dehydrated masa is quality of the finished product. Those suppliers who have developed a dehydrated masa process must maintain high quality in order to be successful in the corn tortilla industry (Anon., 1985). Current issues of trade journals (Anon., 1985; Vandaveer, 1984; Clark, 1984; and Levy, 1985) debate the question of whether manufacturers should purchase dehydrated masa or raw corn. Although the fresh corn approach offers lower raw material costs and is uncomplicated, it requires additional equipment and expertise. Despite the higher raw material cost, dehydrated masa requires only a mixer and eliminates several steps from tortilla production. The production of dehydrated masa using a drum dryer method was shown to be cheaper than the traditional method of masa production. The principle difference in cost was attributed to energy savings (Molina et al., 1977).

Dehydrated Masa Suppliers

A successful pioneer in the production of dehydrated masa is Grupo Maseca, S.A. (Gruma), headquartered in Guadalupe, Neuvo Leon, Mexico. The company started as a small mill producing dehydrated masa in 1952. As of 1984, Gruma had 13 plants worldwide; 11 in Mexico, one in the U.S., and one in Costa Rica (Anon., 1985). Gruma is not the only producer of dehydrated masa. Compania Nacional de Subsistencias Populares (CONASUPO) also produces large qualtities of prepared masa flour. An estimated 60% of the total dehydrated masa in Mexico is supplied by Gruma and 40% is supplied by CONASUPO. Nonetheless, in Mexico the largest share of all manufactured tortillas is still handmade. Gruma's product, Maseca, accounts for only 10% of all tortillas manufactured in Mexico (Anon., 1985).

Processing Methods

Gruma equipment has been developed by the company and is covered by a number of patents. Others have developed similar but distinct methods for producing dehydrated masa. Buhler Brothers, Uzwil, Swizerland, have built plants for producing dehydrated masa. Technology recently developed by dry corn millers in the U.S. is somewhat controversial (Anon., 1985). U.S. munufacturers have converted dry corn meal into dehydrated masa by running the corn meal through an extruder then pulverizing the resulting product.

Regardless of the method of processing used, trade journals emphasize that preparing masa is the most important aspect of tortilla chip production. While masa preparation only represents about 30% of the cost of production, masa accounts for more than 60% of the quality of the finished product (Anon.,1983). This finished product will be only as good as the raw materials. Since every corn variety has different cooking characteristics, masa flours, in turn, will vary in cooking characteristics (Clark, 1984).

Tempering

Commercially, tortilla chips are produced similar to the traditional hand process of tortilla making. The masa is rolled out into a thin sheet, cut into the desired shape and transported into an open flame oven. The heat sets the structure, drives off most of the moisture, and changes the flavor slightly by creating a small amount of browning. Before frying, the chips are held in a tempering chamber where moisture is equilibrated throughout the chip (Stauffer, 1983). This reduces puffing caused by steam escaping from the center of the tortilla chip as it is fried (Pallares, 1981).

Frying

For the final step, the chips are very briefly deep fried to create a crisp texture, salted, and packaged (Stauffer, 1983). During frying, the lipid acts as a heat transfer medium. First, the tortilla is dehydrated and then new flavors are generated and concentrated due to reactions such as pyrolysis, browning, or the Maillard reaction. In the process of heating, corn proteins are denatured and starch gelatinized. The spaces vacated by water shrink. Oil is absorbed and becomes part of the tortilla chip.

Lipid Content

A corn chip may contain 30% or more of its frying medium. Work by Smith and co-workers (1985) determined the total lipid content and the fatty acid composition of three brands of tortilla chips (g/ 100g edible portion). They found total lipid values to range from 22.9 - 26.4g with a mean of 24.1g and standard deviation 2.0. Greatest variation in fatty acid composition was in the percentages of elaidic, linoleic, and oleic acids. Smith et al. (1985) attributed these differences to the different types of frying oils used, such as palm and sunflower, and the extent of hydrogenation of these oils.

Tarone and Matthews (1982) reported the proximate and mineral composition of taco shells. A taco shell is a corn tortilla that has been fried, using a method similar to that used in the production of tortilla chips. The data presented by Tarone and Mattews represent the data on baked products in the United States Department of Agriculture (USDA) Nutrient Data Bank. Amount of lipid in taco shells (g/ 100g edible portion) was reported as 18.6 grams.

Type of Lipid Used

If the oil used in frying is bland, a good portion of the tortilla will be bland. If the oil has flavor, the tortilla also could be flavorful, depending on the stability of the flavoring components (Vandaveer, 1984b). Frying oils generally are categorized as follows: liquid vegetable oil, hydrogenated oils, processed oils which may be hydrogenated and precipitated with melted saturated fats (Vandaveer, 1985). Tortilla chip manufacturers generally do not use lard except in animal fat products such as pork skins (Vandaveer, 1984b). Some tortilla manufacturers use a processed vegetable oil which has a slight flavor. Generally, a processed soybean oil is used because of cost. Processed corn and cottonseed oils may provide a more flavorful tortilla chip. A processed corn oil having a 500 hr Active Oxygen Method (AOM) value gives a sweet buttery, flavor to tortilla chips (Vandaveer, 1984b). When chips are fried in a liquid vegetable oil, such as cottonseed, soybean, peanut, or sesame seed, they may have slightly different flavors from those fried in hydrogenated oils. Generally, when oils are hydrogenated to an Iodine Value (IV) of 80-88, corn chips fried in them tend to be blander. Highly hydrogenated oils or fats tend to conceal desirable parched corn flavors in corn chips but not in tortilla chips (Vandaveer, 1984b). If corn chips are fried in lightly hydrogenated bean oils, the "hydrogenated" flavors can be detected only by trained experts (Vandaveer, 1985).

Sensory Analysis

Preference Test

Hedonic rating scales can be used to measure the level of liking for a food by a population. These scales are converted easily to numerical scores and statistical analysis is applied to determine difference in degree of liking between samples (IFT Sensory Evaluation Division, 1981). By indicating the degree of liking of each sample, the test subject indicates whether all samples are equally liked, one is liked more than the other, or whether all are relatively good or relatively poor products. This test can be used effectively with central-location consumer panels (Hirsh, 1975).

Descriptive Analysis

The rating scale evaluation of intensity was designed to measure the preceived intensity of some specified characteristic or attribute of material (ASTM 434, 1968). The dimension of evaluation may be general (for example, overall flavor intensity) or specific (for example, corn flavor in a fried tortilla). A series of samples are served to trained subjects who have been specifically instructed in regard to the attribute to be evaluated. Each sample is evaluated for every attribute being tested.

Stone et al. (1974) developed a scaling method that met requirements of complex products. The scale was an interval scale with a line six inches long with anchor points 1/2 inch from each end; usually, but not necessarily, a third anchor at midpoints; and usually one word or expression at each anchor. The subject places a vertical mark across the line at that point which best refects the magnitude of his or her perceived intensity of that attribute.

McLellan and Cash (1983) indicated that conducting sensory evaluations with the use of a microcomputer was beneficial and feasible. A microcomputer was integrated with a sensory evaluation booth for a Quantitative Descriptive Analysis (QDA) panel conducting ordor analysis of raw carrot purees. The approach of evaluation used emulated the paper ballot method of input. The first portion of the program established the conditions for the experiment. The sensory analyst in charge of the experiment inputed the number of samples, panel number, sample number, and attributes to be tested. Each panelist entered his or her name, and the computer program automatically randomized the order in which samples were to be evaluated. McLellan and Cash (1983) reported the amount of time required to answer questions did not differ greatly from that required by the traditional paper ballot method. The researchers noted the time required to measure and record data was reduced significantly using the computer method of evaluation.

PRELIMINARY STUDY

EVALUATION OF DEHYDRATED MASA FLOURS, DOUGHS, AND SOFT TORTILLAS

MATERIALS AND METHODS

Materials

Four types of flour were used for this study:

1. Lincoln Grain - #344 Golden Masa Flour
2. Lincoln Grain - #344 Golden Masa Flour, enriched
3. Valley Grain Products - Masa Mixta (#2Y) Yellow Flour
4. Azteca Milling Co. - Maseca Yellow Flour

Preparation

In preliminary laboratory work, amounts of distilled water were added to the masa. Optimal water to flour ratios from which an acceptable product could be made were determined. This method of tortilla preparation was based on an earlier similar project comparing two commercially produced dehydrated masas. Both Lincoln Grain dehydrated masas required 90 ml of distilled water per 100 g of dehydrated masa. Per 100 g of dehydrated masa, distilled water amounts of 110 ml for Valley Grain and 120 ml for Azteca were used. These ratios resulted in tortillas with similar rheological characteristics. All were mixed by hand only until all of the masa had been moistened (approx 1 min). Thirty-five g of the masa dough were weighed, hand-rolled into balls, and pressed between two sheets of waxed paper using a standard tortilla press. The waxed sheets were peeled off carefully, and uncooked tortillas were placed on an electric griddle heated to 400°F. After 90 sec, the tortillas were turned then cooked an additional 90 sec on the second side. After cooking, the tortillas were wrapped in cloth towels, placed in Pyrex bowls, and kept warm until needed.

Test Methods

1. Flour Evaluation

For all dehydrated masa flour evaluations, random samples were taken from fifty lb bags of flour stored at room temp. For each of the four dehydrated masas, nine instrumental measurements were made.

Proximate Analysis

Both a Five-Step Proximate Analysis and a Neutral Detergent Fiber approximation were determined following AOAC (1980) methods.

pH

pH of the flours was determined on duplicate samples following AOAC (1980) procedures and using a Horizon pH meter (Model 5998-10).

Granulation Size

Granulation size was determined based on the percentage of a 100 g sample remaining on each of ten screens (10, 16, 20, 28, 35, 70, 100, 150, 200, 270 - Tyler Screen no) following a 10 min test with a Ro-Tap method of shaking (Anon., 1961). Granulations were calculated according to Pfost Headley, American Society of Agri. Engineers Rec. R246.1.

Color

L-, a-, b- color values were determined for the flours using a HunterLab Spectrophotometer (model 554P-5). Samples of dehydrated masa flour were placed in optically clear plastic bags for presentation to the spectrophotometer. The incident light in the instrument was Illuminant C, as it emits the most uniform radiant energy. The instrument was standardized using a white ceramic plate with an L-value of 100.

2. <u>Dough Evaluation</u>

For each of the four masa doughs, four instrumental measurements were made.

pH

pH of the masa dough was determined on duplicate samples following AOAC (1980) methods and using a Horizon pH meter (Model 5998-10).

Color

Color differences were determined using the HunterLab Spectrophotometer. Dough was pressed into flat disks using a standard tortilla press and wrapped in optically clear plastic for L-, a-, b- determinations. For each replicate, readings were taken four times, turning the pressed dough by quarter turns each time to insure uniformity.

Spreadability

A Carver Laboratory Press was utilized to determine the spreadability of each of the dough types. Five g of masa dough was flattened under 1000 lbs of pressure. The resulting area was measured in sq cm using a planimeter.

Shelf Life

Shelf life of each type of dough was determined by individually packaging uncooked soft tortilla samples in polyethylene bags and storing at 5°C. Two uncooked tortillas from each batch were observed daily at a specific time for visible signs of mold growth. Shelf life was calculated based on the number of days each sample maintained a mold-free appearance.

3. Soft Tortilla Evaluations

Five instrumental measurements were completed for soft tortillas made from each of the dehydrated masas. A study of consumer preference by Latin American subjects study and a flavor/texture profile were determined for soft tortillas made from each of the unenriched dehydrated masas.

pH

pH of the soft tortillas was determined on duplicate samples following AOAC (1980) methods and using a Horizon pH meter (Model 5998-10).

Moisture

Moisture content of the soft tortillas was determined using a Brabender Semi-Automatic Rapid Moisture Tester. For each replication, 10 g duplicate samples were torn into approx 2-cm sq pieces and dried at 120°C for 2 hrs.

Color

Color measurements were taken using a HunterLab Spectrophotometer (D54P-5). Soft tortillas were cooled, wrapped in optically clear plastic and presented to the machine. Each side of the tortilla was read twice, for a total of 4 readings for each sample.

Texture

The tortillas' texture was measured as resistance to puncture using an Instron Universal Testing Machine (IUTM) (Model 1122). Using a 0.7 cm rod, tortillas were punctured 10 times each, following a similar pattern. Crosshead speed and chart speed of the IUTM were set at 0.2. Peak heights were measured, and the average of the ten measurements for each replicate was recorded.

Shelf Life

Freshly cooked tortillas were cooled and individually sealed in polyethylene bags in order to determine shelf life. The tortillas were stored at 5°C, and shelf life was determined on a daily basis.

Sensory Evaluation

Profiling. An overall comparison of the aroma, flavor, and texture of soft tortillas made from different dehydrated masas was determined by four trained members of the Sensory Center of the Kansas State University Department of Foods and Nutrition. Their findings were completed after 10 one-hour sessions (Appendix A).

Consumer Panel. Eighteen Latin American or Puerto Rican students attending KSU and/or their spouses participated in a panel to determine consumer preferences.

A three-digit randomized number was given to each type of soft tortilla. Soft tortillas were presented simultaneously along with a questionnaire (Appendix B). Order of tasting was randomly determined on each questionnaire.

Data Analysis

Three replications were used for flour and dough evaluations; four replications were used for soft tortilla evaluations. Data from these measurements were analyzed by Analysis of Variance (ANOVA) using a complete block design (Snedecor and Cochran, 1980). Least square means were compared to identify treatment effects.

PRELIMINARY STUDY

RESULTS AND DISCUSSION

Flour Evaluation

There were no significant differences among flours in % fat, % crude fiber, % NDF, or granulation (Table 1). Azteca dehydrated masa flour had a lower ($p<0.05$) % moisture than did the other flours tested (Table 2). Protein content varied significantly ($p<0.05$) among the masa flours (Table 1). Azteca flour had the highest level of protein, and Valley Grain flour had the lowest. However, Azteca flour was not significantly different from Lincoln Grain unenriched flour, and Lincoln Grain enriched was not different ($p<0.05$) from Valley Grain. The two Lincoln Grain dehydrated masa flours were not different ($p<0.05$) from each other (Table 2). There was a difference ($p<0.001$) in % ash content among the flours (Table 1). Azteca flour had a higher ash content than did the other three (Table 2). pH differed ($p<0.001$) among the dehydrated masa flours. Valley Grain masa was the most alkaline while Azteca was the least. Both Lincoln Grain masa flours were the same (Table 2).

The dehydrated masas differed in color (Table 1). Valley Grain flour was more reddish-yellow (higher a- and b- values) than were the other flours (Table 2). All samples except Valley Grain exhibited a slight greenish cast (negative a-value).

Table 1. Mean[1] squares and F-values from ANOVA of dehydrated masa flour evaluations.

Variable	Mean Square	F-Value
% Moisture	1.652	6.72*
% Fat[2]	0.258	0.65
% Protein	0.464	7.27*
% Crude Fiber	0.300	2.15
% NDF[3]	8.992	3.98
% Ash	0.030	19.44***
pH	0.161	68.18***
Granulation[4]	0.016	1.36
Color[5]		
L - value	84.13	5.12*
a - value	8.15	10.91**
b - value	9.09	1.94

*, $p<0.05$; **, $p<0.01$; ***, $p<0.001$

[1]mean of 3 samples

[2]ether extract

[3]neutral detergent fiber

[4]based on % of a 100 g sample remaining on each of ten screens (10, 16, 20, 28, 35, 70, 100, 150, 200, 270 - Tyler Screen no.)

[5]measured by HunterLab Spectrophotometer

Table 2. Least square means[1] for evaluation of dehydrated masa flours.

VARIABLE	AZ[2]	VG[2]	LU[2]	LE[2]
% Moisture	7.91[b]	9.67[a]	9.02[a]	9.17[a]
% Fat[3]	5.65[a]	5.03[a]	5.23[a]	5.58[a]
% Protein	10.27[a]	9.32[c]	9.94[ab]	9.77[bc]
% Crude Fiber	1.70[a]	1.50[a]	2.15[a]	2.11[a]
% NDF[4]	7.07[b]	8.69[ab]	11.45[a]	11.17[a]
% Ash	1.83[a]	1.61[b]	1.67[b]	1.62[b]
pH	7.05[c]	7.73[a]	7.50[b]	7.46[b]
Granulation[5]	1.27[a]	1.37[a]	1.44[a]	1.41[a]
Color[6]				
L - value	84.15[a]	81.08[c]	83.92[b]	84.54[b]
a - value	-0.41[b]	0.06[a]	-0.61[bc]	-0.78[c]
b - value	20.73[b]	21.97[a]	20.54[b]	20.38[b]

[1]mean of 3 samples

[2]AZ - Azteca; VG - Valley Grain; LU - Lincoln Grain, unenriched; LE - Lincoln Grain, enriched.

[3]ether extract

[4]neutral detergent fiber

[5]based on % of a 100 g sample remaining on each of ten screens (10, 16, 20, 28, 35, 70, 100, 150, 200, 270 - Tyler Screen no.)

[6]measured by HunterLab Spectrophotometer

[abc]Means with different letters in the same row differ significantly ($p<0.05$).

Dough Evaluation

As in dehydrated masa flour pH, masa dough pH differed ($p<0.001$) (Table 3); Valley Grain masa dough was the most alkaline while Azteca masa dough was the least alkaline. Lincoln Grain masa doughs were different from each other. Lincoln Grain unenriched masa dough was more alkaline than Lincoln Grain enriched masa dough (Table 4). Spreadability varied ($p<0.01$) among doughs (Table 3). Valley Grain had the highest spreadability, and Lincoln Grain enriched masa dough had the lowest spreadability (Table 4). However, Valley Grain dough was not significantly more spreadable than Lincoln Grain unenriched masa dough. Lincoln Grain unenriched masa dough was not significantly more spreadable than Lincoln Grain enriched dough.

The masa doughs differed in all color values ($p<0.001$) (Table 3). Lincoln Grain enriched masa dough was the darkest (lowest L- value) (Table 4). It also was the only dough having a greenish cast. Lincoln Grain unenriched dough was the most yellow while Lincoln Grain enriched dough was the least. Azteca dough was the lightest, and Valley Grain dough had a slight reddish cast.

Table 3. Mean[1] squares and F-values from ANOVA of masa dough evaluations.

Variable	Mean Square	F-Value
pH	0.21	76.82***
Spreadability[2]	23.51	7.43**
Shelf life[3]	1.00	0.30
Color[4]		
L - value	27.20	358.93***
a - value	3.01	320.28***
b - value	9.98	166.91***

*, $p<0.05$; **, $p<0.01$; ***, $p<0.001$

[1]mean of 3 samples

[2]measured by Carver Press

[3]at 3-5°C

[4]measured by HunterLab Spectrophotometer

Table 4. Least square means[1] for evaluation of masa doughs.

VARIABLE	AZ[2]	VG[2]	LU[2]	LE[2]
pH	7.03[d]	7.74[a]	7.65[b]	7.54[c]
Spreadability[3]	60.61[ab]	62.20[a]	58.29[bc]	57.43[c]
Shelf life[4]	20.33[a]	19.33[a]	19.33[a]	20.33[a]
Color[5]				
L - value	72.03[a]	67.78[c]	68.41[b]	63.06[d]
a - value	0.33[b]	1.07[a]	0.32[b]	-1.78[c]
b - value	24.19[b]	23.54[c]	25.26[a]	20.11[d]

[1]mean of 3 samples

[2]AZ - Azteca; VG - Valley Grain; LU - Lincoln Grain, unenriched; LE - Lincoln Grain, enriched.

[3]as measured by Carver Press determination

[4]at 3-5°C

[5]measured by HunterLab Spectrophotometer

[abcd]Means with different letters in the same row differ significantly ($p<0.05$).

Soft Tortilla Evaluation

There were no significant differences among soft tortillas in tenderness or shelf life (Table 5). pH differed ($p<0.001$) among the soft tortillas. Lincoln Grain unenriched tortillas were the most alkaline, and Azteca tortillas were the least alkaline. Valley Grain tortillas and Lincoln Grain unenriched tortillas were tortillas and Lincoln Grain unenriched tortillas were the most alkaline, and Azteca soft tortillas were the least alkaline. Valley Grain soft tortillas and Lincoln Grain soft tortillas were not different from each other (Table 6). Moisture content varied ($p<0.01$) among soft tortillas (Table 5). Azteca soft tortillas and Valley Grain soft tortillas had a higher moisture content than either of the Lincoln Grain soft tortillas. However, Azteca soft tortilla did not differ from Valley Grain soft tortillas and Lincoln Grain unenriched tortillas did not differ from Lincoln Grain enriched tortillas (Table 6).

As seen on the masa dough color values, the soft tortillas differed ($p<0.001$) in all color values (Table 5). Lincoln Grain unenriched soft tortillas were darker than those made from Azteca and Valley Grain flours. However, yellowness (b-value) was the same for all three unenriched tortillas (Table 6). Again, Lincoln Grain enriched tortillas had the lowest L-, a-, and b- values and were the only soft tortillas having a slight greenish cast. Azteca soft tortillas and Valley Grain tortillas were not different from each other for L-, a-, or b- values (Table 6).

Table 5. Mean[1] squares and F-values from ANOVA of soft tortilla evaluations.

Variable	Mean Square	F-Value
pH	0.18	63.71***
% Moisture	14.08	8.05**
Tenderness[2]	0.15	0.51
Shelf life[3]	7.15	0.97
Color[4]		
L - value	70.79	45.27***
a - value	1.84	30.74***
b - value	10.37	33.93***

*, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$

[1]mean of 3 samples

[2]measured as resistance to puncture using IUTM

[3]at 3-5°C

[4]measured by HunterLab Spectrophotometer

Table 6. Least square means[1] for objective measurements of soft tortillas.

VARIABLE	AZ[2]	VG[2]	LU[2]	LE[2]
pH	7.09[c]	7.63[b]	7.75[a]	7.66[b]
% Moisture	44.99[a]	45.76[a]	40.67[b]	41.30[b]
Tenderness[3]	7.25[a]	7.08[a]	7.23[a]	7.08[a]
Shelf life[4]	20.33[a]	19.33[a]	19.33[a]	20.33[a]
Color[5]				
L - value	61.88[a]	61.00[a]	54.29[b]	50.56[c]
a - value	0.96[b]	0.76[b]	1.92[a]	-0.39[c]
b - value	23.67[a]	22.80[a]	23.64[a]	19.14[b]

[1]mean of 4 samples

[2]AZ - Azteca; VG - Valley Grain; LU - Lincoln Grain, unenriched; LE - Lincoln Grain, enriched.

[3]measured as resistance to puncture using IUTM

[4]at 3-5°C

[5]measured by HunterLab Spectrophotometer

[abcd]Means with different letters in the same row differ significantly ($p<0.05$).

MAJOR STUDY

MATERIALS AND METHODS

Materials

Masa

Three brands of dehydrated masa were obtained from Lincoln Grain, Inc. of Atchinson, Kansas:

(1) Lincoln Grain, Inc. - #344 Golden Masa

(2) Valley Grain Products - Masa Mixta (#2Y) Yellow

(3) Azteca Milling Co. - Maseca Yellow

Fats

For Parts 1 and 2 of this study, tortillas were fried in partially hydrogenated soybean oil supplied by Lincoln Grain, Inc. For Part 3, tortillas made from Lincoln Grain, Inc. - #344 Golden Masa were fried in four types of lipids:

(1) King Taste Corn Oil - a refined, bleached, and deordorized corn oil.

(2) Liquid Super Fry - a fluid frying shortening made from partially hydrogenated soybean oil with added TBHQ and methyl silicone.

(3) Sta-bland - a high stablity salad oil made from partially hydrogenated soybean oil.

(4) Fluid Fry - a pourable frying shortening made from 100% beef fat (Duxbury, 1986).

Three of the fats were supplied by Capital City Products Company, Columbus, Ohio. The fourth lipid was supplied by Rustco Products Company, Denver, Colorado.

No seasonings were added to the tortillas, and distilled water was used in preparation.

Preparation

The tortillas were made by the traditional Mexican method (Katz and Hediger, 1974; Bressani et al., 1958). Optimal water to flour ratios were determined in preliminary work. The milliliters of distilled water to gram of flour ratios were as follows: Lincoln Grain 0.9, Valley Grain 1.1, and Azteca 1.2. These ratios gave dough with similar rheological characteristics.

Doughs were mixed by hand only until all the flour had been moistened (approx. 1 min.). Thirty-five grams of dough were weighed, hand-rolled into balls, and pressed between two sheets of waxed paper using a standard tortilla press. The waxed sheets were peeled off carefully, and tortillas, measuring 11.5 - 12.5 cm in diameter and 0.2 to 0.3 cm in thickness, were placed on an electric griddle heated to 204 °C (400 °F). After 90 sec, the tortillas were turned and cooked an additional 90 sec on the second side. After cooling to ambient temperature of approx. 22 °C (72 °F), the tortillas were fried in hot (200-210 °C) oil for one min on each side. The fried tortillas were drained on paper towels to remove excess oil. After cooling 15 to 30 min, color, moisture, and texture measurements were obtained.

For consumer product testing in Part 1, soft corn tortillas were mixed, pressed, and cooked by the traditional Mexican method as stated above. These were refrigerated until the day of the panel (1-2 days). The day of the testing the soft tortillas were cut into sixths and fried in hot (204° C) oil 20-30 sec on each side. The chips were cooked throughout the day and held in a warm oven (200° F) until needed, but no longer than 20 min.

For sensory evaluation during Part 3, tortillas were cooled 3-5 min then cut into sixths using kitchen scissors (Appendix C). Sensory measurements were determined within 30 min after cooling to assure maximum flavor.

Test Methods

1. Comparison of fried tortillas made from different masas

Four instrumental measurements plus a consumer preference panel were used to compare tortillas made from three dehydrated masas. Instrumental measurements included moisture content, fat content, color, and resistance to puncture. Four replicate samples were used.

Color

Color measurements were taken using a HunterLab Spectrophotometer (D54P-5). Samples were torn to fit an optically clear cylinder cup. The first cooked side of the tortilla faced toward the machine. Measurements of L-, a-, b-, and percentage reflectance at 520 nm were recorded, since this wavelength characterizes the color yellowness (MacDonald, 1984). The incident light in the instruments was Illuminant C, as it emits the most uniform radiant energy. The instrument was standardized using a white ceramic plate with an L- value of 100. Saturation Index (S.I.) was calculated using the following formula:

$$S.I. = a^2 + b^2$$

This value was calculated based on results by MacDonald (1984) indicating L-values and S.I. values best indicate the color of corn gruels, which are similar in color to corn tortillas.

Texture

Textural evaluation was measured with an Instron Universal Testing Machine (IUTM)(Model 1122) with modification of a procedure described by Harbers et al (1984). Using a 7-mm rod, each tortilla was punctured 5 times using a similar pattern. Each puncture gave two peaks, resulting from the two layers the tortilla separated into as it was fried; and both were measured. Two tortillas from each tempering period were punctured, using a full scale load of 0.2 (2 kg). Chart and crosshead speeds of 100 mm/min were used. The peak height reported by the IUTM was an indication of hardness in kilograms.

Moisture

Moisture content of tortillas was determined using a Brabender Semi-Automatic Rapid Moisture Tester. For each replication, 10 g duplicate samples were torn into approximately 2 cm square pieces and dried to constant weight at 120 °F (Harbers et al., 1984).

Fat

Fat content was determined by Soxlet method of ether extract (AOAC 1980). Samples were ground for 30 sec using a Waring Blender. After drying, two g of ground sample were analyzed using a Soxlet extractor.

Sensory Analysis

A consumer product test was conducted to determine consumer degree of liking and overall preference of fried tortillas made from different dehydrated masas. On March 30, 1985, persons touring Justin Hall at Kansas State University were asked to participate in a consumer taste panel. Testing was done in an open laboratory area. Consumers were drawn into the room by a poster located in the hallway which read, "Homemade Tortilla Chip Tasting". A display emphasizing Mexican cooking also was located in the room.

Next to the display table, three baskets of tortilla chips were kept warm using a warming tray. The baskets were marked with three-digit randomized numbers. Those persons who agreed to participate were given a small paper plate marked with the three basket numbers. Participants, assumed to be typical consumers, placed a chip from each basket over the corresponding number marked on their plate. Most panelists took advantage of available seating to complete their questionnaire (Appendix D). One hundred seventy-eight persons participated. All questionnaires were marked in random order with the three-digit numbers so that each chip had an equal chance of being tried first. Panelists were urged to rinse with distilled water between samples.

Panelists were asked to mark a six-point hedonic scale indicating their degree of liking. For statistical analysis, this information later was given a numerical value (6 = like very much, 5 = like moderately, 4 = like slightly, 3 = dislike slightly, 2 = dislike moderately, and 1 = dislike very much).

2. Investigation of Tempering

Time between cooking and frying tortillas was varied to determine the effect of tempering. Cooked tortillas were allowed to set 15, 30, 60, 90 and 120 minutes before frying. Five instrumental measurements were used to evaluate the effect of tempering on fried corn tortillas: color, resistance to shear, moisture content, fat content, and stack height. Four replicate samples were evaluated for each instrumental measurement.

Color

A HunterLab Spectrophotometer (D54P-5) was used to determine color difference among samples. Tests used were the same as those used for comparison of fried tortillas.

Texture

Textural evaluation was determined using an Instron Universal Testing Machine (Model 1122). Using a blunt blade, each tortilla was sheared in the center (Appendix E). Two tortillas from each tempering period were completely sheared using a full scale load of 1.0 (10 kg). Chart and crosshead speeds of 100mm/min were used. Maximum height of the force-distance curve for shear was measured as an indicator of sample hardness.

Moisture

Moisture content was analyzed using 2 g ground tortillas. Samples were dried using AOAC method 14.003 (1984). Tortilla samples were added to pre-weighed aluminum boats, dried overnight in a Thermotainer drying oven (Model PW-1) at 150°C, cooled in a dessicator, and re-weighed.

Fat

Fat content was determined using a Soxlet method of ether extraction (AOAC 1980). (See Part 1 - Comparison of soft tortillas from different masas.)

Height

To measure the effect of tempering on tortilla puffing, four fried tortillas from each tempering time were randomly stacked four different ways. These heights were measured using a metric scaled ruler. Stack height was recorded in cm and averaged for each tempering time.

3. Comparison of fats

Three instrumental measurements plus a descriptive sensory panel were used to compare the effect of frying tortillas in four types of lipid.

Color

Color was measured using the same method as described in Part 2 - Effect of tempering.

Moisture

Moisture content was measured using the same method as described in Part 2 - Effect of tempering.

Fat

Fat content was measured using the same method as described in Part 2 - Effect of tempering.

Sensory Analysis

Six panelists from the Department of Foods and Nutrition were trained during two 1-hour sessions. Ten attributes to be examined were chosen based on work by Feria-Morales and Pangborn (1983), and suggestions given by Vandaveer (1984). These were: corn taste, soybean taste, lardy taste, limey taste, toasty taste, sweet taste, corn aftertaste, bitter aftertaste, sweet aftertaste, and browned aftertaste. References used are given in Appendix F. Scoring was done using a ballot consisting of ten 6-inch unmarked lines with anchor points 1/2 inch from each end (Appendix G). Samples were served in covered glass custard cups. Each cup was marked with a randomized 3-digit number chosen from a table of randomly assorted digits (Snedecor and Cochran, 1980).

During the first training session, panelists were familiarized with the score cards, terminology, and computers to be used in the study. Individual reference samples were given for each of the ten flavor attributes measured. Panelists used the term "lardy" to refer to the taste of animal fat. Those references were the high anchor on the scorecard. After tasting all references, panelists were given tortilla pieces from each of the treatments. The panelists evaluated the four treatments and discussed their results. Panelists believed edge pieces and center pieces on the same tortilla had different flavor intensities. Therefore, the group decided to evaluate only the center bites of their 1/6 triangular shaped pieces (Appendix C). Panelists were satisfied with all attributes suggested and chose not to delete or add to the attribute list.

During the second training session, panelists were asked to determine the maximum number samples they could evaluate before becoming fatigued. Individual references samples were provided for each panelist. After tasting each sample, panelists cleansed their palate with Jonathan apple slices and rinsed with deionized distilled water. The group was able to evaluate six samples before becoming fatigued. Scorecards were provided during training sessions. Actual data were collected from the panelists using a computerized scorecard. A computer program based on work by McLellan and Cash (1983) was used. The co-workers reported that use of computer scoring reduced time required to measure and record data. During training, panelists familarized themselves with the directions for computer scoring. Additional help was offered for those unfamiliar with the procedure.

Over a period of three weeks, eight testing sessions were held. All sessions were held in individual, well-lit booths containing a computer terminal. At each session, panelists evaluated six samples. Samples were served at room temperature within 40 min after the tortillas had been fried. Two 1/6 triangular shaped pieces of tortilla were placed in each glass custard cup. Each panelist was provided six samples, a glass of deionized distilled water, and two slices of Jonathan apple. Reference samples for each attribute were available to the panelists. Due to computer difficulty, four session were conducted using a hand score sheet which was similar to the computer scorecord.

Data analyses

A complete block design was used for the study. After data were collected, Analysis of Variance (ANOVA) was used to analyze data. For descriptive analysis of tortillas fried in different oils, an incomplete block design was used due to missing data. Least square means were compared to determine treatment effects. When F-values were significant, Least Significant Differences were calculated at 5% level to determine significance of difference between means (Snedecor and Cochran, 1980). The Analysis of Variance tables for each of the data sets were:

1. Comparison of Masa

A. Instrumental Measurements

Source of Variation	Degree of Freedom
Treatment (masa)	2
Error	9
Total	11

B. Preference Test

Source of Variation	Degree of Freedom
Consumer	177
Treatment (masa)	2
Error	354
Total	533

2. Effect of Tempering

Source of Variation	Degree of Freedom
Treatment (time)	4
Error	15
Total	19

3. Comparison of Fats

A. Objective Measurements

Source of Variation	Degree of Freedom
Treatment (oil)	3
Error	12
Total	15

B. Descriptive Analysis

Source of Variation	Degree of Freedom
Treatment (oil)	3
Panel Session	7
Error	21
Total	31

RESULTS AND DISCUSSION

1. Comparison of Soft Tortillas from different masas

There were no significant differences in moisture, fat, hardness, b-value, or saturation index among fried tortillas made from the three masas (Table 7). Moisture content varied from 18.29 to 24.06%, fat content varied from 18.70 to 20.49%, hardness varied from 12.06 to 13.64, tansmittance varied from 20.23 to 29.39%, b-value varied from 17.02 to 20.03, and saturation index varied from 320.89 to 407.57 (Table 8). Tarone and Matthews (1982) reported taco shells to be 18.6% lipid and 4.4% water. Taco shells are characteristically lower in moisture than tortillas which have been fried (Pallares, 1981; Bedolla and Rooney, 1982). Tan et al. (1985) reported lipid content of commerical tortilla chips to be 22.9-26.4%. These are higher values than those seen in this study (18.70-20.49). An explanation for the difference is that the surface to area volume, cooking time, and extent of oil drainage may vary between the traditional method of tortilla chip making and the commerical method of manufacturing tortilla chips.

Reflectance and L-values differed ($p<0.05$) among masas (Table 7). Azteca masa gave the lightest tortillas, while Lincoln Grain masa gave the darkest tortillas (Table 8). A-value differed ($p<0.01$) among tortillas, with Lincoln Grain tortillas having a higher a-value than tortillas made from either Azteca or Valley Grain masa (Table 8).

Table 7. Mean[1] squares and F-values from ANOVA of fried tortillas made from different masas.

Variable	Mean Square	F-Value
% Moisture	33.38	1.09
% Fat[2]	2.56	0.75
Hardness[3]	3.00	0.20
% Reflectance[4]	83.88	6.59*
Color[5]		
L - value	84.13	5.12*
a - value	8.15	10.91**
b - value	9.09	1.94
Saturation Index[6]	7659.10	1.25

*, $p<0.05$; **, $p<0.01$; ***, $p<0.001$

[1]mean of 4 samples

[2]ether extract

[3]measured as resistance to puncture using IUTM

[4]reflectance at 520nm wavelength

[5]measured by HunterLab Spectrophotometer

[6]Saturation Index = $a^2 + b^2$ as measured by HunterLab Spectrophotometer

Table 8. Least square means[1] for comparison of fried tortillas made from different masas.

Variable	Azteca	Lincoln Grain	Valley Grain
%Moisture	24.06^{a}	21.33^{a}	18.29^{a}
Fat[2]	18.95^{a}	20.49^{a}	18.70^{a}
Hardness[3]	12.06^{a}	13.64^{a}	13.46^{a}
% Reflectance[4]	29.39^{a}	20.23^{b}	25.03^{ab}
Color[5]			
L - value	59.56^{a}	50.38^{b}	54.98^{ab}
a - value	2.29^{b}	4.63^{a}	2.04^{b}
b - value	20.03^{a}	17.02^{a}	18.68^{a}
Saturation Index[6]	407.57^{a}	320.89^{a}	353.78^{a}

[1] Each value is a mean for four determinations.

[2] ether extract

[3] resistance to puncture as measured by IUTM

[4] reflectance at 520nm wavelength

[5] measured by HunterLab Spectrophotometer

[6] Saturation Index = $a^2 + b^2$ as measured by HunterLab Spectrophotometer.

[abc] Means with different letters in the same row differ significantly ($p<0.05$).

Preference test results indicated no significant difference among the tortilla chips made from the masas (Table 9). All rated slightly above the "like slightly" rating category. Candid comments from consumers during the tasting were that if the chips were not eaten shortly after frying, they became "chewy", "hard", "tough", and "greasy". Preparation does not seem to be at fault, as chips were cooked periodically throughout the testing to assure freshness. The problem seems to be two-fold. First, consumers expect a "tortilla chip" to have the texture of those commercially manufactured and sold in stores. This chip is very thin and is a result of a manufacturing technique which mass produces chips from a thin layer of dough. Second, tortilla chips which are made in the home typically are made from frying soft corn tortillas made by the traditional Mexican method (Kennedy, 1975) or frying commerially made tortillas (Ortiz, 1979). Thus, there is a large difference between what consumers expect and are used to, and what they would be able to create in their own home by standard methods.

Table 9. Consumer preference mean[1] values[2] and significance for tortilla chips made from different masas.

Flour type	Mean
Valley Grain, Inc.	4.07[a]
Lincoln Grain, Inc.	4.13[a]
Azteca Milling Co.	4.26[a]

[1]Each value is a mean for 178 determinations.

[2]Using a 6-point hedonic scale, 1 = dislike very much, 6 = like very much.

[abc]Means with the same letter are not significantly different ($p<0.05$).

2. Investigation of Tempering

There was no significant difference among temper times in moisture, fat, break, height, transmittance, color values, or saturation index (Table 10). Average stack height tended to be highest after tempering 15 and 60 min (Table 11). All tortillas fried within two hrs after cooking showed some puffing. Pallares (1981) reported that the inclusion of tempering time in the process of making taco shells allows for a more even distribution of moisture and the tempering time of 120 min was ideal for minimum puffing. This does not support the findings of this study which show a tendency for mimium puffing to occur after 90 min.

Table 10. Mean squares[1] and F-values from ANOVA of fried tortillas tempered for different lengths of time.

Variable	Mean Square	F-Value
% Moisture	20.15	1.41
% Fat[2]	3.18	1.92
Break[3]	19.24	1.29
Height[4]	1.48	2.13
% Reflectance[5]	7.40	0.94
Color[6]		
L - value	11.57	0.79
a - value	0.37	1.12
b - value	1.15	0.30
Saturation Index[7]	1026.51	0.32

*, $p<0.05$; **, $p<0.01$; ***, $p<0.001$

[1]mean of 4 samples

[2]ether extract

[3]measured as resistance to break using ITUM

[4]average height of 4 stacked tortillas

[5]reflectance at 520nm wavelength

[6]measured by HunterLab Spectrophotometer

[7]Saturation Index = $a^2 + b^2$

Table 11. Least square means[1] for fried tortillas tempered for different lengths of time.

VARIABLE	MINUTES				
	15	30	60	90	120
%Moisture	20.34[a]	20.30[a]	19.66[a]	17.30[a]	15.22[a]
%Fat[2]	14.23[a]	14.07[a]	12.46[a]	13.01[a]	12.32[a]
Break[3]	11.55[a]	15.28[a]	13.13[a]	17.35[a]	14.58[a]
Height[4]	6.10[a]	4.95[a]	6.08[a]	4.83[a]	5.28[a]
%Reflect.[5]	16.97[a]	16.39[a]	19.19[a]	16.17[a]	18.62[a]
Color[6]					
L - value	45.71[a]	44.88[a]	48.34[a]	44.38[a]	47.50[a]
a - value	4.07[a]	3.37[a]	3.36[a]	3.60[a]	3.38[a]
b - value	14.12[a]	13.88[a]	14.80[a]	13.43[a]	14.51[a]
Satur. Index[7]	222.52[a]	204.95[a]	234.45[a]	195.74[a]	226.69[a]

[1]Each value is a mean for four determinations.

[2]ether extract

[3]resistance to break as measured by IUTM

[4]average height of four stacked tortillas

[5]reflectance at 520nm wavelength

[6]measured by HunterLab Spectrophotometer

[7]Saturation Index = $a^2 + b^2$ as measured by HunterLab Spectrophotometer.

[abc]Means with different letters in the same row differ significantly ($p<0.05$).

3. Comparison of Tortillas Fried in Different Fats

There were no significant differences in moisture content, fat content, transmittance, color, or saturation index among tortillas fried in the different fats (Table 12). All fats displaced water equally as well as the tortillas cooked. Type of fat used did not affect color or calculated Saturation Index (Table 12).

Table 12. Mean squares[1] and F-values from ANOVA for comparison of tortillas fried in different fats.

Variable	Mean Square	F-Value
% Moisture	5.06	1.13
% Fat[2]	3.19	1.38
% Reflectance[3]	17.51	1.47
Color[4]		
L - value	36.80	1.63
a - value	0.26	1.44
b - value	11.31	2.05
Saturation Index[5]	10061.10	2.03

*, p<0.05; **, p<0.01; ***, p<0.001

[1]mean of 4 samples

[2]ether extract

[3]reflectance at 520nm wavelength

[4]measured by HunterLab Spectrophotometer

[5]Saturation Index = $a^2 + b^2$ as measured by HunterLab Spectrophotometer.

Tortillas fried in Stabland, a salad oil, tended to have a higher moisture content and a lower fat content than tortillas fried in any of the other oils (Table 13). Tortillas fried in Super Fry, a hydrogenated frying oil, tended to be lighter than tortillas fried in any of the other oils (Table 13).

Table 13. Least square means[1] for comparison of tortillas fried in different fats.

VARIABLE	CORN OIL	FLUID FRY	STABLAND	SUPER FRY
%Moisture	10.71[a]	12.16[a]	13.47[a]	12.10[a]
%Fat[2]	15.58[a]	16.15[a]	14.62[a]	16.72[a]
%Reflect.[3]	17.39[a]	19.36[a]	18.80[a]	14.67[a]
Color[4]				
L - value	46.12[a]	49.03[a]	48.17[a]	42.22[a]
a - value	3.00[a]	3.38[a]	3.25[a]	2.82[a]
b - value	15.16[a]	16.31[a]	15.80[a]	12.53[a]
Satur. Index[5]	245.89[a]	280.15[a]	264.95[a]	167.35[a]

[1]mean of 4 samples

[2]ether extract

[3]reflectance at 520nm wavelength

[4]measured by HunterLab Spectrophotometer

[5]Saturation Index = $a^2 + b^2$ as measured by HunterLab Spectrophotometer.

[abc]Means with different letters in the same row differ significantly ($p<0.05$).

There were significant differences in flavor characteristics of tortillas fried in different fats. To determine this, data were analyzed using a two way analysis of variance. This method determined whether or not interactions existed between oil and panelist.

If F-values were significant for this interaction, a plot was made of mean panelist scores versus oil. Only two of the ten attributes, lardy and corn aftertaste, showed significant interaction. A plot for each was constructed (Appendixes H,I). Based on the advice of the author's statistician, a professor of Statistics at Kansas State University, corn aftertaste was analyzed further as if no significant differences between panelist and oil existed, since no single panelist gave data not matching other panelists (Appendix H). A plot of lardy was constructed (Appendix I). Panelist #6 scored the tortillas noticeably different than did the other panelists. For this reason, this panelist's data was not further analyzed.

A one-way analysis of variance which pooled panelists' data was conducted (Table 14). All panelists' data were used except in the case of lardy, for which data from Panelist 6 was eliminated, based on the suggestion of the statistician. Soybean taste was perceived to vary among tortillas fried in the different oils (Table 15). Stabland, a salad oil made from soybean oil, was perceived to have more soybean flavor than corn oil or Fluid Fry, a 100% animal fat. Stabland and Super Fry, a frying oil made from partially hydrogenated soybean oil, were not perceived as different in soybean taste.

Table 14. Mean[1] squares and F-values of sensory parameters for comparison of tortillas fried in different oils.

ATTRIBUTE	MEAN SQUARE	F-Value
Corn	15.82	0.67
Soybean	69.65	2.71**
Lardy[2]	85.72	1.28
Limey	12.58	1.74
Toasty	26.08	1.38
Sweet	24.20	3.62
Corn Aftertaste	8.52	1.37
Bitter Aftertaste	5.68	1.00
Sweet Aftertaste	10.50	4.81
Browned Aftertaste	13.50	1.92

*, $p<0.05$; **, $p<0.01$; ***, $p<0.001$

[1]mean of 11 samples

[2]data from 4 panelists

Table 15. Least square means[1] of sensory parameters for comparison of tortillas fried in different fats.

VARIABLE	CORN OIL	FLUID FRY	STABLAND	SUPER FRY
Corn	22.19^{a}	23.26^{a}	20.10^{a}	25.04^{a}
Soybean	20.35^{bc}	16.37^{c}	27.09^{a}	23.17^{ab}
Lardy[2]	30.77^{a}	26.24^{a}	20.84^{a}	21.15^{a}
Limey	8.28^{a}	7.83^{a}	7.21^{a}	7.40^{a}
Toasty	25.53^{a}	28.65^{a}	23.29^{a}	27.14^{a}
Sweet	10.84^{a}	13.04^{a}	11.03^{a}	11.23^{a}
Corn Aftertaste	13.68^{a}	13.74^{a}	12.28^{a}	13.40^{a}
Bitter After.	7.04^{a}	7.24^{a}	7.36^{a}	6.62^{a}
Sweet After.	7.84^{a}	8.39^{a}	7.90^{a}	7.78^{a}
Browned After.	9.04^{a}	11.16^{a}	7.82^{a}	9.32^{a}

[1]mean of 11 samples

[2]data from 4 panelists

[abc]Means with different letters in the same row differ significantly ($p<0.05$).

No other tastes or aftertastes were perceived as different among tortillas fried in the different oils (Table 15). Lack of more significance among attributes can best be attributed to inadequate training of panel members. During training sessions, the author relied heavily upon group discussion and concensus decision to determine if panelists were correctly identifying flavor attributes. Further training would have been helpful to determine if each panelist was distinguishing among the different types of fats used to fry the tortillas.

Evidence of lack of panel training was seen when evaluating data from the lardy (animal fat) attribute (Appendix H). Panelists #6 perceived the "lardiness" of tortillas quite differently from the other five panlists. However, this panelists gave perfect results for what would be expected. Since only one lipid contained any animal fat, one would expect "lardiness" for tortillas fried in this oil to be high and "lardiness" for all other oils to be low. As mentioned previously, the author took the recommendation her statistician and eliminated Panelist #6 from further analysis. This avoided a panelist by oil interaction for "lardiness". One cannot rule out the possibility that tortillas fried in corn oil may be perceived as having a flavor indistiguishable from lardy. Vandaveer (1984b) noted that tortilla chips fried in corn oil had a sweet buttery taste.

In order to see which tortillas tended to be more flavorful than others, mean scores for each attribute were ranked one through four, one being high for the attribute and four being low for the attribute (Table 16). Tortillas fried in Stabland, a salad oil made from soybean oil, tended to be perceived as having less flavor than tortillas fried in any of the other oils. This is what was expected since normal oil refining is designed to produce a bland, tasteless vegetable oil which provides little or no flavor to tortilla chips (Vandaveer, 1984b). Tortillas fried in corn oil and Super Fry, a frying shortening made from hydrogenated soybean oil, ranked similiar in total amount of flavor (Table 16). One would expect corn oil to provide a more flavorful chip due to flavor components that are left in the finished product (Vandaveer, 1984b). Tortillas fried in animal fat ranked highest in perceived flavor. This could be due to the very distinct flavor notes present in animal fat that are not found in vegetable fats. Panelists may have been biased towards the strongest overall taste of the tortilla fried in Fluid fry and, therefore, tended to rate this tortilla higher in all attributes. Generally, lard is not used for tortilla chip frying (Vandaveer, 1984b).

Table 16. Rank for mean[2] scores of sensory parameters for comparison of tortillas fried in different fats.

VARIABLE	CORN OIL	FLUID FRY	STABLAND	SUPER FRY
Corn	3	2	4	1
Soybean	3	4	1	2
Lardy[3]	1	2	4	3
Limey	1	2	4	3
Toasty	3	1	4	2
Sweet	4	1	3	2
Corn Aftertaste	2	1	4	3
Bitter After.	3	2	1	4
Sweet After.	2	1	3	4
Browned After.	2	1	3	4
TOTAL	24	17	31	26

[1]rank of 1 to 4; 1 = highest, 4 = lowest

[2]mean of 11 samples

[3]data from 5 panelists

SUMMARY

This research was conducted in two parts: (1) preliminary study evaluating flours, doughs, and soft tortillas made from dehydrated masas, and (2) major study evaluating dehydrated masa, tempering time, and fats used in tortilla chip manufacture.

For the preliminary study, flour evaluation included moisture, fat, protein, crude fiber, neutral detergent fiber, ash, pH, granulation, and color (HunterLab L-, a-, b- values). Dough evaluation included pH, spreadability, shelf-life, and color. Soft tortilla evaluation included pH, moisture, tenderness, shelf-life, and color. Aroma, flavor, and texture evaluations of the soft tortillas were made by four trained members of the Sensory Center of Kansas State University Department of Foods and Nutrition. Eighteen Latin American or Puerto Rician students attending KSU and/or their spouses participated on a consumer-type sensory panel.

Other than color, there was very little difference between the unenriched and enriched masas purchased from the same company. The enriched tortilla gave a greenish color atypical of tortillas. Based on other objective measurements, the tortillas made from the three different unenriched flours were comparable, with some variations observed in pH, % moisture, and color. One masa contained

considerably more dietary fiber than the others.

Professional profiling found Valley Grain soft tortillas to be full in aroma, strong in flavor, moist inside, and had processed corn aromatics. Azteca soft tortillas were found to be mild in aroma, low in flavor, doughy inside and had very low corn aromatics. Lincoln Grain tortillas were ample in aroma, full in flavor, dry inside, and had grain aromatics.

Latin American panelist preference did not show significant differences, although panelists tended to prefer Azteca soft tortillas more than Valley Grain or Lincoln Grain products.

The major part of the study was divided into three parts: (1) fried tortillas made from three dehydrated masas were compared, (2) fried tortillas were tempered for different lengths of time and compared, and (3) tortillas were fried in four types of cooking oil, and were compared.

Four instrumental measurements (% fat, % moisture, color, and resistance to puncture) plus a consumer preference panel were used to compare the three dehydrated masas. There were no significant differences in fat, moisture, resistance to puncture, b-value, or saturation index. Per cent transmittance and lightness values differed ($p<0.05$) among tortillas. Redness-greenness value (a-value) differed ($p<0.01$) among tortillas made from different masas. Consumers liked all fried tortillas equally well.

Time between cooking and frying tortillas was varyed to determine the effect of tempering. Cooked tortillas were allowed to set 15, 30, 60, 90 and 120 min before frying. Five instrumental measurements were used: color, resistance to shear, moisture content, fat content, and stack height.

There were no significant differences among temper times in moisture, fat, break, height transmittance, color values, or saturation index. All tortillas fried within two hours after cooking showed some puffing. A tendency for mimium puffing to occur after 90 minutes was seen.

Three instrumental measurements (% fat, % moisture, and color) plus a descriptive sensory panel were used to compare the effect of frying in four types of lipid. There were no significant differences in moisture content, fat content, or color among tortillas fried in the different fats. During decriptive analysis, soybean taste was perceived to vary among tortillas fried in the different oils. Stabland, a salad oil made from soybean oil, was perceived to have more soybean flavor than corn oil or Fluid Fry, a 100% animal fat. Stabland and Super Fry, a frying oil made from partially hydrogenated soybean oil, were not perceived as different in soybean taste. Tortillas fried in Stabland tended to be perceived as having less flavor than tortillas fried in any of the other oils. Tortillas fried in corn oil and Super Fry ranked similiarly in total amount of flavor perceived. Tortillas fried in animal fat ranked highest in perceived flavor.

CONCLUSIONS

Under the conditions of this study it was concluded that:

(1) There were no significant differences in fat, moisture, or resistance to puncture of fried tortillas made from three dehydrated masas.

(2) Azteca dehydrated masa gave fried tortillas with the lightest color. Lincoln Grain tortillas were darker than either Azteca or Valley Grain tortillas.

(3) Consumers liked fried tortilla chips made from three dehydrated masas equally well.

(4) Varying the tempering time did not affect color, moisture, fat, resistance to shear, or height of fried tortillas.

(5) Varying the type of fat used to fry tortillas did not affect their color, moisture, or fat content.

(6) Varying the type of fat used to fry tortillas affected the soybean flavor of the fried tortillas. Frying in soybean oil produced an identifiable soybean flavor in tortillas.

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APPENDIX

APPENDIX A

PROFESSIONAL PROFILE OF SOFT TORTILLAS

This report compares the eating properties of tortillas made from three dehydrated masa flours. These were studied November 26 through December 6, 1984.

	VALLEY GRAIN	AZTECA	LINCOLN GRAIN
Aroma	A full, robust, aroma with a processed corn note -- corn that has been treated with calcium hydroxide; the calcium hydroxide was of a moderate level (in good proportion to the corn note).	A mild corn aroma more reminiscent of baked cream corn than processed corn. There was a low level dairy/whey note that was equal to the corn note in intensity. There was also a calcium hydroxide/ vinegary/sour note at the same level as the corn and dairy notes.	A full, ample aroma but there was strong slightly more grainness, nutty-ness and cooked popcorn hulls in the aroma than the actual processed corn note; the calcium hydroxide was at a slight level and blended in with other notes. There was also a threshold musty/wet grain impression.
Flavor	The flavor had a strong, full processed corn note with a well-blended, moderate calcium hydroxide note. Notes related to the calcium hydroxide were a threshold peppery and bitter. Also a threshold oily-ness was noted. The robust flavor developed immediately. This	The flavor consisted of a very low processed corn note; a creamed corn impression that had a low level of sweetness; and a slight calcium hydroxide note that had an edge that was slightly vinegar-like or sour milk-like and had some peppery-ness. The flavor developed	The full flavor had slightly more of a grain-ness, nutty-ness, cooked popcorn hull impression than of the processed corn note. The calcium hydroxide was at a low level with a threshold peppery and alkaline note. The grain-ness and nutty-ness carried a slight sweetness. The flavor developed immedi-

was a typical, processed corn tortilla.	slowly. This was a mild flavored tortilla with a very low corn tortilla identity.	ately. This was a full, grain flavored tortilla; it did not have a strong processed corn note.
Texture		
Tender chewy	Tender chewy	Tough chewy
Fine grained	Fine grained	Coarse, gritty grained
Moist inside	Doughy inside	Inside drier than Valley Grain or Azteca
Narrow crispy outer edges	Tough, dry outer edges	Tough, dry outer edges
Aftertaste		
Processed corn aromatics	Very low corn aromatics threshold creamed corn/ dairy note	Grain aromatics
Slight oilyness on lips, tongue and roof of mouth	Threshold level oilness in mouth	Threshold level oilyness in mouth
Slightly peppery/ tingle on tongue	Lower level peppery/tingle than Valley Grain or Lincoln Grain	Slight peppery/ tingle, less than Valley Grain
Slight chalky/ alkaline feel in mouth	Slightly higher chalky/alkaline feel in mouth, more than Valley Grain or Lincoln Grain.	Slight chalky/alkaline feel in the mouth, more than Valley Grain
Slight tongue and mouth numbness	Slight tongue and mouth numbness	Slight tongue and mouth numbness
All notes are present at levels in	A slightly sour/ bitter note at back of mouth.	Grainy particles left in the mouth; some panelists had

a typical tortilla--these notes are not unpleasant or detracting.		threshold bitter.
Color		
Light golden color with a greyish cast	Very pale golden color	Dark golden color with a shiny/ crystal appearance
Slightly darker outer ring	No darker ring on outer edge	Slightly darker, oily-like ring on outer edge
Interior of tortilla slightly darker than Azteca	Interior and surfaces are the same color	Interior darker than surface; more than Valley Grain
Surface		
Bumpy with small air bubbles, some of which had browned	More smooth than Valley Grain or Lincoln Grain; there were a few browned spots	Bumpy with small bubbles, some of which had browned
Would tear easily in a straight line with some layering and flaking	Would tear easily in a straight with some layering and flaking	Would tear easily a in straight with some layering and flaking
Was stiff, and cracked some when rolled but not as much as Lincoln Grain; the first cooked side rolled slightly better than the second cooked side.	Was quite flexible and rolled easily without cracking.	Was stiff, and cracked when rolled--this happened when either the first cooked side or the second cooked side was rolled in.

APPENDIX B

Thank you for participating in this study. There are no wrong or right answers. We are studying Latin American and Puereto Rican predderences towards three types of corn tortillas.

TASTE EACH TORTILLA IN ORDER. MARK THE ANSWER THAT BEST REFECTS YOUR OPINION. RINSE WITH WATER BETWEEN SAMPLE.

1. Taste tortilla ______.
How would you rate the flavor of this tortilla?

____ like very much
____ like moderately
____ like slightly
____ neither like nor dislike
____ dislike slightly
____ dislike moderately
____ dislike very much

How would you rate the color of this tortilla?

____ like very much
____ like moderately
____ like slightly
____ neither like nor dislike
____ dislike slightly
____ dislike moderately
____ dislike very much

How would you rate the tenderness of this tortilla?

____ like very much
____ like moderately
____ like slightly
____ neither like nor dislike
____ dislike slightly
____ dislike moderately
____ dislike very much

2. Taste tortilla ______.
How would you rate the flavor of this tortilla?

____ like very much
____ like moderately
____ like slightly
____ neither like nor dislike
____ dislike slightly
____ dislike moderately
____ dislike very much

How would you rate the color of this tortilla?

____ like very much
____ like moderately
____ like slightly
____ neither like nor dislike
____ dislike slightly
____ dislike moderately
____ dislike very much

How would you rate the tenderness of this tortilla?

____ like very much
____ like moderately
____ like slightly
____ neither like nor dislike
____ dislike slightly
____ dislike moderately
____ dislike very much

3. Taste tortilla ______.
How would you rate the flavor of this tortilla?

____ like very much
____ like moderately
____ like slightly
____ neither like nor dislike
____ dislike slightly
____ dislike moderately
____ dislike very much

How would you rate the color of this tortilla?

____ like very much
____ like moderately
____ like slightly
____ neither like nor dislike
____ dislike slightly
____ dislike moderately
____ dislike very much

How would you rate the tenderness of this tortilla?

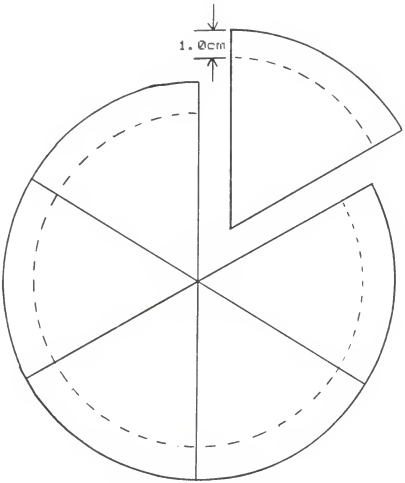
____ like very much
____ like moderately
____ like slightly
____ neither like nor dislike
____ dislike slightly
____ dislike moderately
____ dislike very much

10. Rank the tortillas in order of preference; the one you like best being #1 and the one you like least being #3:

#1 _______ #2 _______ #3 _______

Figure 1. Diagram of tortilla used for descriptive analysis.

APPENDIX C

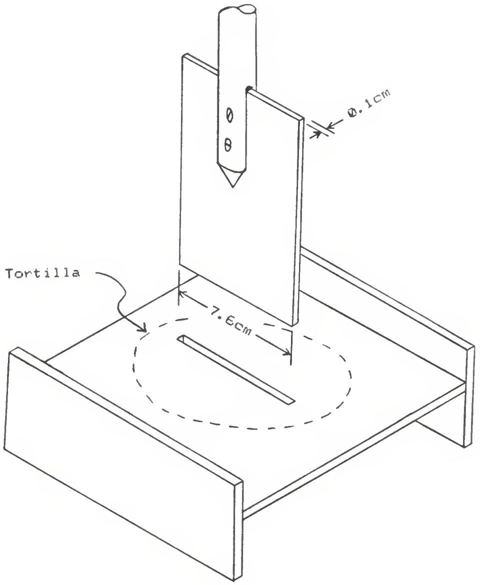


Diameter = 10.1cm

Thickness = 0.2cm

Figure 2. Diagram of IUTM (Instron) attachment used to shear tortillas.

APPENDIX D



APPENDIX E

TORTILLA CHIP STUDY

In front of you are 3 kinds of tortilla chips. Sample each chip in the order given below. Check one point on the following scale to indicate acceptance. NOTE: PLEASE RINSE WITH WATER BETWEEN SAMPLES.

CODE: ______	______	______
____ Like very much	____ Like very much	____ Like very much
____ Like moderately	____ Like moderately	____ Like moderately
____ Like slightly	____ Like slightly	____ Like slightly
____ Dislike slightly	____ Dislike slightly	____ Dislike slightly
____ Dislike moderately	____ Dislike moderately	____ Dislike moderately
____ Dislike very much	____ Dislike very much	____ Dislike very much

COMMENTS:

Thank you for your help!

APPENDIX F

REFERENCE SAMPLES USED FOR DESCRIPTIVE ANALYSIS

Stage I: TASTE

Corn	cooked yellow field corn
Soybean	100% soybean oil
Lardy	100% beef fat
Limey	0.04% $Ca(OH)_2$ solution
Toasty	Kellogg's Corn Flakes
Sweet	20% sucrose solution

Stage II: AFTERTASTE

Corn	cooked yellow field corn
Bitter	0.07% caffeine solution
Sweet	20% sucrose solution
Browned	burnt toast

APPENDIX G

Name ________________ Date ________________ Code ________________

Please taste the corresponding sample. Answer each question in sequence, placing a vertical line across the horizontal line at the point that best describes that property in the sample.

After you have answered all questions, return this sheet and the sample, and wait for the next sample.

Thank you!

1. Taste

a). Corn ├────────────────────┤
weak moderate strong

b). Soybean ├────────────────────┤
weak moderate strong

c). Lardy ├────────────────────┤
weak moderate strong

d). Limey (CaOH) ├────────────────────┤
weak moderate strong

e). Toasty ├────────────────────┤
weak moderate strong

f). Sweet ├────────────────────┤
weak moderate strong

2. Aftertaste

a). Corn ├────────────────────┤
weak moderate strong

b). Bitter ├────────────────────┤
weak moderate strong

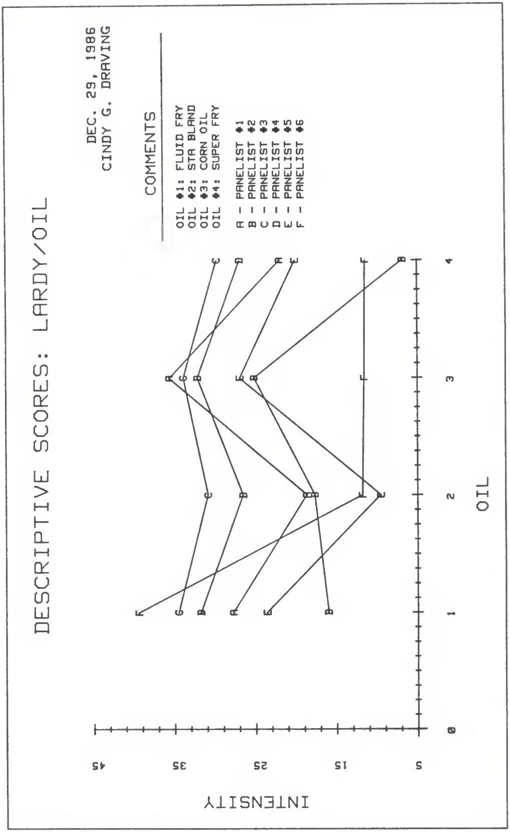
c). Sweet ├────────────────────┤
weak moderate strong

d). Browned ├────────────────────┤
weak moderate strong

<u>Comments</u>

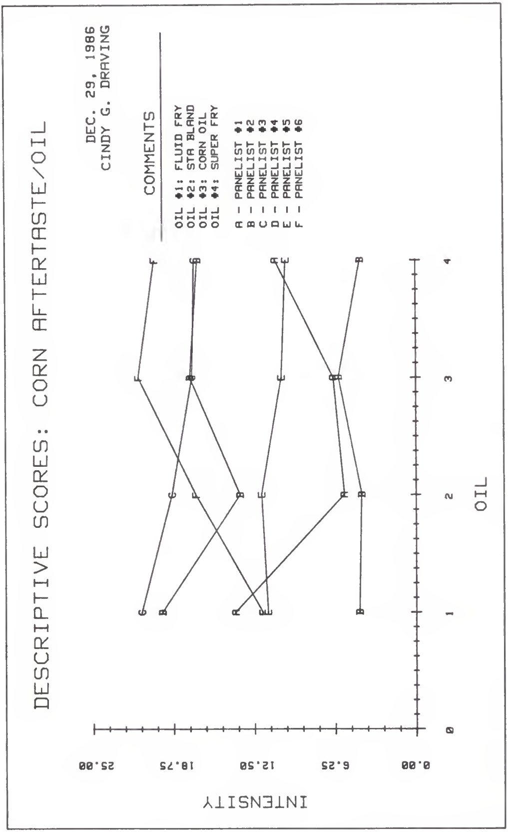
Figure 3. Plot of panelist scores for lardy taste of fried tortillas.

APPENDIX H



DESCRIPTIVE SCORES: LARDY/OIL
DEC. 29, 1986
CINDY G. DRAVING
COMMENTS
OIL #1: FLUID FRY
OIL #2: STA BLAND
OIL #3: CORN OIL
OIL #4: SUPER FRY
A - PANELIST #1
B - PANELIST #2
C - PANELIST #3
D - PANELIST #4
E - PANELIST #5
F - PANELIST #6
INTENSITY
5
15
25
35
45
OIL
0
1
2
3
4

Figure 4. Plot of panelist scores for corn aftertaste of fried tortillas.


DESCRIPTIVE SCORES: CORN AFTERTASTE/OIL
DEC. 29, 1986
CINDY G. DRAVING
COMMENTS
OIL #1: FLUID FRY
OIL #2: STA BLAND
OIL #3: CORN OIL
OIL #4: SUPER FRY
A - PANELIST #1
B - PANELIST #2
C - PANELIST #3
D - PANELIST #4
E - PANELIST #5
F - PANELIST #6
INTENSITY
0.00
6.25
12.50
18.75
25.00
OIL
0
1
2
3
4

TORTILLAS: A STUDY OF DEHYDRATED MASAS, TEMPERING TIME AND FATS USED IN TORTILLA CHIP MANUFACTURE

by

Cindy Greenlee Draving

B. S. Kansas State University, 1984

AN ABSTRACT OF A MASTERS THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTERS OF SCIENCE

Food Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1987

ABSTRACT

The popularity of Mexican food is increasing in the United States. Food manufacturers must develop processes to meet consumer demand. Although trade journals discuss fried tortilla chips, scientific literature concerning fried tortillas and tortilla chips is scarce.

This research evaluated dehydrated masa, tempering time, and fats used in tortilla chip manufacture. Four instrumental measurements (% fat, % moisture, color, and resistance to puncture) plus a consumer peference panel were used to compare the three dehydrated masas.

There were no significant differences in fat, moisture, resistance to puncture, b-value, or saturation index. Per cent transmittance and lightness values differed ($p<0.05$) among tortillas. Redness-greenness value (a-value) differed ($p<0.01$) among tortillas made from different masas. Consumers liked all fried tortillas equally well.

Time between cooking and frying tortillas was varyed to determine the effect of tempering. Cooked tortillas were allowed to set 15, 30, 60, 90 and 120 min before frying. Five instrumental measurements were used: color, resistance to shear, moisture content, fat content, and stack height.

There were no significant differences among temper

times in moisture, fat, break, height transmittance, color values, or saturation index. All tortillas fried within two hrs after cooking showed some puffing. A tendency for mimimum puffing to occur after 90 min was seen.

Three instrumental measurements, %fat, %moisture, and color as measured by a HunterLab Spectrophotometer, plus a descriptive sensory panel were used to compare the effect of frying in four types of lipid. There were no significant differences in moisture content, fat content, or color among tortillas fried in the different fats. During descriptive analysis, soybean taste was perceived to vary among tortillas fried in the different oils. Stabland, a salad oil made from soybean oil, was perceived to have more soybean flavor than corn oil or Fluid Fry, a 100% animal fat. Stabland and Super Fry, a frying oil made from partially hydrogenated soybean oil, were not perceived as different in soybean taste. Tortillas fried in Stabland tended to be perceived as having less flavor than tortillas fried in any of the other oils. Tortillas fried in corn oil and Super Fry ranked similiarly in total amount of flavor perceived. Tortillas fried in animal fat ranked highest in perceived flavor.