THE USE OF SORGHUM FLOUR IN PREMIXES FOR GRIDDLE CAKES, WAFFLES AND GINGERBREAD

by

GERALDINE ENOD ACKER

B. S., North Dakota
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INTRODUCTION

Grain sorghums are well adapted to the semi-arid, climatic conditions of the Great Plains area and often produce grain when other crops fail. Therefore, they are of increasing agricultural economic importance in Texas, Kansas, Oklahoma, Nebraska, Colorado, and New Mexico. At the present time, they are used mainly for forage on the farms where produced; hence, the quantity entering industry is small. Investigations are needed to develop new markets and uses for the grain sorghums.

Research on the use of grain sorghums for human food purposes has been limited. Therefore, this study was undertaken to investigate the possibility of using a flour milled from grain sorghum in the production of premixes for the preparation of griddle cakes, waffles and gingerbread. Sorghum flour premixes would offer a possible market for sorghum flour products. The general plan of investigation was to develop premixes containing more than 66-2/3 percent sorghum flour and to study the acceptability of increased percentages of sorghum flour in the baked product. If a premix containing 100 percent sorghum flour could be developed, it could be used as a substitute for wheat flour in wheat-free allergy diets as well as in normal diets.

REVIEW OF LITERATURE

Literature dealing with the grain sorghums has been limited

mainly to identification, varieties, history and production of the crop. A few studies have been made on the chemical composition and the nutritive value of the grain and there is one recent publication on the use of grain sorghum flour in breads.

Swanson and Laude (1942) defined the term "sorghum" as a general group name for the classes of sorghum and further stated that the term should be used in the same sense as the words wheat, barley, corn, alfalfa or cotton. In the opinion of these workers, the addition of the word "corn" to kafir (kafir corn) and "maize" to milo (milo maize) is undesirable and confusing; they believed the simple terms kafir and milo to be preferable. Kiltz et al. (1933) have divided the grain sorghums botanically into six groups: milo, kafir, feterita, durra, kaoling and shallu. Edwards and Curtis (1943) classified the grain sorghums as milo, kafir, feterita, durra and miscellaneous varieties.

These same workers compiled information on the production, composition and uses of grain sorghums. Grain sorghum resembles other cereal grains in both structure and general composition. Structurally, it consists of the seed coat, the endosperm and the embryo or germ. The endosperm makes up the major part of the kernel and its characteristics and properties determine the value and the utility of the kernel. The endosperm is comprised mainly of starch which may be sugary, waxy or nonwaxy. The most common type is the nonwaxy starch variety and the starches of this type resemble that of other grains. Horan and Heider (1946) found that there was a close similarity between corn and sorghum

starches. These investigators in analyzing 87 samples of grain sorghum observed that there appeared to be very little difference in the proportion of protein, crude fat and starch in the samples which contained waxy and nonwaxy starches. This fact they considered to be important for general industrial utilization of grain sorghums. From results of chemical determinations made by the Northern Research Laboratory, Edwards and Curtis (1943) reported that grain sorghums contained more protein but were lower in both fiber and fat content than corn. Barham et al. (1946) found that there was no correlation between any chemical constituent of the grain sorghums and the quality of their starches. These workers considered kafir starches to be best for food purposes since kafir starches gave firm gels which were more workable, clearer and of better texture than those of most other types studied. It was noted also that kafir starches did not evidence as great a degree of syneresis as some of the other sorghum starches studied.

Sorghum was one of the earliest of wild plants to be domesticated and utilized for human food and livestock feed. Vinall, Stephen and Martin (1936) stated that there was some disagreement as to the exact history of sorghum. However, most authorities agreed that a carving taken from the palace of Sennacherib in the ancient city of Ninevah of Assyria depicted sorghum and showed that as early as 700 B.C. sorghum was an important crop. Ball (1910) compiled a comprehensive history of sorghum. From the data which he collected, he concluded that a form of sorghum

was grown in Egypt as early as 2200 B.C.

Sorghum is indigenous to Africa, Asia and India. It is known that the crop was grown in India in the first century A.D. and in China in the thirteenth century A.D. Today Africans and Asiatics who cannot afford rice or wheat, use grain sorghums for food in the form of bread and porridge. They also make a fermented drink and a confection from the grain.

Edwards and Curtis (1943) reported that the early white settler in the semi-arid regions of the United States used grain sorghums as an important source of food, especially during years of severe drought and of corn and wheat crop failures. These investigators stated that since this time, grain sorghums have been used very little in the diet of the American. Grain sorghums have been used mainly for forage, silage and sirup. Data compiled by Ball (1910) showed that the first sorghums were brought to this country from Africa during colonial times. The continuous production of sorghums began in the United States in 1853 with the culture of saccharine type sorghums which were grown chiefly in Georgia and South Carolina. Edwards and Curtis (1943) reported that the earliest grain sorghums were introduced to California from Egypt in 1874. The success of the grain sorghums, White durra and Brown durra, in California marked the beginning and the expanding of grain sorghum production. Milo was introduced to the United States from Africa about 1880-1885 and was first grown in South Carolina. By the last decade of the nineteenth century, grain sorghums had reached the great plains.

Smith, Nordgren and Andrews, Knox, Heller and Sieglinger, and, recently, Tanner, Pfeiffer and Curtis have reported on the vitamin content of grain sorghums. Smith (1930), using the rat growth and development method, found that yellow corn contained 10 times more vitamin A activity than yellow milo sorghum and 20 times more than the Hegari variety. Nordgren and Andrews (1941) reported that the thiamine content of seven unidentified samples of grain sorghum averaged 2.68 mg per pound as compared with a per pound average of 2.75 mg for spring wheat, 2.17 mg for winter wheat and 2.03 mg for soft wheat. According to work done by Knox, Heller and Sieglinger (1944), the riboflavin, pantothenic acid and the niacin content of grain sorghums compared favorably with that of other cereals. Tanner, Pfeiffer and Curtis (1947) found that the riboflavin and the pyridoxine content of grain sorghums was approximately the same as for corn; but that the pantothenic acid, nicotinic acid and biotin content was considerably higher than corn. Variations in vitamin content among the samples analyzed led these workers to believe that possibly the nicotinic acid content of grain sorghums could be increased appreciably through hybridization.

Ball and Rothgeb (1915), in commenting on the use of grain sorghum for food, likened it to cornmeal as to flavor and use. They suggested that it might be used in the making of battercakes such as johnnycake and that the grain also might be used successfully for popcorn. They further stated that the grain should not be ground into a flour but rather into a meal which could be

used alone or in a mixture with wheat flour in varying proportions in such ways as cornmeal was used. They described the meal of sorghum grain as being somewhat distinctive in flavor -- not nearly as different from that of corn as the flavor of buckwheat is from that of wheat flour. Though these workers were of the opinion that sorghum could and should be used for food, they gave the following reasons as to why grain sorghum was not used as food: the chemical analysis did not indicate it had a higher food value than other grains, the flavor was distinct but not attractive enough to be desired, its uses were limited to the same uses as cornmeal and there was no reason to believe that it could be produced cheaply in proportion to its actual value.

Early investigators suggested the use of grain sorghum as a meal rather than a flour. Bavousett and Kleppe (1942) and Edwards and Curtis (1943) stated that flours might be made very easily from grain sorghums and that their use as flour added pleasing variety to breads and other cereals. Bavousett and Kleppe (1942) used kafir, hegari and yellow milo flour successfully in the making of quick and yeast breads. In the making of quick breads, these workers found that the substitution of two-thirds sorghum flour for wheat flour produced a satisfactory product but that batters and doughs containing this amount of sorghum flour were more moist during mixing and yielded a more crumbly product than if made from wheat flour alone. For this reason, they suggested that it might be desirable to decrease the liquid slightly when making substitutions with sorghum flour.

In the making of yeast breads and biscuits, they suggested that a more satisfactory product would be produced if one-half sorghum flour rather than two-thirds was used to replace wheat flour. According to these workers, products containing half sorghum and half wheat flour are more compact and crumbly than the average whole wheat breads.

Considerable work has been done on the role played by each ingredient in premixes and batters. Both Nason (1939) and Lowe (1943) recommended that a double action type of baking powder be used for griddle cake batters which had to stand a long time before baking. Otherwise the type of baking powder used did not seem to produce a difference in volume or texture. Lowe (1943) found that increasing the baking powder in a griddle cake batter caused it to be stiffer and the resulting cakes to be less moist, more porous and tender. Waffles, however, required less baking powder than griddle cakes. Blumenthal (1947) stated that the amount of leavening added to a pancake flour depended on the types of flour used.

Lowe (1943) observed that gingerbreads containing large proportions of soda were darker in color than those made with baking powder and no soda. She also found that gingerbreads made with a large proportion of soda often formed a hollow in the center of the gingerbread during baking as a result of the action of soda upon the gluten in the flour. If the cake sank across the top without forming a hollow in the center, she recommended longer mixing and greater attenuation of the gluten. Excess soda pro-

duced an alkaline flavor.

Hudson (1949) reported that basic formulas for pancake mixes do not call for dried egg because the addition of dried whole egg limited the shelf life of the dry mix. However, he believed that if dried egg of superior keeping quality were incorporated into dry mixes, smoother batters would be formed and better products would result. Geddes (1944) stated that the addition of dried whole egg to ready-mixed flours increased the strength or toughness of the baked product.

He also classified nonfat dry milk solids as toughenerers which acted as important governors in premix formulas and which affected the crust color and symmetry of the product. Hoffman et al. (1948) found that the addition of nonfat dry milk solids of good baking quality increased the moisture absorption of a dough. Blumenthal (1947) recommended between 2 and 5 percent nonfat dry milk solids based on the flour used, as sufficient for most commercial formulas for waffle and griddle cake mixes.

If the mix contained insufficient nonfat dry milk solids to flavor and/or to obtain a desired brown color, Blumenthal (1947) recommended that between 2 and 5 percent sugar be added to the pancake and waffle flours to produce the desired results. Lowe (1943) stated that the use of large amounts of sugar in waffles caused a limp waffle when it was first removed from the iron but if it had been baked long enough it would become crisp. Geddes (1944) classified sugar as a flavorer and tenderizer.

In summary, Geddes (1944) emphasized that a ready-mixed

flour should contain all the necessary ingredients other than liquid in the proportion required to make the product. He further stated that since each ingredient performs a definite function, it was essential to have a properly balanced formula in order to produce baked goods of optimum quality.

Platt and Kratz (1933) found that there was little correlation between the lightness of a dough and/or batter and the volume of the finished product. Hood and Lowe (1948) found that viscosity was not always a good criterion for cake quality. Recent work done by Ohlrogge and Sunderlin (1948) showed that there was a high correlation between viscosity of a cake batter and the acceptability score and that moisture absorption ability was directly related to the cake score.

EXPERIMENTAL PROCEDURE

All research for this study was conducted in the Foods Research laboratories in Calvin Hall.

In each of the premixes studied, a basic formula was used containing 66-2/3 percent sorghum flour. This was the amount that Bavousett and Kleppe (1942) recommended for the making of a standard product. The basic formula served as the control in each of the premixes tested. Each premix variation was checked five times. In order to facilitate handling and judging of the products, a number was assigned to each.

A palatability committee was selected and given an opportunity to become familiar with the scoring of the sorghum flour

product prior to the recording of any scores. A score sheet, Form 1 (Appendix), was developed for the judging of griddle cakes and waffles. A modified form of this score sheet, Form 2 (Appendix) was used in the scoring of gingerbreads made from the gingerbread premix.

The experimental procedure was divided into three parts. In the first part a study was made of the use of sorghum flour in a griddle cake premix. Since preliminary work had shown that an acceptable griddle cake premix could be made from 100 percent sorghum flour, this study was concerned with the effect of varied amounts of liquid, nonfat dry milk solids, sugar and baking powder on the quality of the griddle cake baked from the premix. Linespread and the specific gravity of the batter and the water absorption ability of the cake were used as an index to the quality of the griddle cake premix. The desirability of the sorghum flour griddle cake was determined by a palatability committee. The second part was a study of the acceptability of a waffle premix containing varied percentages of sorghum flour as influenced by decreased amounts of dried whole egg, liquid and added sugar. The tests for the waffle premix study were the same as for the griddle cakes. The third part was a study of the acceptability of a gingerbread premix containing increased percentages of sorghum flour. High and low amounts of leavening were tested with each percentage of sorghum flour tried. The tests used with this premix were specific gravity, linespread, compressibility of crumb, standing height, shortness and quality as judged by a

palatability committee.

The sorghum flour used in this study was milled from Country Milo. Analysis of the flour showed the following percentage composition: 7.44 protein, 0.66 fat (ether extract), 0.32 crude fiber, 11.72 moisture, 0.36 ash, 79.50 nitrogen free extract and 78.82 total carbohydrate. This flour was obtained in one lot and upon delivery was placed in a closed metal container and refrigerated until used. All other ingredients were kept as uniform as possible by ordering an initial supply large enough to last throughout the study. The spray dried whole egg; nonfat dry milk solids; Primex, a hydrogenated vegetable shortening; and the all-purpose flour were refrigerated in tightly closed containers. Calumet baking powder; gold label Brer Rabbit, a mild flavored light molasses; granulated sugar; ginger; cinnamon; salt and baking soda were placed in tightly closed containers and stored at room temperature. Thus ingredients in each premix were as nearly identical as possible.

The equipment used in this study included a torsion balance; a centigrade thermometer; an Eastman timer; a Westinghouse electric range; a gas oven equipped with a revolving hearth and an accurate thermostatic heat control; a Sunbeam waffle iron, thermostatically controlled; a Griswold ten-inch cast iron griddle; and a KitchenAid mixer of five quart capacity. All other equipment used in preparation of the premixes and mixing of the batters was similar to that found in any well-equipped foods research laboratory.

Griddle Cake Premix

A standard griddle cake formula widely used at Kansas State College was modified and used as the basic formula for the premix. The fresh milk in the original formula was replaced by nonfat dry milk solids, two-thirds of the wheat flour by sorghum flour, the melted fat by solid fat and the egg eliminated. The method of mixing the ingredients was changed so as to produce a dry mix which upon the addition of water would give a griddle cake batter. The basic formula for the griddle cake premix and the detailed procedure of mixing were as follows:

Basic Formula for Griddle Cake Premix

Ingredients	Weight (grams)	Approximate measure
Flour, all-purpose	36.6	1/3 cup
Flour, sorghum	74.4	2/3 cup
Salt	3.0	1/2 teaspoon
Baking powder, Calumet	4.0	1 teaspoon
Milk solids, nonfat dry	30.0	3 tablespoons
Fat, Primex	12.5	1 tablespoon
Water	230.0	15 tablespoons

Method used for preparing premix:

1. Weigh all the dry ingredients and the fat.

2. Using a sifter with a two mm screen mesh, sift together all the dry ingredients twice.

3. Add fat to the dry ingredients and partially blend the mixture with 25 strokes.

4. Rub the mixture through a three mm screen strainer.

Method used for preparing griddle cakes from premix:

1. Weigh the water, temperature 18-22°C.

2. Place premix in a three-quart enamel bowl. Make a well in the center of the mixture. Add water and stir with a wooden spoon at medium speed for 20 strokes.

3. Place an asbestos mat under the griddle. Turn the large burner to moderate high heat and preheat the griddle for 10 minutes.

4. Weigh and record the weight and temperature of a 57 cc cup of batter for calculation of specific gravity.

5. Weigh out 80 grams of the batter into a one cup container and pour this batter onto the center of the hot griddle. Use a rubber scraper so as to remove as much of the batter as possible from the container.

6. Test the linespread of the batter. Record four readings. Average.

7. When the edges of the griddle cake are slightly baked and the cake appears risen, full of bubbles, turn the hot cake and finish baking.

8. Place the hot cake on a rack and score for aroma and appearance. Then tear the cake into two sections. Use the first section for judging palatability and the second section for determination of water absorption ability.

The specific gravity determinations were made by filling a 57 cc cup with batter, weighing it, and recording the weight of

the batter in grams. The specific gravity was calculated by dividing the weight of the batter by the weight of an equal volume of water at the same temperature as the batter.

The objective test used to determine the consistency of the batter was the linespread test. Adams and Birdsall (1946) described an apparatus in which the substance to be tested was poured from a cup onto the center of a large disc scored with concentric circles at one-fourth-inch intervals. By counting from the outer circle to the innermost visible circle, the linespread of the substance was determined. Thus the lower the numerical designation, the thinner the consistency of the batter; and the higher the numerical designation, the thicker the consistency of the batter. These workers suggested that this type of objective test be used for pancake mixes as a possible means of indicating the quality of the pancake. The linespread test was adapted and used in this study in the following manner: The griddle upon which the griddle cakes were baked was scored at five millimeter intervals radiating from the center of the griddle. Eighty grams of the griddle cake batter was poured onto the center of the hot griddle and as soon as the edges of the batter set, readings at four different points were taken. The readings were averaged and the average used as the index to the consistency of the mixture.

The water absorption ability test used in this study was adapted from the test used by Swartz (1938). Three one-inch circles were cut with a sharpened cylinder from one-half the

griddle cake. Each circle was weighed carefully, the weight recorded; then placed in an evaporating dish containing 10 cc of water at 22°C. The circle was allowed to remain in the water for 15 seconds; then it was removed carefully from the water, quickly inverted so as to prevent loss of water by dripping and immediately placed on a balance and weighed. The difference in the weights represented the water absorbing ability. The ease with which the product takes up moisture is believed to be related to the eating quality of that food.

Subjective testing of the griddle cake was done by a palatability committee consisting of four members of the staff of the Department of Foods and Nutrition and one graduate student enrolled in that department. Form 1 (Appendix) was used for scoring. Immediately after removing the cake from the griddle, it was scored for aroma and appearance. Then the cake was torn into two sections, one of which was subdivided into five wedge-like pieces for the judging of texture, moisture, tenderness and flavor.

In the first group of griddle cakes studied, the premix contained 100 percent sorghum flour. The variation in this group was the amount of water added to the premix to form a batter. Decreasing amounts of water, 230 g, 210 g, and 190 g were used. The second group of premixes studied contained 100 percent sorghum flour with nonfat dry milk solids at three levels, 30 g, 20 g, and 10 g. The effect: of two levels of baking powder, 4.0 g and 5.5 or 3.6 and 5.0 percent based on the flour used;

of the addition of 5.5 or 5.0 percent sugar to the premix; and of decreased amount of water to form the batter were studied in each premix containing varied percentages of nonfat dry milk solids. The basic premix formula served as the control with each variation tested. Each formula was checked five times. The formula for each griddle cake premix studied is given in Table 1. All griddle cake premix variations were made and tested as outlined for the basic formula.

Waffle Premix

The basic formula used for the waffle premix was adapted from the formula given for waffles by Bavousett and Kleppe (1942). The modified formula contained both dried whole egg and nonfat dry milk solids in lieu of the fresh products.

Basic Formula for Waffle Premix

Ingredients	Weight (grams)	Approximate measure
Flour, all-purpose	33.4	5 tablespoons
Flour, sorghum	66.6	10 tablespoons
Salt	1.8	1/3 teaspoon
Baking powder, Calumet	3.8	1 teaspoon
Milk solids, nonfat dry	17.0	1 2/3 tablespoon
Egg, dried whole	10.0	1 2/3 tablespoon
Fat, Primex	15.2	1 1/3 tablespoon
Water	175.0	3/4 cup minus 1 teaspoon

Method used for preparing premix:

1. Weigh all the dry ingredients and the fat.

2. Using a sifter with a two mm screen mesh, sift together all the dry ingredients twice.

Table 1. Griddle cake premix variations.

Product variation	Formula number	Ingredients in premix, grams: All-purpose flour	Sorghum flour	Salt	Baking powder	Nonfat dry milk solids	Fat	Sugar	Added to premix: Water
66-2/3% SF[1], control	1	36.6	73.4	3.0	4.0	30.0	12.5	0.0	230
100% SF									
Amount of liquid									
1. 230 g	2	0.0	110.0	3.0	4.0	30.0	12.5	0.0	230
2. 210 g	3	0.0	110.0	3.0	4.0	30.0	12.5	0.0	210
3. 190 g	4	0.0	110.0	3.0	4.0	30.0	12.5	0.0	190
Amount of dms[2]									
1. 230 g liquid									
a. 30 g dms	2	0.0	110.0	3.0	4.0	30.0	12.5	0.0	230
b. 20 g dms	5	0.0	110.0	3.0	4.0	20.0	12.5	0.0	230
c. 10 g dms	6	0.0	110.0	3.0	4.0	10.0	12.5	0.0	230
2. 210 g liquid									
a. 30 g dms	3	0.0	110.0	3.0	4.0	30.0	12.5	0.0	210
b. 20 g dms	7	0.0	110.0	3.0	4.0	20.0	12.5	0.0	210
c. 10 g dms	8	0.0	110.0	3.0	4.0	10.0	12.5	0.0	210
3. 5% baking powder									
a. 30 g dms	9	0.0	110.0	3.0	5.5	30.0	12.5	0.0	230
b. 20 g dms	10	0.0	110.0	3.0	5.5	20.0	12.5	0.0	230
c. 10 g dms	11	0.0	110.0	3.0	5.5	10.0	12.5	0.0	230
4. 5% added sugar									
a. 30 g dms	12	0.0	110.0	3.0	4.0	30.0	12.5	5.5	230
b. 20 g dms	13	0.0	110.0	3.0	4.0	20.0	12.5	5.5	230
c. 10 g dms	14	0.0	110.0	3.0	4.0	10.0	12.5	5.5	230

[1] SF = sorghum flour

[2] dms = nonfat dry milk solids

3. Add fat to the dry ingredients and partially blend the mixture with 25 strokes.

4. Rub the mixture through a three mm screen mesh strainer two times.

Method used for preparing waffles from premix:

1. Weigh the water, temperature 18-22°C.

2. Preheat the waffle iron with the thermostat set at medium dark heat until the indicator shows that the iron has attained the correct temperature.

3. Place premix in a three-quart enamel bowl. Make a well in the center of the mixture. Add the water and stir with wooden spoon at medium speed for 20 strokes.

4. Weigh and record the weight and temperature of a 57 cc cup of batter for calculation of specific gravity.

5. Weigh out 90 grams of the batter and pour into one section of the hot waffle iron. In the same manner fill the three remaining sections with other premixes to be tested. Use a rubber scraper when pouring the batter so as to remove as much of the batter as possible from the container.

6. Bake the waffle until the indicator light shows that the baking has been completed.

7. Test the linespread of the batter. Record four readings. Average.

8. Place the baked waffle on a rack. Score for palatability.

9. Determine the water absorption ability of the waffle

three minutes after removing waffle from the iron.

The waffles were baked in a 9 by 9 inch square iron which was divided further into four sections 4-1/2 by 4-1/2 inches. This waffle iron held 14 ounces of batter so that by pouring 90 grams of batter into each of the sections it was possible to bake three variations of the product and the control at one time. In order to have each section filled at approximately the same time, two workers poured the batter into the hot waffle iron with each operator filling two of the sections. This procedure permitted the filling of the iron within so short a time that each premix batter variation received approximately the same baking period.

Specific gravity, linespread and water absorption ability were the objective tests used as an index to the quality of the waffle premix. Specific gravity of the waffle batter was determined in the same manner as for the griddle cake batter. To determine the consistency of the batter, the linespread test as used by Adams and Birdsall (1946), was modified so that the batter was poured into a ring 1-3/4 inches in diameter and 3/4 of an inch deep. This ring was placed on a glass plate under which had been placed a drawing of concentric circles at 1/8 inch intervals. The diameter of the smallest circle was the same as the diameter of the receptacle for the batter. The ring was placed over the first circle, filled with batter and then the batter leveled. The ring was lifted and the batter allowed to flow for 90 seconds. Readings were taken at four points by counting from the outermost circle to the innermost circle

visible. These four readings were then averaged, the average representing the linespread of the batter.

A portion of the baked waffle was cut into three by three centimeter squares for the water absorption ability test. The squares tested were cut so that each square contained an impression of four typical waffle iron patterns with the cut edge being made at the ridge part of the pattern. Each square was weighed and the weight recorded. Then the square was placed in an evaporating dish which contained 20 cc of water at 22°C. The square was allowed to remain in the water for 90 seconds. At the end of this period, it was lifted carefully out of the evaporating dish, quickly inverted so as to prevent loss of water in dripping, and then placed on the scale and reweighed. The difference in the weights represented the water absorbing ability. An average of three readings was recorded as the water absorbing ability of that product.

The palatability committee for the judging of the waffle premix was comprised of five members of the staff of the Department of Foods and Nutrition and one graduate student in the same department. Form 1 (Appendix), the same score card as used for the judging of griddle cakes, was used for the scoring of waffles except that the word "crisp" was added to the description of desirable characteristics for texture. Immediately after the waffle was removed from the iron, the judges scored it for aroma, appearance, texture, moisture, tenderness and flavor.

The variations used in the study of the waffle premixes were

the percentage of sorghum flour, 80, 90 and 100 percent; the amount of dried whole egg; 10 and 3 g or 10 and 3 percent, based on the flour used; and the addition of 5 g or 5 percent sugar to the premix. The effect of two different amounts of water added to the premix was studied also. Each variation was checked five times. The basic waffle premix was used as the control with each variation tested. Details of the formula variations tested are given in Table 2.

Gingerbread Premix

The basic formula used as control for the gingerbread premix was adapted from one used by Halliday and Noble (1946). Two-thirds of the wheat flour was replaced by sorghum flour. Dried whole egg was used in lieu of shell eggs and the required amount of water necessary to reconstitute the egg powder was added to the amount of water in the original formula.

Basic Formula for Waffle Premix

Ingredients	Weight (grams)	Approximate measure
Flour, all-purpose	42.0	3/8 cup
Flour, sorghum	84.0	3/4 cup
Baking powder, Calumet	3.0	3/4 teaspoon
Salt	2.3	1/3 teaspoon
Ginger	2.0	3/4 teaspoon
Cinnamon	2.0	3/4 teaspoon
Soda	2.4	1/2 teaspoon
Sugar	37.5	3 tablespoons
Fat, Primex	39.7	3 tablespoons
Egg, dried whole	10.0	1 2/3 tablespoons
Molasses	122.0	3/8 cup
Water	103.5	7 tablespoons

Table 2. Waffle premix variations.

Product variation	Formula number	Ingredients in premix, grams: All-purpose flour	Sorghum flour	Salt	Baking powder	Nonfat dry milk solids	Dried whole egg	Fat	Sugar	Added to premix: Water
66-2/3% Sorghum flour, control	20	33.4	66.6	1.8	4.5	17.0	10.0	15.2	0.0	175.0
80% Sorghum flour	21	20.0	80.0	1.8	4.5	17.0	10.0	15.2	0.0	175.0
90% Sorghum flour	22	10.0	90.0	1.8	4.5	17.0	10.0	15.2	0.0	175.0
1. Decreased liquid	23	10.0	90.0	1.8	4.5	17.0	10.0	15.2	0.0	160.0
2. 3% dried egg	24	10.0	90.0	1.8	4.5	17.0	3.0	15.2	0.0	170.6
3. 5% added sugar	25	10.0	90.0	1.8	4.5	17.0	10.0	15.2	5.0	175.0
100% Sorghum flour	26	0.0	100.0	1.8	4.5	17.0	10.0	15.2	0.0	175.0
1. Decreased liquid	27	0.0	100.0	1.8	4.5	17.0	10.0	15.2	0.0	145.0
2. 3% dried egg	28	0.0	100.0	1.8	4.5	17.0	3.0	15.2	0.0	170.6
3. 5% added sugar	29	0.0	100.0	1.8	4.5	17.0	10.0	15.2	5.0	175.0

Method used for preparing premix:

1. Weigh all the dry ingredients and the fat.

2. Using a sifter with a two mm screen mesh, sift all the dry ingredients together twice.

3. Add fat to the dry ingredients and mix in the KitchenAid mixer at speed number one for five minutes. Use the paddle attachment for the mixing process.

Method used for preparing gingerbread from premix:

1. Line bottom of pans, 6-3/4 x 3 x 2 inches, with oiled paper.

2. Weigh molasses and water, temperature of water 18-22°C. Blend together.

3. Place premix in a three-quart enamel bowl. Make a well in the center of the premix, add the liquid mixture and stir with wooden spoon at moderate speed for 60 seconds (90-100 strokes).

4. Weigh and record the weight and temperature of a 57 cc cup of batter for calculation of specific gravity.

5. Test and record the linespread of the batter. Record four readings. Average.

6. Pour batter into pans. Cut with spatula two times in each direction.

7. Allow filled pans to set for 10 minutes. Place in oven and bake at 350°F for 50 minutes.

8. Remove from oven. Cool for five minutes, then remove from pan by loosening the gingerbread with a spatula and inverting the pan over a wire rack and allowing the gingerbread to fall

from the pan. Remove oiled paper from the bottom and turn to an upright position.

9. When cool, place on a cookie sheet, cover with a larger pan.

10. Approximately 20 hours after baking, measure, test and record standing height, compressibility and shortness. Score for palatability.

The specific gravity and the linespread determinations were made the same as for the waffle premix.

In order to obtain uniform slices for testing, an apparatus as described by Roberts (1945) was used for slicing the gingerbread. This apparatus was similar to a mitre box, made of wood closed at both sides and one end, with a kerf on each side one inch from the closed end and into which fitted a long knife. A second similar box which was designed to cut one-half inch slices was used also. From each loaf of gingerbread the following samples were taken: first, three one-half inch slices were cut, the end slice with the crust was discarded and the remaining two slices were divided into three portions each to be used for scoring of palatability; second, three one-inch slices were cut to be used for testing the compressibility; third, three one-half inch slices were cut to be used for testing the shortness.

Standing height was used as an index to the volume of the gingerbread. The height of each sample was determined by measuring in centimeters the cut edge of the gingerbread just prior to the slicing of the last three one-half inch slices. A measurement

was taken one centimeter in from each outer edge and the third measurement made at the center of the loaf. The average of the three measurements was recorded as the standing height.

The compressibility test was made by means of an apparatus similar to that used by Platt and Kratz (1933) This consisted of a remodeled laboratory balance in which the left hand pan was fitted with a linked chain which could be removed by winding on a wooden drum extending over the left hand pan. Beneath the right hand pan of the balance was fastened a metal plunger 31 mm in diameter. A 200 g weight was placed on the right hand pan in order to balance the chain on the left hand pan. The sample to be tested was placed on a platform just below the plunger so that when a 10 g weight was placed on the pan above, the plunger rested easily upon the surface of the sample. A pointer suspended from the cross arm of the balance indicated in centimeters on a scale at the lower part of the balance the degree of compressibility of the sample. The pointer was adjusted to zero and the chain wound onto the drum in 30 seconds time. Ninety seconds after removing the chain, the reading on the scale was recorded. The average reading from three samples was recorded as the compressibility of the gingerbread.

The shortometer, designed and built at Kansas State College and described and used by Gordon (1947), was used to test the shortness of the gingerbread. Each gingerbread slice to be tested was placed across two parallel bars which were attached to the weighing pan of a spring balance. A plunger rod was suspended

from a movable platform on which rested a metal cup into which shot was let from a funnel. By allowing shot to pour into the cup, the plunger bar was brought in contact with the sample until enough weight was applied to break the slice of gingerbread. The pressure required to break the gingerbread was measured by watching the hands on the 1000 gram spring balance. Three samples of each gingerbread were tested. An average of the readings was recorded as the shortness of the product. This test was used as an index to the tenderness of the gingerbread.

The palatability committee for the scoring of the gingerbread premix was the same as the one that judged the waffle premix. Form 2 (Appendix), Score card for gingerbread, was a modified form of that used for judging griddle cakes and waffles.

In the gingerbread premix, a study was made of the effect of the percentage of sorghum flour substituted for wheat flour. The percentages of sorghum flour used were 75, 83-1/3, 87-1/2 and 100 percent. Also, a study was made of the effect of decreased leavening agents, baking powder and soda, at the given levels of sorghum flour. Details of formula variations studied are listed in Table 3. The basic formula, containing 66-2/3 percent sorghum flour, served as the control with each variation tested. All formulas were checked five times.

Table 3. Gingerbread premix variations.

Product variation	Formula number	Ingredients in premix, grams: All-purpose flour	Sorghum flour	Sugar	Dried whole egg	Baking powder	Soda	Ginger	Cinnamon	Salt	Fat	Added to premix: Molasses	Water
66-2/3% SF[1], control	30	42.0	84.0	37.5	10.0	3.0	2.3	2.0	2.0	2.3	39.7	122.0	103.5
Increased SF													
1. 75% SF	31	31.0	94.0	37.5	10.0	3.0	2.3	2.0	2.0	2.3	39.7	122.0	103.5
2. 83-1/3% SF	32	20.5	105.5	37.5	10.0	3.0	2.3	2.0	2.0	2.3	39.7	122.0	103.5
3. 87-1/2% SF	33	16.4	109.6	37.5	10.0	3.0	2.3	2.0	2.0	2.3	39.7	122.0	103.5
4. 100% SF	34	0.0	100.0	37.5	10.0	3.0	2.3	2.0	2.0	2.3	39.7	122.0	103.5
Decreased baking powder and soda													
1. 75% SF	35	31.0	94.0	37.5	10.0	1.0	1.6	2.0	2.0	2.3	39.7	122.0	103.5
2. 83-1/3% SF	36	20.5	105.5	37.5	10.0	1.0	1.6	2.0	2.0	2.3	39.7	122.0	103.5
3. 87-1/2% SF	37	16.4	109.6	37.5	10.0	1.0	1.6	2.0	2.0	2.3	39.7	122.0	103.5
4. 100% SF	38	0.0	100.0	37.5	10.0	1.0	1.6	2.0	2.0	2.3	39.7	122.0	103.5

[1]SF = sorghum flour

RESULTS AND DISCUSSION

Griddle Cake Premix

All data obtained from the griddle cake premixes studied were summarized, averaged and recorded in Table 4.

In the first group of griddle cake premixes tested, there was a variation in the amount of liquid added to the premix to form a batter. The formulas for the premixes and the results of the griddle cakes produced by decreased amounts of water are as follows:

Formula 1, which contained 66-2/3 percent sorghum flour, was used as the control and served as a basis for the comparison of all other griddle cake premixes tested. To the basic formula was added 230 g of water. In preliminary work, this amount of liquid was found to produce a batter of proper consistency for griddle cakes. Justin, Rust and Vail (1948) described a standard wheat griddle cake as one which should be evenly brown on both sides, fairly regular in shape, light and tender, moderately moist, even grain and pleasing in flavor. Griddle cakes from the basic formula were similar to the standard as described for wheat cakes except that the texture produced with 66-2/3 percent sorghum flour was slightly compact and had a thick cell wall structure. The cakes were also rather moist but they were not sticky or gummy.

Formulas 2, 3 and 4 contained 100 percent sorghum flour and 230, 210 and 190 g of water, respectively. The specific gravity

Table 4. Average results for all variations in griddle cake premixes.

Product variation	Formula number	Objective tests: Specific gravity	Objective tests: Line-spread	Objective tests: Moisture absorption	Palatability[1]: Aroma	Palatability[1]: Appearance	Palatability[1]: Texture	Palatability[1]: Moisture	Palatability[1]: Tenderness	Palatability[1]: Flavor	Palatability[1]: Total[2]
66-2/3% SF[3], control	1	1.07611	7.0	1.2	9.2	8.7	7.9	7.1	7.6	8.2	49.0
100% Sorghum flour											
Amount of liquid											
1. 230 g water	2	1.09395	7.1	1.2	9.2	8.7	7.7	7.1	7.7	8.4	49.1
2. 210 g water	3	1.08509	8.0	1.4	9.5	9.1	8.2	7.3	8.3	8.8	51.1
3. 190 g water	4	1.06799	8.3	2.0	9.5	8.6	7.8	7.6	7.8	8.7	50.3
Amount of dms[4]											
1. 230 g water											
a. 30 g dms	2	1.09395	7.1	1.2	9.2	8.7	7.7	7.1	7.7	8.4	49.1
b. 20 g dms	5	1.10626	7.2	1.4	9.0	8.2	7.6	6.8	7.4	8.1	47.6
c. 10 g dms	6	1.11267	7.4	1.3	8.9	7.8	7.1	5.8	7.4	7.6	44.7
2. 210 g water											
a. 30 g dms	3	1.08509	8.0	1.4	9.5	9.1	8.2	7.3	8.3	8.8	51.1
b. 20 g dms	7	1.09766	7.2	1.3	8.6	6.0	6.8	7.2	7.2	8.0	43.8
c. 10 g dms	8	1.10180	8.8	1.4	9.0	7.4	7.0	6.0	7.2	7.7	44.5
3. 5% baking powder											
a. 30 g dms	9	1.05268	7.0	1.5	9.2	8.7	7.0	6.5	7.6	8.1	48.6
b. 20 g dms	10	1.06987	7.1	1.4	9.0	8.1	7.6	6.5	7.6	7.4	46.4
c. 10 g dms	11	1.08879	7.2	1.3	9.0	6.5	6.5	6.0	7.4	7.0	42.3
4. 5% added sugar											
a. 30 g dms	12	1.06688	6.9	1.5	9.4	8.9	7.2	6.4	7.7	8.5	48.3
b. 20 g dms	13	1.08995	7.1	1.1	9.4	9.1	7.8	6.2	8.0	8.4	49.1
c. 10 g dms	14	1.10164	7.3	1.4	9.2	9.0	7.0	5.0	7.9	8.0	46.4

[1] Highest possible score for each palatability factor = 10

[2] Highest possible total = 60

[3] SF = Sorghum flour

[4] dms = Nonfat dry milk solids

of the batter tended to decrease as the amount of water used to form the batter was reduced. The use of less liquid resulted in a thicker batter yielding smaller, thicker griddle cakes than when the average amount of water, 230 g, was used. Those griddle cakes made from thinner batters were more moist than those which contained decreased amounts of liquid. In scoring griddle cakes with less water, the judges graded the quality of moistness of the cake slightly higher at the decreased level of water. The aroma, appearance, texture, moisture, tenderness and flavor of all the 100 percent sorghum flour griddle cakes, regardless of amount of water, was comparable with or better than the control. Formula 3 to which was added 210 g of water, a decrease of 20 g from the average, received an average total score of 51.1 as compared with a 49.1 score for formula 2, containing 230 g of water, and a 50.3 score for formula 4, containing 190 g of water. This result agreed with Bavousett and Kleppe (1942) who found that a slight decrease in liquid might be desirable in using sorghum flour in some formulas. In the opinion of the judges, the use of 100 percent sorghum flour in griddle cake premixes was slightly more desirable because of the improved flavor of the cake.

Formulas 2, 5 and 6 were 100 percent sorghum flour premixes containing 30 g, 20 g, and 10 g of nonfat dry milk solids, respectively. The amount of water used to form the batter was 230 g. Results of the objective tests showed that as the nonfat dry milk solids were decreased, the specific gravity of the batter increased. Linespread showed little difference in the consistency of the batter and the moisture absorption ability test gave

no appreciable variation in the quality of the griddle cakes. With a decrease in nonfat dry milk solids in the premix, the addition of water resulted in batters which manifested greater syneresis than those batters made from premixes containing 30 g of nonfat dry milk solids. With the lowest amount of nonfat dry milk solids in the formula, syneresis of the batter occurred in the short time required to test and record its linespread. There was a general decrease in palatability scores of premixes containing the lower percentages of nonfat dry milk solids. The appearance score dropped from 8.7 with 30 g of nonfat dry milk solids to 7.8 with 10 g of nonfat dry milk solids in the premix. The major factor involved in the lowering of the appearance score was the pale and slightly uneven color of the griddle cake. Texture became more compact and the cakes became increasingly soggy as the nonfat dry milk solids were decreased. This was reflected in the palatability scores on texture and moisture. Higher quantities of nonfat dry milk solids improved the flavor of the griddle cake.

Because results with formulas 2, 3 and 4, in which decreasing amounts of water were used, indicated that a slight decrease in liquid would improve the griddle cake, it was decided to test the effect of lower amounts of nonfat dry milk solids on griddle cakes made from batters containing less liquid.

Formulas 3, 7 and 8, containing 30 g, 20 g and 10 g of nonfat dry milk solids, respectively, were made into batters with 210 g of water. The resulting griddle cakes evidenced the same

general results as those made from formulas 2, 5 and 6 containing corresponding amounts of nonfat dry milk solids but using 230 g of water to form the batter. However, formula 7, 20 g of nonfat dry milk solids and 210 g of liquid, made a thinner batter than formulas 3 and 8 and the resulting griddle cakes received a lower palatability score than those from formula 8 which had 10 g of nonfat dry milk solids and 210 g of water. At present, no explanation can be offered for the thinner consistency as indicated by linespread and the drop in the appearance score as judged by the palatability committee for the griddle cake made from formula 7 below that of the one produced from formula 8.

Formulas 9, 10 and 11 contained 5 percent baking powder, 1.5 g more than the amount used in other formulas, and 30 g, 20 g and 10 g of nonfat dry milk solids, respectively. In each of these formulas 230 g of water was used. The higher percentage of baking powder and the largest quantity of nonfat dry milk solids gave a batter with comparatively low specific gravity. As the nonfat dry milk solids were decreased in premixes containing the higher amount of baking powder, the specific gravity of the batter tended to increase. Considered as a group, an increase in baking powder in the formula caused the batters to have lower specific gravity than other premixes studied. Neither consistency, as measured by linespread, nor moisture absorption ability appeared to be influenced appreciably with a reduction in nonfat dry milk solids in those formulas containing 5 percent baking powder. The appearance of the griddle cakes in this group was

characterized by an increasingly pale color as the nonfat dry milk solids were lessened and by an unevenly raised griddle cake at all levels of nonfat dry milk solids. Flavor in this group was scored lower than for any other variation studied. In the opinion of the judges, the lower score was due to a bitter flavor which they frequently described as a "baking powder" taste.

Formulas 12, 13 and 14 contained 30 g, 20 g and 10 g of nonfat dry milk solids, respectively, and all had 5 percent sugar added to the premix. Reducing the amount of nonfat dry milk solids in the formulas containing sugar caused a lowering of the specific gravity. The linespread test showed that the consistency of the batter became slightly thicker at the lowest amount of nonfat dry milk solids. Moisture absorption ability was least with 20 g of nonfat dry milk solids in premixes containing sugar. The aroma of these griddle cakes was slightly sweet. The appearance of griddle cakes containing less nonfat dry milk solids was improved by the addition of sugar. With the addition of sugar to formulas containing 30 g of nonfat dry milk solids, the griddle cakes were very dark, whereas, cakes resulting from premixes containing sugar and less nonfat dry milk solids were a golden brown. Texture and tenderness were slightly improved with the addition of sugar. A more moist product, almost to the point of being gummy and sticky, was noted by the judges. At the lowest level of nonfat dry milk solids this was particularly true as the comment "gummy" and "sticky" was written frequently by the judges. Addition of sugar to the mixture seemed to compensate

in a degree for a decrease in the amount of nonfat dry milk solids in regard to the flavor and the appearance of the resulting griddle cake.

Waffle Premix

All data from the waffle premixes were summarized, averaged and recorded in Table 5.

In this part, a study was made of the effect of decreased water, decreased dried egg and added sugar to premixes containing 90 and 100 percent sorghum flour. The control for waffles, formula 20, contained 66-2/3 percent sorghum flour. This formed, on the addition of 175 g of water, a batter that was thin as shown by the average linespread reading of 4.2. The moisture absorption ability averaged 7.8. The high moisture absorption ability of this product might have been due to the nature of the crust and the slightly drier crumb of the waffle. Justin, Rust and Vail (1948) stated that a waffle with a uniform golden brown color, regular shape, crisp tender crust, light, slightly moist crumb and a pleasing flavor were the characteristics of a standard product. The control, formula 20, gave a waffle conforming to this description of a wheat flour waffle with the exception that the crumb was slightly dry and the texture compact. The texture and appearance of the control waffle were similar to a part cornmeal product. On the average, the judges deemed the texture, moistness, tenderness and flavor desirable and the aroma and appearance very desirable. The average total palatability

Table 5. Average results for all variations in waffle premixes.

Product variation	Formula number	Objective tests: Specific gravity	Objective tests: Line-spread	Objective tests: Moisture absorption	Palatability[1]: Aroma	Palatability[1]: Appearance	Palatability[1]: Texture	Palatability[1]: Moisture	Palatability[1]: Tenderness	Palatability[1]: Flavor	Palatability[1]: Total[2]
66-2/3% SF[3], control	20	1.07775	4.2	7.8	9.0	9.1	7.7	7.6	7.9	8.4	50.0
80% Sorghum flour	21	1.06759	4.9	7.9	8.8	8.9	7.4	7.0	7.4	8.5	48.1
90% Sorghum flour	22	1.06231	4.9	7.9	8.9	9.0	7.3	7.1	7.5	8.4	48.2
1. Decreased liquid	23	1.06109	6.1	8.8	9.1	9.2	7.5	7.4	7.4	8.1	48.8
2. 3% dried egg	24	1.08648	5.0	7.3	9.0	7.9	7.2	7.3	7.4	8.0	47.9
3. 5% added sugar	25	1.09652	3.3	8.6	9.0	9.1	6.2	6.8	7.5	8.6	48.0
100% Sorghum flour	26	1.06262	3.8	7.8	8.9	8.9	7.1	6.7	7.3	8.3	47.4
1. Decreased liquid	27	1.03492	8.1	7.8	9.3	9.1	6.7	7.2	7.1	7.8	47.4
2. 3% dried egg	28	1.08985	4.2	7.4	9.0	8.9	6.9	7.0	7.0	7.9	47.0
3. 5% added sugar	29	1.09160	3.4	8.2	9.0	9.1	6.6	6.4	7.5	8.6	47.4

[1] Highest possible palatability score for each factor = 10

[2] Highest possible total = 60

[3] SF = Sorghum flour

score was 50 points out of a possible total of 60.

Formula 21, containing 80 percent sorghum flour, gave a batter with a slightly lower specific gravity, slightly thicker consistency as indicated by the linespread test and approximately the same moisture absorption ability as the basic formula which had a lower percentage of sorghum flour. The waffle produced from formula 21 was slightly less desirable than the control in the estimation of the palatability committee.

Formula 22, containing 90 percent sorghum flour, gave approximately the same results as the one containing 80 percent sorghum flour. Written comments of the judges were essentially that there was little difference between waffles using 66-2/3, 80, 90 and 100 percent sorghum flour.

Formula 23, 90 percent sorghum flour, used 15 g less water to form the batter than formula 22. The slight decrease in liquid gave a batter of thicker consistency as evidenced by linespread and a waffle of greater moisture absorption ability than did formula 22, to which more water was added. The palatability score of this waffle more closely approached that of the control than did other premixes in this study. This was in accord with the suggestion of Bavousett and Kleppe (1942) that it might be desirable to decrease liquids slightly in bread products when substituting sorghum flour for wheat flour.

Formula 24 contained 90 percent sorghum flour and 3 percent dried egg, 7 percent less dried egg than in other formulas made with the same amount of sorghum flour. Reducing the percentage

of dried egg in the waffle premix produced a batter with slightly higher specific gravity and thicker consistency than the basic formula. Moisture absorption ability was slightly less than for the control. Premixes using 10 percent dried egg yielded waffles with a very yellow interior, whereas, with 3 percent dried egg the interior was a creamy color. Apparently, the judges preferred the more yellow product since the appearance of the waffle containing 3 percent dried egg was scored lower than those with the higher percentage.

Formula 25 was made from 90 percent sorghum flour and had 5 percent sugar added. The specific gravity of the batter formed from this premix was greater than the control and the consistency was thinner. The average moisture absorption ability of the waffle was approximately the same as the one made from formula 23 which had the same percentage of sorghum flour but had no added sugar and which used less liquid in the batter. The increase in moisture absorption ability over that of the control might be explained by the fact that the waffle had a crisp crust. The opinion was voiced by the judges that those waffles that contained sugar were more moist than those with no sugar. Lowe (1943) stated that sugar peptizes egg and flour proteins, elevates the temperature of coagulation and adds to the flavor of the product. Concurring with this statement were the palatability scores given for texture, moisture and flavor.

Formula 26 contained 100 percent sorghum flour. The batter formed from this premix had as low or lower specific gravity and

was thinner than batters from formulas made with less sorghum flour. Syneresis in the batter of 100 percent sorghum flour premixes was greater than in those containing less sorghum flour. The average moisture absorption ability for the 100 percent sorghum flour waffles was the same as for those containing a lower percentage. All sorghum flour gave waffles with more compact texture and moist crumb than did part sorghum flour. Hence, these palatability factors were scored slightly lower.

Formula 27 was made from 100 percent sorghum flour and had 30 g less liquid used to form the batter than in the previous formula. The specific gravity of this batter was less than that of any other one studied. It was thick in consistency and appeared to be heavy. Moisture absorption ability was the same as for the control. The aroma of the waffles was pleasing. The texture was very compact but the moistness was scored higher than for that of a 100 percent sorghum flour waffle containing more liquid. A crisper, drier waffle was produced by using less liquid in the formula. Several judges characterized the flavor of the product as being bitter and scored the flavor down accordingly.

Formula 28 contained 100 percent sorghum flour with three percent dried egg. In general, this premix gave the same results as the 90 percent formula containing the same proportion of dried egg (formula 24).

Formula 29 was a 100 percent sorghum flour premix with 5 percent sugar added to it. The statements made about formula 25, 90

percent sorghum flour and 5 percent sugar, also apply to formula 29.

Gingerbread Premix

All data obtained from the gingerbread premixes were summarized, averaged and recorded in Table 6.

The basic gingerbread premix, formula 30, contained 66-2/3 percent sorghum flour. Upon the addition of water, a batter with an average specific gravity of 1.09582 and with a thick consistency resulted. Lowe (1943) stated that gingerbreads containing a large proportion of soda sometimes sink in the center. This characteristic was observed in the control product. The breaking strength of this gingerbread as measured by the shortometer was lower than for gingerbreads containing larger percentages of sorghum flour. There appeared to be no relationship between the shortness of the gingerbread and the palatability score for tenderness. A possible explanation might be that the judges tended to score tenderness lower because of crumbliness due to dry crumb. Also, it was noted by the worker, that as the percentage of sorghum flour was increased, the gingerbreads became more crumbly and difficult to slice and to test.

Formula 31 differed from the basic one only in the percentage of sorghum flour in the premix, 75 percent. The batter produced from this tended to have greater specific gravity than that of the control. Compressibility of the crumb was less and the force required to break a one-half inch slice was greater than

Table 6. Average results for all variations in gingerbread premix.

Product variation	Formula number	Objective tests: Specific gravity	Objective tests: Line-spread	Objective tests: Standing height cm	Objective tests: Compressibility cm	Objective tests: Shortness g	Palatability[1]: Aroma	Palatability[1]: Appearance	Palatability[1]: Texture	Palatability[1]: Moisture	Palatability[1]: Tenderness	Palatability[1]: Flavor	Palatability[1]: Total[2]
66-2/3% SF[3], control	30	1.09582	8.0	4.6	1.2	159.0	8.8	7.2	6.9	7.4	7.7	8.3	46.2
Increased SF													
1. 75% SF	31	1.11157	8.0	4.5	0.9	173.0	8.8	6.2	6.3	6.8	7.4	8.1	43.8
2. 83-1/3% SF	32	1.11431	9.0	4.7	1.0	161.0	8.5	7.0	5.9	6.1	7.4	8.1	43.4
3. 87-1/2% SF	33	1.11450	8.4	4.5	1.1	162.0	8.5	6.3	5.8	6.7	7.4	8.1	43.1
4. 100% SF	34	1.12103	8.8	4.5	0.9	169.0	8.7	6.2	5.6	6.1	7.1	7.1	41.8
Decreased baking powder and soda													
1. 75% SF	35	1.13706	7.5	4.6	1.0	175.0	8.9	7.8	7.3	7.6	7.8	8.6	48.2
2. 83-1/3% SF	36	1.12890	8.1	4.5	1.0	183.0	8.9	8.0	7.2	7.4	7.8	8.4	48.0
3. 87-1/2% SF	37	1.14212	7.5	4.7	1.0	181.0	8.9	7.6	7.0	7.4	7.5	8.4	47.1
4. 100% SF	38	1.13695	7.6	4.5	0.9	174.0	8.9	7.5	6.6	7.0	7.4	8.3	45.5

[1] Highest possible score for each palatability factor = 10

[2] Highest possible total = 60

[3] SF = Sorghum flour

for the control. A pronounced sinking in the center of the loaf was evident in the baked gingerbread. This fact was reflected in the appearance score which was one point lower. Use of 75 percent sorghum flour in the formula gave a product that was crumbly and dry with palatability factors of appearance, texture, moisture, tenderness and flavor being lowered accordingly.

Formula 32 contained 83-1/3 percent sorghum flour. The specific gravity and linespread readings were somewhat higher than from premixes made with less sorghum flour. Compressibility of crumb, shortness and total palatability showed the same tendencies as the formula containing 75 percent sorghum flour.

Formula 33 was made from 87-1/2 percent sorghum flour. Objective and subjective testing of this gave results similar to those from formulas containing 75 and 83-1/3 percent sorghum flour.

Formula 34 was made from 100 percent sorghum flour. A thicker batter of slightly higher specific gravity than the 75 percent sorghum flour one but not as thick as the 83-1/3 percent sorghum flour batter resulted. There was a general decline in the palatability score with the flavor score dropping the most. This gingerbread was very crumbly and dry and had a flavor which the judges often described as "bitter".

Formulas 35, 36, 37 and 38 contained 75, 83-1/3, 87-1/2 and 100 percent sorghum flour respectively. All of these formulas had 2 g less baking powder and 0.7 g less soda than in the foregoing formulas. Lowe (1943) stated that "baking powder or their

residual salts may modify the hydration capacity of the flour proteins". Therefore, by reducing the baking powder, it was hoped to obtain a less crumbly dry product. Baking soda was decreased slightly because Lowe (1943) had found that the amount of soda required to neutralize the acid varied and that too much soda might cause a sinking in the center of the cake and an alkaline flavor. Results from this group of premixes produced the general trends observed in formulas 31 through 34. However, a decrease in baking powder and soda yielded batters of slightly higher specific gravity and less thick consistency than did those produced from formulas with the same percentage sorghum flour and a higher level of leavening agents. Shortometer readings were higher possibly indicating a firmer structure. Appearance of the products at all levels of sorghum flour was improved in that the sinking in the center of the loaf, if any, was not conspicuous; the interior color was less dark. Higher scores in texture, moisture, tenderness and flavor resulting from a decrease in leavening agents were given probably because of the better structure, more moist crumb and lack of bitterness in the gingerbreads made from formulas 35 through 38, inclusive.

Gingerbreads, regardless of the amount of sorghum flour or leavening agent, were of approximately the same volume. Compressibility of the crumb at the various sorghum flour levels evidenced negligible differences.

SUMMARY

The purpose of this study was to determine the percentage of sorghum flour that could be used to replace wheat flour in griddle cake, waffle and gingerbread premixes and to ascertain the desirability of premixes that contained maximum amounts of sorghum flour.

A basic formula using 66-2/3 percent sorghum flour as recommended by Bavousett and Kleppe (1942) was used for the control and served as a basis for comparison of products. By increasing the percentage of sorghum flour and decreasing the amount of wheat flour proportionately, the formula was adjusted to obtain a product containing the maximum amount of sorghum flour. Each variation in amount of sorghum flour and ingredient other than flour was checked five times.

Preliminary work on the griddle cake premix showed that a satisfactory product could be made with 100 percent sorghum flour. However, a more desirable cake was produced when the amount of water added to the premix was cut 20 g. As the quantity of nonfat dry milk solids was decreased from 30 g to 20 g and to 10 g, the batters tended to show considerable syneresis and to produce cakes which were increasingly pale, moist and slightly less desirable in flavor. When 5 percent sugar, based on the flour used, was added to the premix, the color and the flavor of the products made with reduced nonfat dry milk solids

were improved. The specific gravity and the moisture absorption ability had no relationship to the quality of the griddle cake. However, there appeared to be a relationship between the quality of the cake and the linespread of the batter. Viscous batters produced cakes that were thicker and smaller in diameter and more breadlike than those from the same weight of less viscous batters.

The waffle premixes studied contained 66-2/3, 80, 90 and 100 percent sorghum flour. There appeared to be very slight differences in the waffles made from formulas containing increased percentages of sorghum flour. The average total palatability score for 80 percent sorghum flour waffles was 48.1; for 90 percent, 48.2 and for 100 percent, 47.4. Decreasing the amount of water added to premixes containing 90 and 100 percent sorghum flour produced more viscous batters with the resulting waffles being slightly more desirable in the quality factors of aroma, appearance, texture and moisture. Ten percent dried egg in waffle premixes gave a better product than 3 percent as used in many commercial formulas. Decreasing the dried egg in both 90 and 100 percent sorghum flour premixes gave batters of comparatively high specific gravity and products with pale interiors and slightly less desirable average palatability scores. Adding 5 percent sugar to 90 and 100 percent sorghum flour formulas produced thin batters of high specific gravity and increased the moisture absorption ability of the baked waffle. The use of sugar resulted in products with a more compact texture and more

moist interior but improved flavor.

In gingerbread premixes containing 66-2/3, 83-1/3, 87-1/2 and 100 percent sorghum flour, there was very little difference in the total palatability scores. The judges were not always able to differentiate between the various levels of sorghum flour in gingerbreads. However, as the sorghum flour was increased, the palatability score tended to decrease slightly. No appreciable difference in volume, as indicated by standing height, was noted. Greater force was required to break a one-half inch slice when the percentage of sorghum flour was increased above 66-2/3 percent. Reducing the baking powder and soda in the formula resulted in less viscous batters and a better quality baked product. All gingerbread premixes yielded a crumbly and dry product. Nevertheless, all gingerbreads were judged acceptable.

Griddle cake and waffle premixes made with 100 percent sorghum flour gave satisfactory products. The effect of decreased nonfat dry milk solids in griddle cakes and decreased dried egg in waffle premixes indicated that ingredients other than flour which give structure to a batter need to be increased when using sorghum flour in lieu of wheat flour. In gingerbread premixes, 75 and 83-1/3 percent sorghum flour produced acceptable products but at 100 percent the gingerbread was very crumbly and dry. There was evidence to indicate that all of these premixes could be used satisfactorily but that considerable investigation is needed to determine characteristics of sorghum flour before properly balanced formulas can be made.

In order of degree of acceptability, the 100 percent sorghum flour premixes studied were griddle cake, waffle, and gingerbread.

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LITERATURE CITED

Adams, M. C., and E. L. Birdsall.
New consistometer measures corn consistency. Food Indus. 18: 844-846. 1946.

Ball, C. R.
The history and distribution of sorghum. U. S. Dept. Agr., Bur. Plant Indus. Bul. 175, 63 p. 1910.

Ball, C. R., and B. E. Rothgeb.
How to use sorghum grain. U. S. Dept. Agr. Farmers' Bul. 972, 15 p. 1915.

Barham, H. N., J. A. Wagoner, Carol L. Campbell, and Edwin H. Harclerode.
The chemical composition of some sorghum grains and the properties of their starches. Kans. Agr. Expt. Sta. Tech. Bul. 61, 47 p. 1946.

Bavousett, N. R., and E. Kleppe.
Breads from whole grain sorghums. Texas Technological College, Res. Pub. 4. 1942.

Blumenthal, Saul.
Food products. Brooklyn: Chemical Publishing Co., Inc., p. 458-465, 484. 1947.

Edwards, W. M., and J. J. Curtis.
Grain sorghums, their products and uses. U. S. Dept. Agr., Commodity Development Division. ACE-193, NM 229. Northern Regional Research Laboratory, Peoria, Ill. 1943.

Geddes, W. F.
Cereal chemistry, ch. XVII. The chemistry and technology of food and food products. Morris Jacobs, editor. New York: Interscience Publishers Inc., 1944.

Gordon, Barbara Eales.
The effect of two mixtures containing lecithin on shortening qualities, palatability, and keeping qualities of certain baked products. Unpublished M.S. thesis. Kansas State College, Manhattan, Kansas. 1947.

Halliday, Evelyn G., and Isabel T. Noble.
Hows and whys of cooking. 3rd ed. Chicago: University of Chicago Press, 1946.

Hoffman, C., T. R. Schweitzer, E. K. Spotts and Gaston Dalby.
Evaluation of baking properties of roller process non-fat dry milk solids by a farinograph procedure. Cereal Chem. 25: 385-390. 1948.

Horan, F. E., and Marie F. Heider.
A study of sorghum and sorghum starches. Cereal Chem. 23: 492-503. 1946.

Hood, Maude Pye, and Belle Lowe.
Air, water vapor, and carbon dioxide as leavening gases in cakes made with different types of fats. Cereal Chem. 25: 244-254. 1948.

Hudson, R. A.
What commercial users expect of dried eggs. U. S. Egg and Poultry Mag. 55: 14-15. 1949.

Justin, M. M., L. O. Rust, and G. E. Vail.
Foods. 3rd ed. Boston: Houghton Mifflin Co., 1948.

Kiltz, B. F., John B. Sieglinger, W. M. Osborn, B. F. Barnes, and H. H. Finnell.
Sorghums for grain and forage. Oklahoma Agr. Expt. Sta. Bul. 210. 47 p. 1933.

Knox, Grace, V. G. Heller, and J. B. Sieglinger.
Riboflavin, niacin, and pantothenic acid contents of grain sorghums. Food Res. 9: 89-91. 1944.

Lowe, Belle.
Experimental cookery. 3rd ed. New York: John Wiley and Sons, Inc., 1943.

Nason, Edith.
Introduction to experimental cookery. 1st ed. New York: McGraw-Hill, 1939.

Nordgren, Robert, and J. S. Andrews.
The thiamin content of cereal grains. Cereal Chem. 18: 802-811. 1941.

Ohlrogge, Harriet B., and Gertrude Sunderlin.
Factors affecting the quality of cake made with oil. Amer. Dietet. Assoc. Jour. 24: 213-216. 1948.

Platt, Washington, and Phillip D. Kratz.
Measuring and recording some characteristics of test sponge cakes. Cereal Chem. 10: 73-90. 1933.

Roberts, Aldene Nussbaumer.
The use of dried eggs of substandard quality in foods. Unpublished M.S. thesis. Kansas State College, Manhattan, Kansas. 1945.

Smith, Margaret.
The comparative nutritive value of yellow corn and the grain sorghums hegari and yellow milo. U. S. Dept. Agr. Jour. Agr. Res. 40: 1129-1145. 1930.

Swanson, A. P., and H. H. Laude.
Sorghums for Kansas. Kans. Agr. Expt. Sta. Bul. 304. 63 p. 1942.

Swartz, Ve Nona W.
Two further simple objective tests for judging cakes. Cereal Chem. 15: 247-250. 1938.

Tanner, F. W., Shirley E. Pfeiffer, and J. J. Curtis.
B-complex vitamins in grain sorghums. Cereal Chem. 24: 268-274. 1947.

Vinall, H. N., V. C. Stephens, and J. H. Martin.
Identification, history, and distribution of common sorghum varieties. U. S. Dept. Agr. Tech. Bul. 506. 101 p. 1936.

APPENDIX

Form 1. Score card for griddle cakes and waffles.

Date_____

Judge_____

		Desirable	Undesirable	product				
AROMA	pleasing, characteristic of cereal	unpleasant off odor						
APPEARANCE	even, golden brown color, symmetrical, smooth	uneven color, too dark, too pale, burned, irregular shape, pitted surface						
TEXTURE	even, slightly spongy, uniform cells, light	compact, uneven grain, heavy, sticky						
MOISTURE	well done but not dry	raw in center, very moist or dry						
TENDERNESS	very tender	tough						
FLAVOR	pleasing	unpleasant or objectionable						

Key

very desirable	9-10
desirable	7- 8
acceptable	5- 6
slightly undesirable	3- 4
undesirable	1- 2

Comments: _____

_____

Form 2. Score card for gingerbread.

Date_____

Judge_____

	Desirable	Undesirable	product						
AROMA	pleasing, characteristic of cereal	Unpleasant off odor							
APPEARANCE	even, brown color, symmetrical, smooth	uneven color, too dark, too pale, burned, irregular shape							
TEXTURE and quality of crumb	even, uniform cell, light	compact, uneven grain, heavy, sticky, very crumbly							
MOISTURE	well done but dry	raw in center very moist or dry							
TENDERNESS	very tender	tough							
FLAVOR	pleasing, typical ginger flavor	unpleasant or objectionable							

Key

very desirable 9-10

desirable 7- 8

acceptable 5- 6

slightly undesirable 3- 4

undesirable 1- 2

Gingerbread Preference

1st choice _____

2nd choice _____

3rd choice _____

Comments: _____

_____