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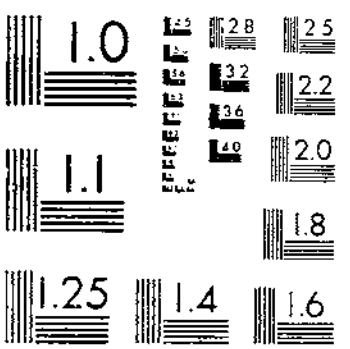
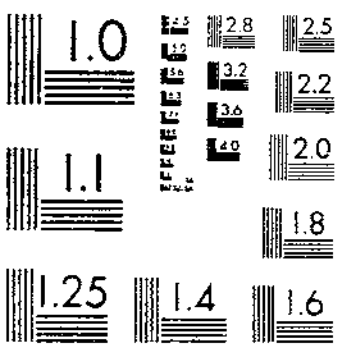


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A



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NATIONAL BUREAU OF STANDARDS 1963-A

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WASHINGTON, D. C.

FLOUR FOR PRETZELS[1]

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QUALITIES OF FLOURS ADAPTED TO VARIOUS USES

The different varieties and classes of wheat grown in this country yield flours of widely different qualities. From these flours bakery products are made which also differ widely in quality as well as in kind. It is an established fact that some of the differences in the quality of baked products are due to differences in the quality of the flour used. It is also known that, although a flour gives excellent results in the making of one kind of bakery product, it does not necessarily follow that the same flour will give excellent results in making other kinds of bakery products.

The baker who would produce high-quality products must select a flour suitable for that purpose. To do this he must know the specifications of such a flour. Going back one step further, millers should appreciate the importance to the successful conduct of their businesses of furnishing bakers with flour of suitable quality for the purpose intended, or of selling their flour for the purpose for which it is best adapted. When this is accomplished not only are the millers' and bakers' interests best served but also those of the farmers, because only then can the different qualities of wheat be marketed and utilized to the best advantage.

For these reasons a study of the bakery product, pretzels, was undertaken. The specific purpose of the study was to find out the

[1] Credit is given to the staff of the chemical research laboratory of the Grain Division for making the chemical tests; to Ruy Weaver, experimental baker, for assisting in the laboratory baking tests; and to the Pennsylvania State Department of Agriculture for assistance in securing samples of pretzel flours.

particular type of flour, and, as nearly as possible, the physical and chemical characteristics of flour, required for the production of pretzels of the most desirable quality when the most intelligent methods of manufacturing are applied.

In order to conduct such a study properly, it is necessary (1) to determine the quality or kind of pretzel most popular with the pretzel baker; (2) to ascertain what commercial methods and practices are most generally used in the manufacture of the pretzels; (3) to obtain samples of the flours used for the commercial production of pretzels and to study their chemical and physical characteristics; (4) to conduct baking tests in the laboratory where the variable conditions affecting the quality of this product can be controlled at will; and (5) to determine the adaptation of the methods and information developed in the laboratory to the system of large-scale production methods in the commercial plant. These five phases of the study have been carried out in relation to the manufacture of the hard type of pretzel, the kind most generally marketed.

EXTENT OF PRETZEL MANUFACTURE

Pennsylvania leads in the production of pretzels and appears to have been the first North American home of the pretzel. From here its manufacture has spread from coast to coast, principally to the northern half of the United States. According to a recent census report, approximately 27,527,088 pounds of pretzels were manufactured by bakeries in the United States in 1925, with a value of nearly $5,000,000.

TYPES OF PRETZELS

There are two distinct types of pretzels. These may be designated as the soft pretzel, which is intended to be eaten the same day it is baked, and the hard pretzel. In the latter type shortening material is usually used and it is the kind referred to and considered hereafter in this bulletin. Most pretzel bakers make two kinds of hard pretzels, one with shortening and the other without shortening, or at least without shortening in quantity sufficient to affect appreciably the quality of the product. The kind in which shortening is used is, as a rule, made from the better "grades" of flour and commands the highest price, whether sold by the count or by the pound.

The use of the terms "grade," "patent," "straight," and "clear" throughout this bulletin, in connection with flour, is based on views and statements furnished by the pretzel bakers. Neither the manner in which they are used nor the meanings ascribed to them are intended to represent the views of the Department of Agriculture.

Pretzels are made in various sizes and shapes. Some of them are machine-stamped and some are shaped by hand. The machine-stamped pretzels are made only in the smaller sizes. They may be in the form of the ordinary twisted variety or in sticks or in animal shapes. The handmade product is usually made in sizes larger than the machine-stamped kind, in the ordinary twisted shape, and in sticks.

DESIRABLE QUALITIES IN PRETZELS

As nearly as could be ascertained, the qualities or characteristics most desired by the consumer in the hard type of pretzels are a rich

pleasing flavor, a smooth, glossy yellow-brown outside appearance as opposed to a rough, streaked, pale yellow, or scorched appearance; a white inside appearance as opposed to a caramelized or scorched inside appearance; and a crisp texture which makes mastication easy without doughing in the mouth. It is the attainment of these qualities with which this study is concerned.

Pretzels which fulfill the quality requirement for crispness and ease of mastication usually have a tendency to break readily, and so are not always suitable for shipping because of the rough handling to which they are liable to be subjected; consequently, bakers who want to ship their product usually sacrifice these qualities to some extent for a firmer texture so that the pretzel will not break readily.

FOOD VALUE OF PRETZELS

The food value per pound in calories and the moisture content of pretzels compared with bread and some other staple baked products, based on data by Atwater and Bryant,[2] are shown in Table 1.

TABLE 1.—*Moisture content and food value of pretzels and other staple baked products*

	Moisture content	Based on moisture content as given	Based on dry matter content
	Per cent	*Calories*	*Calories*
Pretzels	9.6	1,700	1,880
Soda crackers	5.9	1,925	2,046
Sponge cakes	15.3	1,795	2,119
White breads	34.1	1,245	1,889
Rye breads	35.7	1,180	1,835

COMMERCIAL PRETZEL MANUFACTURE

As in the manufacture of bread, there are two general methods of making pretzels—the "sponge-and-dough" method and the "straight-dough" method. From a survey made during the summer and fall of 1926 of approximately 50 pretzel bakeries, most of which were located in Pennsylvania, it was found that about as many favored one method as the other.

A brief description of the methods of a pretzel bakery of average size, including some of the more noteworthy features found in the operation of a few large plants, is here given.

The following formulas, figured on the basis of a barrel of flour, are given as representative of what was found to be in use in the average shop:

"Sponge-and-dough" formula:

Sponge—		
Flour	196	pounds.
Water	115	pounds (55 quarts).
Yeast	10	ounces.

[2] ATWATER, W. O., and BRYANT, A. P. THE CHEMICAL COMPOSITION OF AMERICAN FOOD MATERIALS. U. S. Dept. Agr., Off. Expt. Sta. Bul. 28, 87 p., illus. 1906. (Revised ed.)

"Sponge-and-dough" formula—Continued.

Dough—

Flour	196	pounds.
Water	84	pounds.
Salt	3	pounds.
Shortening	7¾	pounds.

NOTE: Usually, in this method, from 30 to 50 pounds of the sponge, after it has fermented for a prescribed length of time, is added to the quantity of dough ingredients given above.

"Straight-dough" formula:

Flour	196	pounds.
Water	80	pounds (38 quarts).
Yeast	12	ounces.
Salt	2	pounds.
Shortening	8	pounds.

The smaller shops, whether employing the "sponge-and-dough" or the "straight-dough" method, seldom use as much as a barrel of flour to a mix, but generally use about 50 pounds. Some of the pretzel bakers who employ the "sponge-and-dough" method make a separate tub of sponge for each dough, the quantity of flour used in this sponge varying from 25 to 50 per cent of the total flour used in the entire mix.

The quantity of yeast and salt used in the mix varies greatly for both methods.

In bakeries in which the "sponge-and-dough" method is employed some bakers take about one-fourth to one-third of the flour to be used in the batch and make a medium slack sponge by the addition of yeast and water. This is allowed to stand from 3 to 12 hours, depending upon weather conditions and the quantity of yeast used. At the time of making the dough this sponge is broken up in a slow or medium-speed mixer and enough additional flour is added, together with other ingredients such as water, salt, and shortening, to make a very stiff dough, much stiffer than any dough intended for use in the production of ordinary white bread.

The length of fermentation period varies greatly for the sponge, but after the sponge is incorporated with the dough it is the practice in most of the shops to send a portion of it immediately to the rolling-out machine. In bakeries in which the "straight-dough" method is employed the dough, after being mixed, usually goes directly to the rolling-out machine, although in some shops the dough is allowed to ferment from 30 minutes to 3 hours before being rolled out.

After the dough has been mixed and is considered ready to be rolled out it goes into the hopper of the rolling machine, from which it is forced out through a small opening by means of a screw conveyor, at which point a rotating knife cuts it into small pieces about the size of a walnut (weighing one-half to 1½ ounces). These pieces of dough then pass between a moving canvas belt and a grooved board which rolls them out into strips the thickness of a lead pencil or slightly larger and about 12 to 14 inches long. These strips of dough are then twisted into the characteristic shape of a pretzel. This is done by hand, for no machine has yet been perfected which will give this characteristic twist. An experienced and skillful operator twists about 25 to 30 per minute.

The doughs are usually mixed at a temperature of 70° to 80° F., and as they pass through the screw conveyor, which is connected with the

hopper of the rolling machine, they sometimes increase in temperature as much as 10°.

In most pretzel-baking establishments, particularly in the small and medium sized shops, the twisted pretzels are placed on wooden boards and proofed for 40 to 60 minutes. In the larger plants, where large traveling ovens are employed, the pretzels are not always allowed to proof but pass by means of conveying belts from the rolling machine to the stamping machine or to the persons who twist them. At this point the pretzels are placed on wire racks which are then passed through a lye solution and under an automatic salt-shaking cylinder or box and into the oven.

The lye solution used in pretzel making consists of water (sometimes the water used is leached from oat straw) in which certain compounds of sodium are dissolved. The commercial names of the sodium compounds used are soda ash, caustic soda, and sal soda. The last two are generally used. Soda ash consists of approximately 97 per cent sodium carbonate and 3 per cent of water; sal soda of approximately 36 per cent sodium carbonate and 64 per cent water of crystalization; and caustic soda of approximately 75 per cent sodium hydroxide. The approximate alkali content of soda ash is 58 per cent, of sal soda 21 per cent, and of caustic soda 60 per cent.

At the end of the proofing period in the ordinary one, two, or three oven plant, and in cases where the belt-conveyor system is not employed, about 15 to 20 pretzels are placed in the lye solution (kept just under the boiling point) at one time. When first put in lye the pretzels sink to the bottom. They are usually allowed to remain there until they rise to the top of the solution, but sometimes the lye solution used is so strong that the pretzels can not be left so long in the lye.

The quantity of sal soda and caustic soda used varies considerably, depending upon whether other ingredients are added to the dough or lye for coloring purposes. The usual quantity is about 1 pound of the sal soda for every 2 gallons of water or about 1 pound of caustic soda of average commercial strength for every 20 gallons of water.

Braun[8] states that in olden times the lye used was prepared by lining an old basket with a nest of straw and filling it with wood ashes (pine or beech wood being preferable). Then the necessary quantity of water was boiled, to which there was sometimes added some redwood or some onion skins and eggshells. Some bakers added spices as well. The boiling water was poured over the ashes and allowed to filter into a tub. This authority also says that the finest lye for this purpose was made from grapevine-wood ashes.

After coming from the lye solution the pretzels are salted as soon as possible and then go immediately to the oven. In no instance among the bakeries studied in Pennsylvania was it found to be the practice to rinse pretzels in clear water after they come from the lye tub.

If too strong a lye solution is used, or if the pretzels are allowed to remain in ordinary lye for too long a time, the pretzels not only color too quickly in the oven before they are thoroughly baked but are likely to taste of the lye after they are baked.

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[8] Braun, E. THE BAKER'S BOOK; A PRACTICAL HAND BOOK OF THE BAKING INDUSTRY IN ALL COUNTRIES. v. 2. New York. 1903.

The type of oven in general use among pretzel bakers is one built of brick. It is fired on the hearth. It has been said that the old-time pretzel baker preferred to use wood in firing his oven, and a few still prefer it, but most bakers now use coal or gas. The pretzels are usually placed on the floor of the oven. With the larger traveling type of ovens found in some bakeries the pretzels are baked on sheets of metal, on stone, or on wire screens. The temperature desired for baking is usually around 500° F. with the heat well distributed throughout the oven and with sufficient air circulation to permit the moisture to escape during the baking. At this temperature the pretzels require from six to eight minutes to bake, depending somewhat upon their size and thickness.

In bakeries of the hearth-oven type the loading peel used is a thin narrow strip of board about the width of an ordinary pretzel and about 5 or 6 feet long, with a long handle. The unloading peel, similar to the ordinary peel used for rye and Vienna breads, consists of a wide tapering board with a long handle.

In putting pretzels in a hearth oven for baking the loading peel is first sprinkled lightly with salt, then the pretzels are placed on it, rough side down. When the peel is filled it is inserted into the oven, and turned over so that the pretzels are placed with the smooth side down on the floor of the oven, and with the salted side up. The peel is then withdrawn from the oven, and allowed to rest on the edge of the hearth for reloading, and the same process is repeated until the oven is filled. Usually the oven is of such a size and the temperature so controlled that as soon as it is filled with the last peelful of pretzels those first put in are ready to come out.

It is the common practice to dry all pretzels after they come from the oven in a compartment either at the side of the oven or over it, the heat of the oven being used; or they are dried in a separate room heated especially for this purpose. The temperature of the drying chamber or kiln varies all the way from 125° to 220° F. and the time of drying varies from 3 to 48 hours.

In packing pretzels for storage or for delivery to the retailer or consumer the containers must be moisture proof to prevent the pretzels from absorbing moisture and thereby losing their crispness, and the packing must be done in such a way that the pretzels will not break in the handling incident to shipment or delivery. Various kinds of moisture-proof containers are used, varying in size from a paper sack limited to a capacity of only a few ounces to tin or pasteboard cartons ranging from a pound or so up to 10 pounds in capacity.

Pretzels are sold by count, by weight, and by package. The containers used for package goods usually hold a pound or less of pretzels and are either of the waxed paper-sack type or of the pasteboard-carton type. Pretzels sold by the piece or by weight are packed in large pasteboard cartons or in tin containers holding usually from 4 to 10 pounds.

Pretzels which are delivered direct to the retailer or consumer by the bakery wagon or truck are usually rather carefully handled and do not need to be so very well packed, but those which are delivered by means of freight, express, or parcel post may be subjected to very

rough handling at times, and, therefore, must be very carefully packed if an excessive amount of breakage is to be avoided.

Many pretzel bakers were found who add special ingredients to their doughs or use certain combinations of lye in connection with the baking of their pretzels to give them an individual taste, but all were agreed that if shortening is used it must be of good quality. Some were using pure lard, some the hydrogenated vegetable oils, and some bakers were adding small amounts of butter as a part of the shortening. A few were not using any shortening.

It was the unanimous opinion of all bakers interviewed that of all their dough ingredients the flour was the one most responsible for variations in the quality of their product. They were also of the opinion that variations in the weather, because of the influence of weather on the "age" of the dough, affect the quality of the pretzels, especially where the long-time sponges are used.

Bakers who were putting out a large volume of pretzels complained that they were not able to get the quantity of the particular kind of flour they desired for their product from local or neighboring mills because of the limited capacities and merchandizing methods of these mills and their inability to supply flour of uniform quality in the quantities needed.

Most of the bakers were agreed that the flour should be allowed to mature for at least three or four weeks after it is milled. Cases were cited in which either "green" or unusually weak flours caused trouble during the rolling out of the dough, which necessitated stopping the rolling machine and cleaning the compressor board too frequently.

Musty flour was considered to be especially objectionable because of the undesirable flavor it imparts to the pretzels. The odor of garlic in flour, on the other hand, is not nearly so objectionable because, if present in only slight degree, it does not usually carry through to the finished product.

The use of "clear" flour was objected to on the same ground, as is the use of a poor quality of shortening, namely, the danger of a rancid odor in the pretzels. This is especially true during hot weather.

TYPES AND CHEMICAL ANALYSES OF PRETZEL FLOURS USED IN COMMERCIAL BAKERIES

At the time the survey of pretzel bakeries was made samples of the flour or blends of flour that were being used for pretzels were obtained, together with samples of the baked product, and information concerning the method of baking used, including the dough formulas and other details of manufacture. The flour samples obtained were analyzed for moisture, protein, and ash, and on some of the samples viscosity tests were made. The results of these analyses and information regarding the kind of flour used and its adaptability for pretzel baking are presented in Table 2.

TABLE 2.—*Chemical analyses*[1] *of flours obtained from commercial pretzel bakeries*

Sample No.	Baker's statement as to the kind of flour used [2]	Content (on basis of 15 per cent moisture [3]) of—		Viscosity [6]	Baker's statement as to pretzel-baking quality
		Crude protein (N×5.7) [4]	Ash [5]		
		Per cent	*Per cent*	*Degrees MacMichael*	
13283	SRW	8.7	0.33	135	Excellent.
13286 13287	SRW	8.5	.57	137	Do.
13288	SRW straight	8.3	.42	169	Do.
13298		9.0	.43	123	Do.
13300	SRW	9.3	.45	128	Do.
13301	SRW	9.5	.44	136	Do.
13302	SRW	9.4	.40	112	Do.
13314	SRW	9.6	.48	111	Do.
13837	SRW straight	9.3	.43	(7)	Do.
13847	SRW	9.1	.44	(7)	Do.
13848	SRW	9.1	.38	(7)	Do.
13853	SRW	9.0	.35	(7)	Do.
13906	SRW	8.9	.46	(7)	Do.
13251	SRW straight	8.9	.41	142	Medium.
13281	SRW	9.5	.42	109	Do.
13282	SRW	10.0	.36	134	Do.
13285	SRW	10.3	.61	94	Do.
13292	SRW	8.5	.41	125	Do.
13295	SRW	10.0	.43	133	Do.
13315 13318	SRW (25 per cent patent and 75 per cent straight).	9.7	.45	128	Do.
13322	SRW straight	9.2	.38	132	Do.
13836	SRW	9.6	.48	(7)	Do.
13850	SRW	9.3	.43	(7)	Do.
13308	SRW	9.0	.56	105	Not stated.
13846	SRW	8.5	.38	(7)	Do.
13849	SRW	8.2	.42	(7)	Do.
13850	SRW	8.2	.40	(7)	Do.
13979	SRW	8.4	.47	(7)	Do.
13284	90 per cent SRW and 10 per cent HRS	9.5	.37	130	Excellent.
13289	70 per cent SRW and 30 per cent HRS	10.5	.44	127	Do.
13290	80 per cent SRW and 20 per cent HRS	9.4	.50	129	Do.
13294	60 per cent SRW and 40 per cent HRS	10.7	.54	124	Do.
13297	Two-thirds SRW and one-third HRS	9.5	.54	115	Do.
13304	95 per cent SRW and 5 per cent HRS patent	9.8	.43	84	Do.
13209 13320	Two-thirds SRW and one-third HRS	10.1	.54	112	Do.
13321	SRW and HRS clear	11.1	.55	122	Do.
13840	SRW and HRS	8.9	.41	(7)	Do.
13842	Two-thirds SRW and one-third HRS	9.5	.44	(7)	Do.
13844	75 per cent SRW and 25 per cent HRS second patent.	10.5	.45	(7)	Do.
13291	50 per cent SRW and 50 per cent HRS	9.6	.54	113	Medium.
13293	Two-thirds SRW and one-third HRS	9.8	.69	135	Do.
13197 13198	90 per cent SRW and 10 per cent HRS patent.	9.8	.47	212	Not stated.
13307 13309 13312	75 per cent SRW and 25 per cent HRS clear	10.3	.48	118	Do.
13310 13311 13313	50 per cent SRW straight, 25 per cent HRS clear, and 25 per cent HRS patent.	11.2	.58	122	Do.
13305 13316	75 per cent SRW straight, 10 per cent HRS clear, and 15 per cent HRS straight.	9.3	.44	117	Do.

[1] The original analyses data in regard to moisture, protein, and ash are omitted from this table, since the samples were not received in air-tight containers and there was no assurance that these data would represent the condition of the flours at the time of sampling.

[2] The letters SRW and HRS given in this column represent soft red winter wheat flour and hard red spring wheat flour, respectively.

[3] The method used in making the moisture determinations on which the protein and ash contents given here are based was that of Spencer, Journal of Association of Official Agricultural Chemists, vol. 8, pp. 301 to 311.

[4] The method used in making the protein determinations given here was that described in U. S. Department of Agriculture Bulletin No. 1460.

[5] The method used in making the ash determinations given here was that described in Methods of Analysis of the A. O. A. C., second edition, p. 225, paragraph 2.

[6] In making the viscosity determinations given here the single concentration method of Sharp and Gortner was used. Minn. Agr. Expt. Sta. Tech. Bul. 19.

[7] Not determined.

TABLE 2.—*Chemical analyses of flours obtained from commercial pretzel bakeries*—Continued

Sample No.	Baker's statement as to the kind of flour used	Content (on basis of 15 per cent moisture) of—		Viscosity	Baker's statement as to pretzel-baking quality
		Crude protein (N×5.7)	Ash		
		Per cent	*Per cent*	*Degrees MacMichael*	
13319	25 per cent SRW and 75 per cent HRS	9.2	0.48	113	Not stated.
13845	75 per cent SRW and 25 per cent HRS	9.6	.49	(1)	Do.
13262	HRS patent	10.6	.52	160	Do.
13317	HRS	11.6	.57	142	Medium.
13834	No information	9.7	.51	(1)	Not stated.
13839	do	9.5	.46	(1)	Excellent.
13841	do	9.9	.52	(1)	Do.
13851	do	8.8	.38	(1)	Do.
13852	do	9.6	.52	(1)	Do.
13859	do	8.7	.46	(1)	Do.
13954	do	9.2	.43	(1)	Do.
13838	do	8.3	.37	(1)	Medium.
13854	do	8.5	.41	(1)	Do.
13957	do	9.2	.49	(1)	Do.
13836	do	9.1	.36	(1)	Not stated
13843	do	8.2	.42	(1)	Do.
13855	do	7.6	.36	(1)	Do.
13956	do	9.1	.42	(1)	Do.
13303	do	9.7	.53	132	Do.

[1] Not determined.

In order to derive the greatest value from the data presented in Table 2, the analyses figures should be compared with typical or average analyses of the various grades of the different commercial classes of flour. For the benefit of those who have not this information at hand the following data are given: Bailey [4] in his book entitled "The Chemistry of Wheat Flour" quotes data from Teller [5] showing the average composition of hard red spring wheat flours and gives data summarized from reports by the Association of Operative Millers [6] showing the average composition of hard red winter and soft red winter wheat flours. The figures given for moisture, crude protein, and ash are as follows:

	Moisture	Crude protein	Ash
	Per cent	*Per cent*	*Per cent*
Hard red spring wheat flours:			
Straight	10.86	12.80	0.49
Patent	11.20	12.00	.43
Clear	10.30	14.20	.72
Hard red winter wheat flours:			
Straight (95 per cent)	13.11	10.93	.429
Patent	13.09	10.62	.379
Clear	12.82	11.95	.632
Soft red winter wheat flours:			
Straight (95 per cent)	12.93	9.74	.391
Patent	13.01	9.40	.341
Clear	12.75	10.46	.478

The data presented in Table 2 show some variation in the types of flour used for pretzel making. They ranged from weak flours

[4] BAILEY, C. H. THE CHEMISTRY OF WHEAT FLOUR. Pp. 172, 175. New York. 1925.
[5] TELLER, G. L. DIFFERENCES IN FLOUR GRADES AND THE CAUSE. Oper. Miller 14: 301–302. 1909.
[6] ASSOCIATION OF OPERATIVE MILLERS. [REPORT OF OPERATIONS FOR WEEKS ENDING AUG. 11, 1923, OCT. 6, 1923, AUG. 16, 1924, OCT. 11, 1924.] Bul. 1923–24. (Privately distributed.)

having the characteristics of a pastry flour of low protein content to medium strong flours of the bread-making type. Different "grades" of flour were used, including "patents," "straights," and "clears" of varying composition.

From the data given, it is apparent that soft red winter wheat flours, and flour blends in which soft red winter predominated, are the principal types of flour used in the manufacture of pretzels in the territory included in this survey. Of the 64 pretzel flours reported in the table, 28 were said to be soft red winter, 19 were said to be blends of soft red winter and hard red spring, and 2 were said to be hard red spring. Judging from the analyses of the samples of the remaining 15 (concerning which information was lacking as to class), it is probable that most of these were soft red winter wheat flours. It might be added that the soft red winter wheat flours were reported as having been milled from Pennsylvania wheats, and that, although no information was furnished in most instances as to the grade of the flour used, it would appear from the analyses given that most of these flours were of the so-called "straight" grade.

Where blends of soft red winter and hard red spring wheat flours were used the quantity of the latter in the blend varied from 5 per cent up to 75 per cent, but was usually under 35 per cent.

In the bakeries that employed the "sponge-and-dough" method of baking and that used hard red spring "straights" or "clears" with soft red winter flour it was observed that in some instances the hard spring wheat flour was added to the sponge and the soft winter wheat flour was added to the dough.

The prevalence of the use of soft red winter wheat flour in pretzel making, although indicative of the suitability of this type of flour for that purpose, does not in this case necessarily prove that this type of flour is superior to other types of flour for this purpose. Other considerations, such as price, convenience, loyalty to local industry, or familiarity with the handling qualities of the flour, or any combination of these considerations, may have been the deciding factor in the baker's choice of that type of flour, because in the territory covered by the survey soft red winter is practically the only class of wheat grown or milled locally, and it is usually sold at a lower price than are the flours of other classes of wheat which must be imported from other sections of the country.

In protein content, based on a 15 per cent moisture content, these flours ranged from 7.6 to 11.6 per cent; the average was 9.4 per cent. The lower extreme protein is very close to the minimum (7.1 per cent, basis 15 per cent water) quantity allowable[7] under the definition and standard for flour adopted for purposes of the Federal food and drugs act. Flours of such low protein content are not considered good bread-making flours, but are usually well adapted to pastry-making purposes. On the other hand, the upper extreme in protein approximates the average percentage found in the so-called bread flours milled from hard red spring and hard red winter wheats.

Comparison of the 9.4 per cent average protein content of the pretzel flours listed in Table 2 with Bailey's[8] averages for flours

[7] UNITED STATES DEPARTMENT OF AGRICULTURE. FLOUR. U. S. Dept. Agr. Food Insp. Decis. 204, 1 p., 1926.
[8] BAILEY, C. H. Op. cit.

milled from hard red spring, hard red winter, and soft red winter wheats, shows it to be about equal to the average given for soft red winter "patents" and "straights."

In ash content, on the basis of 15 per cent moisture content, the flours studied ranged from 0.33 to 0.69 per cent, with an average of 0.46 per cent. The lower extreme of 0.33 per cent ash is what might be expected from a high-grade soft red winter "patent"; the upper extreme of 0.69 per cent might be expected from a "clear" flour; and the 0.46 per cent average ash content of these flours is about what might be expected from a soft red winter or white wheat "stuffed straight," from a "first clear" flour, or from a hard red winter or hard red spring "straight" flour.

Of the 64 flours of which samples were obtained, 31 were reported by the bakers as of excellent quality for pretzel making and 16 as of medium quality. In the case of the remaining 17 the quality was not reported, but, inasmuch as they represented flours that were actually being used for pretzel making, it may be assumed that they were at least partially satisfactory.

Taking into account the type of flours used, their analyses, and the fact that of the 64 flours studied none were reported as unsatisfactory for pretzel making, it would seem fair to conclude that a sound medium-strength flour of either a "patent" or "straight" grade will about fit the requirements for a suitable pretzel flour.

TEST BAKES IN THE LABORATORY

Laboratory tests were made on a number of different flours to determine their respective suitability for pretzel making. In these tests both the "sponge-and-dough" and the "straight-dough" methods of baking were used. In addition, numerous tests were made in order to try out the effect on the quality of the baked pretzel of various lengths of time of dough fermentation, ranging from strictly "no-time" and "no-proof" to "overnight sponges"; of various kinds and quantities of added ingredients such as butter and other shortenings, milk powder, sugar, malt, and yeast foods; of various oven temperatures for baking; and of various strengths and kinds of lye solutions.

In these tests 12 ounces of flour were used for each batch, and commercial methods of procedure were followed as closely as practicable. The pretzels were rolled out by hand, as no rolling machine was available. It was found that when dough is rolled out by hand it is impossible to make as stiff a dough as can be made by a machine method of rolling out.

Variations that occurred in the baked products resulting from the various tests were noted in the case of such factors as taste and texture and outside and inside appearance.

Overfermentation tended to produce pretzels of a bloated appearance with large inside air spaces. Underfermentation tended to produce undersized pretzels of solid or tight texture.

In the case of each flour used very little difference in taste between pretzels made by the "sponge-and-dough" method and the "straight-dough" method could be noticed. When the pretzels from the "sponge-and-dough" method were proofed the same length of time

TABLE 3.—*Chemical analyses* [1] *and pretzel-making quality of flour samples on which laboratory pretzel-baking tests were conducted by a method similar to that employed in a commercial pretzel bakery*

Sample No.	Class and grade of flour	Content (on basis of 15 per cent of moisture) of—		Quality and characteristics of the pretzels produced					
		Crude protein (N×5.7)	Ash	Taste	Texture	Outside color	Inside color	Surface appearance	Remarks
		Per cent	*Per cent*						
1	Hard red spring patent (bleached).	11.7	0.39	Good	Too hard [2]	Light brown	Light creamy	Good shape and well-rounded.	Dough was tough and hard to roll out.
2	do	11.2	.40	do	Too hard, flinty [2]	do	do	Slightly shriveled	Do.
3	Hard red spring patent	10.9	.42	do	do [2]	do	do	Drawn, wrinkled	Pretzel ends worked loose after removal from lye kettle.
4	Hard red spring straight	11.4	.51	do	do [2]	do	do	do	Dough tough and hard to roll out.
5	Hard red spring clear	13.0	.71	Fair	Too hard [2]	Brown (dull)	Gray, creamy	do	Pretzel flat in taste, dull (not glossy) outside appearance. More brittle than Nos. 2, 3, and 4.
6	Hard red winter straight	11.7	.48	Good	Too hard, slightly flinty.	Light brown	Light creamy	Good shape and plump.	Pretzel not easily crumbled; too hard to be of the standard type desired.
7	Soft red winter patent (bleached).	7.2	.36	Excellent [4]	Crisp, weak, very easily crumbled.	do	do	Appearance of being slightly lye soaked.	Dough dried quickly during proof; dough had tendency to crack open when picked up to be placed in lye kettle.
8	Soft red winter patent	8.6	.54	Very good	Crisp, easily crumbled.	Lighter brown than from hard red spring.	do	Slightly pale in outside color but plump.	A little stronger lye solution gave a better outside color to pretzel.
9	Soft red winter straight	9.9	.33	Good	do	do	do	do	Flour from same wheat as No. 11 but ground about three months later. Pretzel slightly more pasty than No. 11 when chewed.
10	do	8.7	.38	Very good	do	do	do	do	Pretzel very similar in quality to that obtained with No. 8.
11	do	9.2	.44	Excellent	do	Light brown	do	Good shape, plump and well-rounded.	Outside color and appearance of pretzel was of standard desired.
12	Soft red winter clear	9.4	.65	Rancid [3]	Slightly hard [3]	Brown (dull)	Slightly gray	Not as well-rounded and plump as No. 11.	Pretzel had commercially objectionable rancid taste. Dough was easier to roll out than when made from the better grades of flour from this class of wheat.

13	Soft red winter straight	9.3	.43	Excellent	Crisp, easily crumbled	Lighter brown than No. 11.	Light creamy	do	Pretzel a little too light a brown for standard type of baked product.
14	Commercial blend: Hard red winter patent 25 per cent. Soft red winter straight 75 per cent.			do	do	Light brown	do	Very good	No detectable difference between this pretzel and the one from No. 11.
15	Soft red winter straight	10.3	.36	do	do	do	do	do	Flour from the same mill as Nos. 9 and 11 and from wheat of same locality and crop year but ground six months later. Resulting pretzels were very similar in quality.
16	Durum straight	10.7	.57	Good	About like No. 1 [1]	Brown	Creamy	Good, rather glossy.	Pretzel not as palatable as those from the other sound flours and slightly more flinty and less crumbly.
17	White wheat straight	8.6	.39	do	Crisp and very easily crumbled. [6]	Lighter brown than others.	Light creamy	Appeared to be slightly lye soaked.	Pretzels had tendency to crack open or "blow."
18	Commercial pretzel flour	9.1	.42	Very good	Crisp and very easily crumbled.	Light brown	do	Very good, plump	Pretzel closely resembled standard type of pretzel desired.
19	Commercial pretzel flour (bleached).	8.4	.47	do	do	do	do	do	Pretzel similar to that from No. 18, except was slightly paler in outside color and very slightly better in inside color.
20	Commercial pretzel flour	8.2	.42	Excellent	do	do	do	do	Pretzel similar to that from No. 13, but slightly better in taste and outside color.

[1] For methods of analysis used in making chemical determinations given here see footnotes to Table 2.
[2] Much too hard to approximate the commercial standard of quality. The use of an increased amount of shortening helped to improve this condition, but no improvement with respect to texture resulted from lengthening the drying period.
[3] Not crumbly enough in texture to compare favorably with the commercial standard type.
[4] Although these pretzels showed slight indications of being lye soaked, they were of excellent taste.
[5] This flour had a rancid odor and the pretzels baked from it had a rancid odor and taste.
[6] Almost too crumbly to make a suitable commercial pretzel.

as those from the "straight" doughs the pretzels were too large and were not up to the standard of quality selected for judging the results obtained from the flours. With the "sponge-and-dough" method the lye solution had to be a little stronger than with the other method to get the same degree of color, because the pretzels came to the surface of the lye kettle in half the time required for those made by the "straight-dough" method.

Pretzels made by the "no-time no-proof" method (in which the dough is taken direct from the mixer, rolled out, twisted in the form of pretzels, placed in the lye, and then sent to the oven with as little fermentation and proof as possible) required a weaker lye solution because the pretzels made by this method took a much longer time to come to the surface of the lye solution. This method was not found practicable nor desirable for any of the flours tested, except for the very weakest or low-protein type of flours. The hard-wheat flours when baked by this method produced a pretzel that was much harder and flintier than the standard type of pretzel made from weaker flours and by the regular method. It was less desirable in comparison.

The experiments in adding shortening to the dough included butter, lard, a vegetable oil, and a vegetable compound. These were added in quantities up to 10 per cent of the weight of flour used. Their use affected the flavor of the pretzel product and the shortness or crumbliness of its texture. The quantity that gave the most satisfactory results was from 2 to 4 per cent. If more than this quantity was used a greasy taste was imparted to the pretzels and they burned more readily in baking.

The use of sugar and malt in the dough gave an undesirable sweet taste to the pretzels. When these two ingredients were added to the lye solution they gave a slightly better outside color but not sufficiently better to justify their use. Milk powder, when added to the dough in appreciable quantities, had a tendency to produce a flinty texture which was not desirable. No differences could be detected in the pretzels when moderate quantities of yeast food were added as a dough ingredient.

Oven conditions had a noticeable effect upon the baked product. The baking temperature found to give the best results was 500° F.

Lye solutions, when too strong, produced dark-colored pretzels which left a disagreeable biting taste in the mouth after eating. Lye solutions, when too weak, produced pretzels of lighter color than desirable, which condition, if corrected by prolongation of the baking period, tended to produce pretzels that had a scorched inside appearance and a corresponding flavor.

In Table 3 are given the protein and ash contents of the flours used in these laboratory tests, and certain detailed information concerning the baking results obtained when employing the "straight-dough" method and formulas described elsewhere in this bulletin under the heading of "Commercial pretzel manufacture."

It will be observed from the information given in Table 3 concerning the quality of the pretzels obtained from the different kinds of flour that the high protein content, or strong flours, because of their tendency to produce a hard and flinty product, are less satisfactory for pretzel making than are those of lower protein content which are

often characterized as weak flours. Increasing the quantities of shortening used in the high-protein-content flours tended to correct this condition. The lower-grade flours, such as "clears," whether used alone or blended with other flour, did not produce as good a quality of pretzel as did the higher grades of flour.

The flours listed in Table 3, as represented by samples 1, 2, 7, and 19, were commercially bleached, but no difference could be detected in the quality of pretzels produced from them in comparison with those produced from the other flours of the same general type and grade which were not bleached.

A study of the data presented in Tables 2 and 3 does not show that crude protein and ash content of flour are closely enough related to the quality of pretzels produced therefrom to justify any very definite conclusion as to the limitation in quantity of these two chemical constituents which should be present in a flour to make it suitable for pretzel-making purposes. Neither is it safe to conclude that any particular type of flour or blend of flours is most suitable for making the type of pretzel striven for in these experiments.

In pretzel making, as in bread making, the quality of the gluten (the chief component of the crude protein of wheat flour) in the flour is probably as important as quantity of gluten. Therefore, it is probable that an actual baking test is necessary before definite conclusions as to the suitability of a certain flour or blend of flours for pretzel manufacture can be determined.

Broadly speaking, "straight" and "patent" grade flours such as those made from the soft winter wheats ranging from 8 to 10.5 per cent in protein content and not exceeding 0.5 per cent ash content, were found to be suitable for pretzel making. Blends of very low-protein or weak flours with possibly 10, 15, 20, or higher per cent of high-protein flours from the hard wheats were also generally found to be satisfactory.

Although the relationship between chemical composition and pretzel-baking quality is not as close as might be hoped for, nevertheless, a knowledge and understanding of the conclusions derived for this study should be of value, particularly in helping to guard against the selection of flours of certain types or composition which are shown to be unsuited to pretzel use.

TEST BAKES IN COMMERCIAL BAKERIES

A flour that had produced very good results in these laboratory tests was taken to two different commercial pretzel bakeries and tested for pretzel manufacture under commercial shop conditions. This flour was an unbleached 95 per cent "straight" milled from Pennsylvania soft red winter wheat. On a 15 per cent moisture-content basis the crude protein (nitrogen $\times$ 5.7) content of this flour was 10.3 per cent and its ash content was 0.36 per cent. Judged from its protein content and from its bread-making qualities, this flour was above the average for soft red winter wheat flours.

In the one plant there were three coal-fired hearth ovens with a total capacity of about 1,200 pounds of pretzels a day. In the other plant there was one large gas-fired traveling oven, and the pretzels, after being twisted, passed automatically by means of mechanical conveyors through the lye tub and under a salting device to the

mouth of the traveling oven. This plant was capable of producing about 10,000 pounds of pretzels in a 9-hour day. A quarter of a barrel of the flour was run in the smaller shop with the formula regularly used at that plant. In the larger plant a barrel of flour was tested out with the formula that was being used for the general run of pretzels there.

The flour used in the smaller plant had been milled about six weeks before the test was made. In order to see if freshly milled flour from this same mill would in any way affect the product, a similar grade of flour from the same mill which had been milled only 10 days previously was used for the test in the larger plant. This flour contained 0.4 per cent less of crude protein and 0.03 per cent less of ash than did the flour used in the smaller bakery. In both tests these two flours from the same mill, which varied but slightly in chemical composition, gave very satisfactory results in the production of the quality of hard pretzels of the standard selected.

Inasmuch as commercial tests were made only on the one type and grade of flour, nothing new was learned concerning the limits in protein and ash content of flour suitable for pretzel making. To determine by commercial tests what these limits are would have required the making of a considerable number of tests, which was not found practicable. The chief value of these tests was in substantiating the reliability of laboratory-baking tests as a means of indicating the suitability of a flour for pretzel making as is evidenced by the fact that the results obtained in the commercial tests were very similar to those obtained from the laboratory-baking tests of the same flour.

It is not the purpose of this bulletin to deal with all the technical problems with which the pretzel baker is concerned, but rather to present and discuss the discovered facts that are primarily related to the type of pretzel flour suitable for pretzel-making purposes.

CONCLUSIONS

Flours of high-protein content were found to have a tendency to produce pretzels of hard and flinty texture.

Flours of low-protein content were found to cause trouble in the rolling machines and to produce a poorer shape and size of product.

The "clear" flours when used alone showed a tendency to produce pretzels of poor outside and inside color, of inferior taste, and of uncertain keeping quality.

Sound flours of both the "straight" and "patent" grades, containing from 8 to 10.5 per cent of protein and not over 0.50 per cent ash, like those milled from soft red winter wheat, were found to be satisfactory for pretzel making.

A satisfactory pretzel flour can be made by blending hard wheat flours and soft wheat flours of high and low protein content or by using a "patent" or "straight" flour with a small percentage of a "clear."

Chemical composition, although not an infallible indicator of quality, is useful for guidance in the selection of suitable flours for pretzel-making purposes and in the blending of flours of different composition.

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