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PRACTICAL AND THEORETICAL CONSIDERATIONS [1, 2] IN THE MANUFACTURE OF CANNED BREAD

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White bread is a staple which has not yet found its way into the military rations issued in the field to individual servicemen or to small groups. Despite its wide demand by troops, the product cannot be supplied in areas removed from bakery facilities because of difficulties in logistics. The Army's solution to this problem has been to provide substitutes in the form of canned crackers or biscuits, but these have not proved entirely satisfactory inasmuch as they do not approximate the product to which American troops are accustomed.

As an initial step in correcting the deficiency in the rations, The Quartermaster General, in 1944, directed that work be conducted on the development of a canned white bread which could be used by the Armed Forces in operational rations.

Surveys showed that the first successful canning of bread was performed in Westphalen, Germany, in 1887. The product, known as *Dauerbrot*, was a German pumpernickel made by the following formula:

Ingredients	*Parts by Weight*
Rye Meal	100
Water (variable)	70
Sour ferment (variable)	5
Salt	2

Prior to the World War II period, however, little or no recorded developmental work has been performed on canned white bread, and it was, therefore, necessary that an experimental product be developed on the basis of the extremely limited data available.

Development

One of the first problems confronting workers at the Quartermaster Food and Container Institute for the Armed Forces was that of judging the proof time of the dough to insure that the baked bread would be no higher than the height of the can. Metal screens were placed on the top of the cans in the oven to prevent the dough from rising higher than the can's upper edge. This procedure left an imprint of the screen on the bread, and, in terms of commercial operations, was found to be impractical.

Baking in sealed cans created excessively high internal pressures, and 98% of the cans used in the unrepeated experiment exploded in the oven.

The problem was ultimately solved by baking in a loose-lidded can

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[2] Contribution from Quartermaster Food and Container Institute, Chicago, Illinois.

with the cover clinched, but not sealed. By this means gases are permitted to escape during proofing and baking. The can is hermetically sealed when the internal temperature of the bread has dropped to 190° F., thus creating a vacuum of from 16 to 20 in. It is highly important that the bread be allowed to cool slightly before sealing, since cans with a high vacuum may collapse if jarred only slightly. For example, canned bread sealed immediately on leaving the oven will develop an internal vacuum equivalent to 25 in. of mercury measured by an aneroid type of gauge. A No. 2½ can with this high vacuum will collapse during packing and transportation.

Of major importance in the development of the canned white bread was the can itself. Some enamels, it was found, imparted an off-flavor to the canned bread, and it became necessary to develop an enamel that would *not* impart an off-flavor to the bread. In cooperation with the can manufacturers such an enamel was developed. A sealing compound had to be developed for the can covers as well. It had to be of a type that could be hermetically sealed and at the same time resist attack by the fat used in greasing the dough pieces. Can manufacturers developed a fat-resistant compound that did not deteriorate during baking and subsequent storage of the canned bread.

Colors of can materials were also found to play a role in the making of canned bread. Since bright surfaces reflect heat and dark surfaces absorb them, the crust color of the product and required oven heat depended to some extent on the color of the can. An olive-drab enameled can such as is commonly used for military supplies would obviously absorb more heat than a plain, brightly finished can, and is therefore preferable.

Early in the developmental stages of canned white bread it was noted that cans must be cooled as quickly as possible after baking and sealing. When packed immediately after sealing, the product developed an off-flavor and crumb browning was accelerated during subsequent storage. It has been found that the internal temperature of the bread should be reduced to 90° F. within 30 minutes if the best results are to be obtained. Suggested methods for cooling include passing the cans through a cold air blast tunnel, cold water spray, or through a long conveyor system at room temperature.

Since space must be carefully conserved in military supply, it was considered desirable to provide a product which would give the soldier as concentrated a bread as possible in as small a space as possible, insofar as density was compatible with acceptability. The specification (CQD No. 399, Bread, Canned) therefore, called for a displacement of 4.5 cu. in. for each ounce of dough used, 1.5 cu. in. less than the displacement ratio of commercially produced Pullman bread.

Not all of the experiments were conducted at the laboratories of the Food and Container Institute. Principal industrial cooperators were the

General Foods Corporation, Hoboken, N. J. and the Kroger Food Foundation, Cincinnati, Ohio. The former in its experiments, attempted to formulate a satisfactory loaf of bread with a moisture content of approximately 25%. The Kroger laboratories, after extensive experiments and storage tests, developed a formula which was considered suitable for experimental studies and pilot runs. The proposed formula was as follows:

Ingredients	*Parts by Weight*
Flour	100
Yeast	2
Water (Approximate)	60
Salt	2
Sugar	6
Shortening	6
Milk solids (nonfat)	6
Monocalcium phosphate	0.25
Mycoban (sodium propionate)	0.25

Storage tests revealed several major deficiencies in this formula, however. The high milk solids content, because of its buffering action, made it impossible to lower the pH of the product sufficiently. Low pH aids in the inhibition of rope and botulinum toxin formation in canned bread. The high sugar content during long storage assisted in the early internal browning of the bread. Furthermore, the sodium propionate was believed to contribute an off-odor and flavor to the bread during storage. Other possible mold and rope inhibitors were therefore substituted for the sodium propionate in the formula. Among these were sodium diacetate, calcium acetate, acetic acid, citric acid, lactic acid, and buttermilk. But the sodium diacetate and acetic acid affected fermentation adversely, especially at the proofing stage, to the point where their use made commercial production of canned bread virtually impossible. After extensive experimentation and numerous storage tests a second formula was developed in an attempt to eliminate the foregoing objections to the product.

Ingredients	*Parts by Weight*
Flour	100
Yeast	2
Salt	1.75
Sugar	4
Shortening	4
Milk solids (nonfat)	2
Water	58
Monocalcium phosphate	0.25
Mycoban (calcium propionate)	0.25

The substitution of calcium propionate for sodium propionate did not, however, materially reduce the off-odor and flavor.

Bacteriological Aspects

Workers at the American Can Company, in October 1945, suggested that there might exist in canned bread a danger of botulism poisoning.

Under normal canning procedures foods are heat-processed sufficiently to destroy botulism organisms. However, the center of a loaf of bread never reaches a temperature above 212° F. during baking (usual temperatures for ordinary pan bread are 208° to 211° F.), which is insufficient to destroy *Clostridium botulinum* spores.

Studies were initiated in the laboratories of the American Can Company in October 1946, and the results reported to the Food and Container Institute indicated that there was a possibility of botulinum growth in canned bread. The results of these tests were inconclusive, however, since many factors in the production and canning of the bread were uncontrolled. Consultants agreed that the possibility of botulinum growth in canned bread was extremely remote but that additional precautions should nevertheless be taken in the manufacture of the product to eliminate the hazard of botulinum toxicity. Recommended measures included (1) revision of the formula to produce a canned bread containing 3 to 4% less moisture than in the previous formula; (2) reduction of the pH to 4.9–5.0; and (3) employment of air cooling and flip test apparatus to reject imperfectly sealed cans prior to case packing.

In subsequent development stages it was found that a loaf of bread with pH 4.9 and a moisture content of 34% was feasible and acceptable.

Plans for new botulinum tests were agreed upon in a meeting held in Chicago on October 22, 1946. Technical representatives of the American Can Company, Continental Can Company, American Institute of Baking, University of Chicago, University of Minnesota, and interested members of the Food and Container Institute attending the meeting established three objectives for the tests:

1. To determine whether *Cl. botulinum* would develop in canned bread according to the "old" specifications.
2. To determine whether *Cl. botulinum* would develop in canned bread made according to the proposed revised specifications.
3. To determine whether there is a symbiotic relationship in the growth of *Cl. botulinum* and *Bacillus mesentericus*.

The following formulae were used in the botulinum studies of canned bread:

Ingredients	Parts by Weight *Old Formula*[1]	*New Formula*[2]
Flour	100.00	100.00
Salt	1.75	1.75
Sugar	4.00	4.00
Shortening	4.00	4.00
Milk Solids (nonfat)	2.00	2.00
Monocalcium phosphate	0.25	0.25
Calcium propionate	0.125	...
Yeast, compressed	2.00	2.00
Water	60.00	54.00
Sodium diacetate	...	0.40
Edible lactic acid (80%)	...	0.125

[1] Specification CQD No. 399, Bread, Canned.
[2] Proposed modified formula.

Methods. Doughs were made in accordance with 100% sponge method, i.e., flour, water, yeast, salt, and monocalcium phosphate were fermented for 2 hours 15 minutes. Sponges were then mixed in the dough stage at which time the remainder of the ingredients were added. The resulting dough was given no floor time. Sponge mixing consisted of 2½ minutes on low speed; dough stage mixing was one minute on low speed and 3 minutes on second speed. The remixed dough was immediately scaled on paper in 11½ ounce pieces which were rolled in melted hydrogenated shortening and placed in tin cans which were then clinched. Proofing time for the "old" formula averaged 44 minutes; for the "new" formula, 55 minutes. The bread dough was thereupon baked at an oven temperature of 450° F. for 30 minutes for the "old" formula, 400° F. for 40 minutes for the "new" formula. Upon removal from the oven the baked cans were allowed a 5-minute cooling period and were then hermetically sealed. The sealed cans were immersed in running city water for a minimum period of 45 minutes, and after cooling were dried and tested for vacuum. Cans and lids employed in these tests were No. 2½ size (401 x 411), outside camouflaged lacquer, C-enamel inside lacquer. Can clinching and sealing operations were performed on pilot plant equipment in the Institute laboratories.[1] Flip tests made on the sealed cans after cooling, indicated the seals to be airtight. Flip test vacuum readings of 23 to 28 in. were obtained on all cans. A second flip test reading was made on each can as it was removed from the storage chambers to determine the efficiency of sealing during storage.

Inoculations. Twenty-six doughs were made, each yielding 29 cans of baked bread with a baked weight of 10½ oz. per can. Each dough was inoculated in the sponge water with 0.5 ml. *Cl. botulinum,* Type A (spore count of 60,000,000 per ml.), thus producing a count of approximately 1,000,000 spores per can of bread. Six of the doughs received an additional inoculation of 1.0 ml. of *B. mesentericus* inoculum (spore count 710,000 per ml.), which produced counts of 1,000,000 *Cl. botulinum* spores and 25,000 *B. mesentericus* spores per can.

Storage. The cans containing bread into which only *Cl. botulinum* had been inoculated were stored at 72°, 90°, and 100° F. Canned Bread containing both *Cl. botulinum* and *B. mesentericus* were stored at 90° F. The two sets of samples stored at 90° F. were removed once each week and stored for 16 hours in a 40° F. cabinet, after which they were returned to the 90° F. room. The objective of this cycling operation was to produce an adverse sweating condition inside the can, thus producing localized areas of high moisture content believed to be conducive to *Cl. botulinum* and *B. mesentericus* germination and growth.

Ten cans from each of the storage sets were withdrawn after one week, 2 weeks, 4 weeks, 3 months, 6 months, 12 months, 18 months, and

[1] Cans, clinching equipment, and sealing equipment provided by the Continental Can Company, Chicago.

24 months, and examined for toxin formation by *Cl. botulinum* and for visible development of *B. mesentericus*. These tests were conducted at the University of Chicago under contract with the Quartermaster Food and Container Institute.

After 3 months' storage, the bread inoculated with *Cl. botulinum* and *B. mesentericus*, "old" formula only, showed signs of rope. As the storage period increased the bread became progressively worse. After 12 months' storage, the ropy area extended to approximately ¼ inch from the crust. It should be noted that these samples were heavily inoculated with viable spores and held at optimum conditions for *B. mesentericus* growth. The bread made from the "new" formula did not exhibit any signs of rope. It was the conclusion of the University of Chicago workers that canned bread, after 2 years' storage at various temperatures, appeared safe from the threat of botulism poisoning when made in accordance with the "new" formula.[1]

Routine storage tests of 2 years' duration are, of course, unfeasible for commercial production to determine whether or not a loaf of bread is safe. The Food and Container Institute has therefore initiated work to develop a more rapid laboratory method.

Current Studies. The Quartermaster Food and Container Institute is currently engaged in improving the palatability of the canned bread, first by decreasing the density of the loaf, second by eliminating from the dough formula such chemical ingredients as monocalcium phosphate, calcium or sodium propionate, sodium diacetate, and calcium acetate. It has been possible to reduce the pH of the baked loaf to 4.7 without the use of chemicals. Cultured dry buttermilk solids, a commercially available product, has replaced the nonfat milk solids, and the monocalcium phosphate and sodium diacetate have been omitted from the formula.

Experimental formulae incorporating these and other revisions cannot be rapidly appraised, however, until a simple and rapid test method has been developed which will adequately show whether or not the bread is safe.

[1] Committee on Food Research progress reports. Contract W11-009-qm-70240, File M-200.