A STUDY OF THE FEASIBILITY OF PRODUCING SWEET DOUGHS BY THE CONTINUOUS DOUGHMAKING PROCESS

by

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INTRODUCTION

Since the introduction of continuous doughmaking units in 1954, many changes have taken place in breadmaking technology. The continuous doughmaking unit has many advantages to offer, such as less labor, less operating space, uniform production rate and uniform product. Unfortunately, there were and still are some problems associated with the advantages. Many ingredients that were used in conventional systems are not directly adaptable to continuous doughmaking units. Flour, because of the large quantities used in proportion to other ingredients, posed one of the first problems encountered. This ingredient requires close scrutiny by both the baker and miller. The utilization of milk presented a serious problem, however, the problems that were encountered had a very healthy effect on the industry. Research and development people were quick to recognize the problems and started to work immediately to solve them by developing uniform ingredients for this new process.

It was felt that the advantages of the continuous doughmaking process should be applicable to other areas of baking (1). Based on studies with the extrusion of conventionally mixed sweet doughs, it appeared feasible to use the laboratory equipment to produce sweet doughs. This study was conducted to determine if it was feasible to produce acceptable sweet doughs on the continuous doughmaking equipment.

LITERATURE REVIEW

Continuous Doughmaking Process

The inception of the continuous doughmaking process in 1954 resulted in many important developments. Baker (2) reported successful production of white pan bread. In 1954 only six commercial units were in operation. Baker reported that the fermentation of conventional sponge could be replaced by fermentation of sugar and suggested replacing the sponge of the sponge dough process with a liquid broth or ferment system. Mixed sugars were used initially with 4% dextrose added in the broth and 4% sucrose added at the premixer. Baker also stated that the melting point of the shortening should exceed $100^{\circ}F$ because of the higher dough temperature of the continuous doughmaking process.

The use of nonfat dry milk in the continuous doughmaking process resulted in delterious effects on the bread, such as decreased volume, poor grain and texture. Swortsfiguer (3) reported oxidation ratio levels of 3 parts potassium bromate to 1 part potassium iodate produced the best results when high milk formulas were used. He also advocated the use of calcium acid phosphate to lower the pH of high milk brews. Meyer (4) recommended the use of buttermilk solid which improved the volume and flavor when used at the level of 6% in the formula.

Methods of continuous mix production were further improved in 1959 by the introduction of continuous doughmaking laboratory units (5). With these small pilot models, very sophisticated experiments could be performed at economical cost because of: (1) decreased ingredient needs, (2) time, and (3) labor. Good reproducability was found when using the American Machine and Foundry (A.M.F.) laboratory continuous doughmaking unit. The calculated delivery rate of the individual ingredient streams was within 1.0-1.5% of the rate of dough delivered through the "developer head" as reported by Redfern, et. al. (6). They found that by increasing the throughput from 200 to 300 pounds of dough per hour, the accuracy was greatly enhanced.

Reproducability of different laboratory scale continuous doughmaking units was studied by Titcomb et. al. (7). They reported that reproducability within a given laboratory could be predicted; however, precision depended on the techniques and particular type of unit involved.

Studies conducted on preferment or stable ferment baking were found to be applicable to the continuous breadmaking process. Some of the earliest work was conducted in 1954 by Choi (8). He reported that high initial bacterial population decreased with time. This resulted from the alcohol produced during fermentation and the lowering of the pH of the medium. He also reported that milk stabilized the pH of the preferment. A stable ferment baking process was described by McLoren (9) in which all ingredients with the exception of flour and shortening were allowed to ferment for approximately six hours. The stable fermented material was mixed with the flour and shortening in a conventional type mixer and the sponge dough process was then followed. The ferment was reported to be stable for up to 36 hours if cooled to 50-60^{o}F.

In 1956, Carroll et. al. (10) described the use of malted wheat flour and fungal enzyme preparations in bread made by the preferment process. No differences in the quality of the bread were reported if the enzymes were added in the preferment or in the dough stage. Johnson and Miller (11) in 1957 reported the results of various analyses performed on preferments. Determinations were for carbon dioxide production, pH, lactic and acetic acid production, ethyl acetate production and amount of protease retained in the various preferments. These workers reported a good quality baking flour for the sponge method also produced good breads by the preferment process. A fair quality baking flour for the sponge process made very poor bread by the preferment process.

Controversy arose when equipment capable of handling high levels of flour in brews was introduced to continuous doughmaking procedures as a means of improving the overall quality of the resultant bread. Trum (12) reported that high-flour brews resulted in stronger bread crumb and body without loss of softness. Significant increase in flavor was also reported. The exclusion of sugar in the brew was made possible by the inclusion of higher percentages of flour. In a later publication (13) Trum expounded on the advantages of using high-flour brews. The advantages reported were as follows:

(1) Increased loaf volume

(2) Stronger crumb body

(3) Greater retention of crumb resistance

(4) Greater consumer acceptance

(5) Reduction of requirements of mechanical work input

(6) Reduction in total sugar in the formula

The advantage of firmer sidewalls, less amylose in crumb (because of enzyme action on the damaged starch) and a more open grain were reported by Snell et. al. (14). They cited disadvantages, however, as 1% decrease in absorption for every 20% flour in the brew and the high cost of equipment for handling. Mauseth et. al. (15) reported that an increase in mixing energy was required for high-flour brews. They also reported that a high percentage of flour in the brew exhibited no effect on cell size. The use of high percentages of flour in the brew somewhat suppressed the deleterious effect of milk.

One of the most critical factors in continuous doughmaking process of bread production is the level of oxidation. The reasons for use of higher oxidation are the tremendous stress on the dough during development, short mixing time and the short time between mixing and oven. The type of flour, age of flour and level of milk affect the needed oxidation. Redfern et. al. (16) reported that an increase in oxidation level in a 20% brew resulted in increased mixing requirements and increased power requirements. The increased oxidation level was found to strengthen the crumb structure. Optimum oxidant ratio was five parts potassium bromate to one part potassium iodate. Altering this ratio affected mixing tolerance and optimum developer speed.

Another important factor in the production of bread by the continuous doughmaking process is the type of flour. Trum and Rose (17) reported that in using a flour in production or in laboratory continuous doughmaking unit, 3% water should be added to the absorption reported from the farinograph value. Flours with long departure time based on standard farinograph values were found to be undesirable. The throughput of the continuous doughmaking unit had to be decreased, because of the increased mixing and power requirements of the long departure flours. By testing in the farinograph at $38^{o}C$ flours with a medium mixing tolerance and with a relatively short departure time were shown to be best for use in the continuous doughmaking process.

Flours that had extreme protein ranges (9.6 - 15.5%) were studied by Schiller and Crandall (18). Blended flours produced high quality bread but the individual flours used for blending produced inferior bread. These findings agreed with information known about flour blending in the conventional breadmaking process. Schiller (19) reported on what he called the "time factor" involved in various steps of the continuous doughmaking process as compared to times for similar steps in the sponge dough process. It was concluded that this "time factor" placed limitations on the type of flour that could be used for continuous doughmaking equipment. The fermentation and mixing times are shorter in the continuous doughmaking process than in the conventional process, therefore greater stresses are placed on the flour. Schiller concluded that the time effects make it mandatory for a flour to be of uniform quality for the continuous doughmaking process.

Baldwin, et. al. (20) reported that the addition of a hard fat fraction or flakes to the normal shortening system was necessary to produce high quality bread by the continuous doughmaking process. Hard flakes added to the normal shortening system increased the quality of the grain, volume and softness of the bread.

A study of optimum developer speed as related to absorption, oxidation level and starch damage was conducted by Schiller and Gillis (21). They reported as absorption increased, developer speed had to be increased. Optimum developer speed and oxidation level were also directly related. As the level of starch increased, optimum developer speed had to be increased. Increasing starch damage also decreased flour tolerance and drastically affected the quality of the bread.

The effect of individual milk proteins on bread made by continuous doughmaking process was characterized by Baldwin, et. al. (22). They used calcium acid phosphate to maintain the pH of the brew at the optimum level of 4.8 - 5.0. It was reported that casein had no effect on dough quality other than dilution of the flour protein. The albumin and globulin fractions weakened and slackened the dough. The weakening and slackening effect was somewhat overcome by heat treatment of the milk prior to drying. The heat treatment was thought to result in a decrease in protein solubility and an increase in protein-protein interaction, thus rendering the groups responsible for dough weakening ineffective.

Automatic Sweet Goods Production

Gicher (23) reported in 1966 on an automatic sweet dough system that is still being operated commercially. The sweet dough is prepared in a conventional vertical or horizontal dough mixer. The dough is allowed to ferment in dough troughs and is then placed in a depositing unit. The conventionally prepared sweet dough is then extruded by a positive displacement pump through special nozzles to a sweet goods production table. The rate of extrusion by the positive displacement pumps is controlled by an electronic system and a varidrive motor attached to the positive displacement pump. The system also contains a fat depositing unit which is controlled to allow either continuous or intermittent application of fat. The fat system is used for minor lubrication of the dough or for full fat application for Danish doughs.

The two machines are operated in conjunction with a conventional pastry make-up table that is equipped with sheeters and conveyor systems. The maximum rate of production for Danish pastry is 8,000 pounds per hour. The rate of cinnamon roll production is limited to the speed of the cutting blade. In normal production, the cutting blade operates at 200 to 300 cuts per minute but the rate could be substantially increased by the use of a high speed guillotine or rotary cutter.

The automatic sweet dough system equipment of Gicher produced a better product than those made by semi-automatic methods. As Danish pastries are uniform in thickness, length and width and a uniform distribution of fat is applied, the finished products are of high quality. The even distribution of fat allows the development of uniform flakiness to develop.

Lehault (24) in 1967 reviewed the changes that have taken place in sweet goods during the previous two decades. In his review, Lehault discussed two types of extrusion equipment based on conventional dough mixing procedures. The first unit is a high speed extrusion machine for plain sweet dough, augmented by a reel cutter. This unit is characterized by an open hopper which receives the conventionally mixed dough and from which the latter is then extruded by a proportioning device as a continuous sheet onto a moving belt for make-up.

The second dough-handling unit is the design of a different manufacturer and operates at a somewhat slower speed but possesses greater versatility. This unit may also be utilized for making Danish pastry as well as plain sweet dough products. Instead of a dough hopper, the unit requires prescaling and preforming of dough strips ranging in weight from eight to twenty pounds to be fed into the sheeting rolls to form a continuous dough sheet for the make-up process.

Stiles (25) reported that with most types of mechanical sheeters some revision or alteration of dough fermentation appears to be necessary. The dough must be sufficiently relaxed and pliable to prevent tearing when it is sheeted. He also stated that there is a "younging" effect on the dough by the action of the sheeting or head rolls. This effect can be compensated for by aging of the dough, retarding, or use of a rather soft dough that is easy to sheet.

Extrusion methods subject the dough to severities not normally found in other methods. To compensate for this, Stiles suggested the following changes in production procedures:

(1) A sponge of 75% flour or greater should be used.

(2) The sponge fermentation time should be increased approximately one-half hour

(3) The yeast food should be increased by 3/4 of 1%

(4) Dough should be prepared so that the temperature out of the mixer is 83 to 85^{o}F

(5) In high-sugar doughs (20 - 22%) the yeast level should be 8% (5% in sponge and 3% in dough)

(6) The floor time should be increased an additional 30 - 60 minutes

(7) The absorption should be increased by 1 - 3% depending on flour and product

Stiles also suggested some changes in the mixing procedure for extruded doughs. The salt should not be added to the dough until full "clean up" is accomplished. The salt should then be added and the dough mixed for 2 - 4 additional minutes.

Mayer (26) reported another method of preparing doughs. Ingredients should be kept at temperatures of 70°F or lower and incorporated in the following manner: (1) butter and/or shortening and the dry ingredients blended until a smooth paste is developed and (2) eggs added in conjunction with the dry ingredients completing the batch. The dough, prior to the addition of the eggs, should have the appearance of pie dough. The first stage of mixing should not exceed five minutes. The dough should be scaled into 10 or 12 pound pieces. The pieces are then placed on bun pans and rolled to fit the pan. The rolled dough is placed on racks and stored in freezers at 10°F.

At the time of make-up the dough should be brought out of the freezer two to three hours before sheeting. The dough will be firm but pliable and may be sheeted into lengths up to 15 feet at this stage.

Cadwell (27) reported that roll-in or Danish doughs should be scaled and placed in retarders at 36°F for four to six hours. The production of Danish dough requires the addition of solid shortening to the sheeted dough and numerous rolling or sheeting steps. The dough should be retarded or cooled for at least one hour between each of the three roll-in procedures. This length of retarding time before make-up gives a very relaxed and pliable dough.

The formula used in the production of sweet goods has a pronounced effect on the quality of the resultant product. Pyler (28) classified sweet yeast doughs as of three types; (1) straight sweet dough, (2) roll-in sweet dough, and (3) remix sweet dough. Straight sweet and remix sweet doughs are used to make coffee cakes, sweet rolls, etc., while roll-in doughs are used for Danish pastries. The formula presented in Table I exemplifies a typical "rich" sweet dough. This formula is typical but practically an unlimited number of variations can be made in the ingredients and percentage of specific ingredients. For example, percentages of sugar, shortening, eggs and nonfat dry milk (NFDM) may be increased if a richer dough is desired. While if a leaner dough is needed a reduction of the same ingredients can be utilized.

The ranges of ingredients used in straight sweet doughs classified as lean, medium and rich are presented in Table II.

It was reported by Lind (29) that when mixing sweet dough by either sponge or straight dough method, incorporation of the enrichment ingredients is necessary. The more thoroughly these ingredients are incorporated, the better the eating characteristics of the product.

Table I. Typical "Rich" Sweet Dough Formula

Ingredients	Flour Base 100 Formula	True % Formula
Bread flour	78.00	35.45
Cake flour	22.00	10.00
Sugar	22.00	10.00
Emulsified shortening	22.00	10.00
Egg whites	8.25	3.75
Egg yolks	8.25	3.75
Nonfat dry milk (NFDM)	5.50	2.50
Water	44.00	20.00
Yeast	8.25	3.75
Salt	1.75	0.79
	220.00	100.00

Table II. Average Levels of Composition of Three Types of Sweet Dough Formulas

	Lean %	Medium %	Rich %
Flour	100.00	100.00	100.00
Sugar	10.00	15.00	20.00
Shortening	10.00	15.00	20.00
Salt	1.75	1.75	1.75
Nonfat dry milk (NFDM)	2.00	4.00	6.00
Whole eggs	5.00	10.00	20.00
Yeast	6.00	8.00	10.00
Water	58.00	52.00	45.00

He suggested four methods of incorporation of ingredients:

(1) The sugars, malt, margarine and/or shortening butter, NFDM, salt and flavors are creamed until light and fluffy, then refrigerated and kept as a stock mixture. A portion of the stock is added to the balance of the ingredients and mixed into a dough.

(2) Two-thirds of the water, salt, sugars, malt, eggs, NFDM, and flavor are thoroughly blended. This slurry is added to the balance of ingredients and mixed into a dough.

(3) The cake flour, sugar, malt, salt, NFDM, dry flavors and dough conditioners are blended dry and held as inventory. The amount needed is added to the mixer with the added water, eggs, yeast and pastry flour and mixed into a dough.

(4) All dry ingredients are blended dry and maintained as stock. These are aerated and added to the mixer with water, yeast and eggs and made into a dough.

Scarborough (30) in a review article discussed methods for the utilization of brew or preferment in sweet dough production. The first method of brew production is based on the use of 6% NFDM in the brew with no added chemical buffers. The brew is fermented for six hours at a temperature of 95 - 100°F. In this system no oxidant is added at the time that the brew and remaining ingredients are brought together and a dough is prepared.

In the second method of preparing a brew, 100% of the formula water is combined with all the yeast, 6% NFDM, 1 - 3% sugar, the salt, malt and mineral yeast food.

The third method is similar to the first except only 2% of the NFDM is placed in the brew. The remaining NFDM is added in the dough stage.

The fourth method is similar to the second except that 5% of the flour is used to replace the sugar.

Scarborough reported that cinnamon rolls and doughnuts made by the brew system exhibited increased volume and excellent grain. The sweet doughs were in a mellow condition, thus allowing rapid machining. The brew system allowed a shorter floor time than other methods.

Generally the following procedure is used in preparing a dough from the formula presented in Table I. The sugar, NFDM, shortening, salt and flavoring are creamed at low speed for approximately five minutes. The eggs are conditioned to a temperature of 70 - 75°F and gradually added during creaming at medium speed for an additional five minutes. The yeast is dissolved in part of the water and added with the remaining water while mixing is continued for one minute. Water temperature should be approximately $80^{o}F$. The flour is then added and mixing continued at medium speed until a complete dough mass is formed which should require about eight minutes. The dough should be at about $80^{o}F$ at the time of removal from the mixer.

Sweet dough should be proofed in a proof cabinet at minimum relative humidity. The baking temperature should be approximately 365 - $380^{o}F$ to prevent an excessive darkening of the crust.

MATERIALS AND METHODS

Basic Ingredients

The basic raw ingredients used in the preparation of sweet dough on the American Machine and Foundry laboratory continuous doughmaking unit were commercially obtained with the exception of the flour.

Flour, milled on the Kansas State University pilot mill, was a blend of flours from Hard Red Winter wheat and Gaines soft white wheat variety. The two wheats were milled individually and blended to produce a flour with a protein level of 11.4%. This flour was malted and enriched to meet the standards of identity for white flour. Laboratory analysis showed the blended flour to contain 11.3% moisture, 11.45% protein and 0.46% ash. The physical dough characteristics are presented in Plates I and II. The absorption was found by the Brabender Farinograph method to be 61.4%. Hydration on arrival time was 0.25 minutes. The curve exhibited two peaks which is not unusual when two different varieties are blended. Brabender Amylograph value for the blended flour was 620 Brabender units.

Dried egg solids were chosen in preference to fortified frozen eggs because of convenience and uniformity of large sample size. The dried egg solids contained whole egg solids,

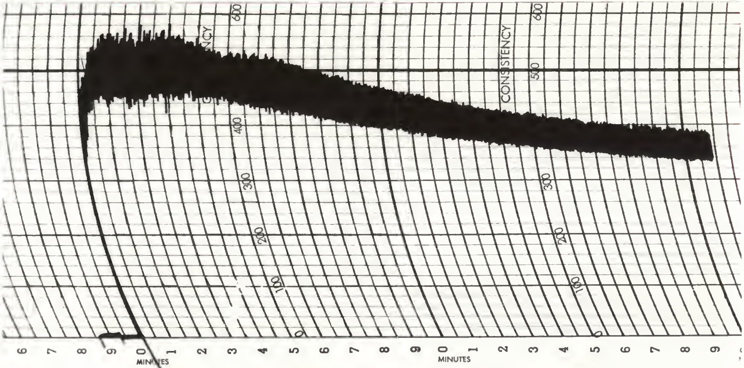

PLATE I. Brabender Farinograph of Blended Flour

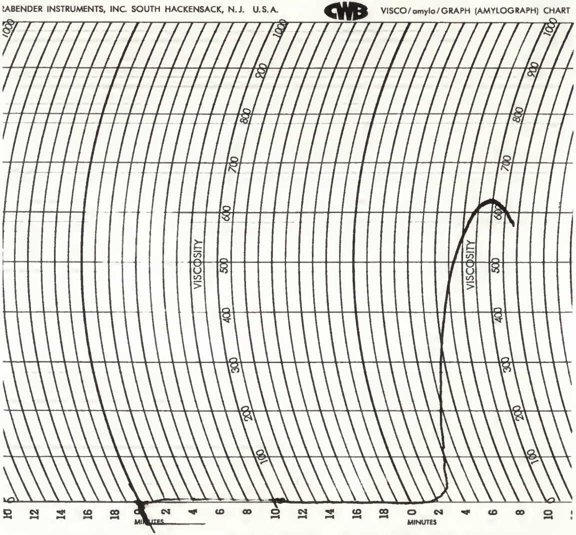

PLATE II. Brabender Amylograph of Blended Flour egg yolk solids, corn syrup solids and salt. Chemical and physical analysis of the fortified egg solids were as follows:

Moisture	2.0 $\pm$ 0.5%
Fat.	37.0 $\pm$ 0.5%
Protein.	31.0 $\pm$ 0.5%
Ash.	3.5 $\pm$ 0.5%
Carbohydrate . .	25.5 $\pm$ 1.0%
Salt	1.25 $\pm$ 0.25%
pH	7.5 $\pm$ 0.5%
Granulation. . .	100% through U.S.A.S. No. 16 screen
Odor	Bland

Liquid shortening was used in this study rather than a plastic type because liquid shortenings do not need to be heated in order to be transferred, whereas plastic shortenings must be melted and held at a temperature of 120^{o}F while being used.

The liquid shortening had the following physical and chemical constants:

Flavor	Bland
Color	2.25R-20Y (max.)
Free fatty acid . . .	0.15% (max.)
Saponification value	189-195
Alpha-monoglyceide . .	2.0-3.0%
Specific gravity . . .	0.92 (approx.)
A.O.M. stability . . .	12 hours (min.)

The emulsifier used in this work was a powdered mono-and-diglyceride designed for use in yeast-raised baked goods. A powdered rather than a plastic type was chosen since the powder could be added to the brew stage. Chemical and physical properties were as follows:

Total monoglyceride content .	55±3%	
Capillary melting point . . .	140°-144°F	
Iodine value.	2 (max.)	
Color (Loviband)	3.0 red (max.)	
Free fatty acid	1.0% (max.)	
Particle size	% retained	Mesh size
	0	60
	20 (max.)	80

Since the flour, fortified whole egg solids, shortening and emulsifier contributed significantly to the dough formation and functional properties of the finished dough, complete analyses of these products were detailed.

The remaining ingredients contributed only minor significance to the dough formation and the finished product, so no analyses were determined. The minor ingredients were of a standard type used in all commercial bakeries in the production of sweet doughs.

Continuous Laboratory Unit

The American Machine and Foundry laboratory doughmaking unit provided the dough formation equipment; a schematic diagram is presented in Figure 1. The unit is a self-contained system that converted basic raw ingredients to a completely mixed raw dough.

The system consisted of two 30-gallon jacketed brew tanks with agitation systems for incorporation of raw ingredients by

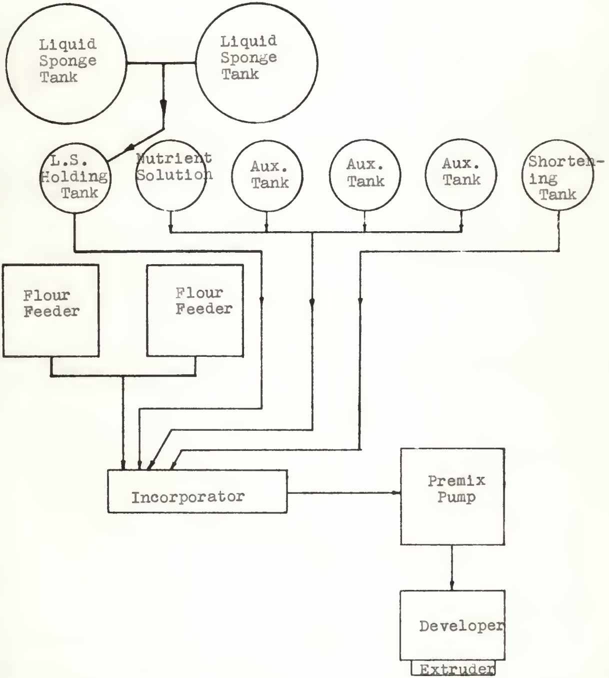

Figure I. Schematic Diagram of A.M.F. Continuous Doughmaking Unit high speed induction and low speed agitation. The water jacketed brew tanks allowed control of the temperature of the brew during fermentation and transfer. On completion of the fermentation cycle, the brew was transferred by a positive displacement pump to a constant-level holding tank. Holding tanks for the brew and other raw ingredients were of the same size. These tanks were connected to separate variable-speed pumps, thus allowing metering of the ingredients into the incorporator or pre-mixer. The unit was equipped with micro feeders made by Sterwin Chemical, Inc. that metered the flour directly into the incorporator.

The following ingredients were added from individual metering tanks: (1) shortening, (2) nutrient solution, and (3) water. In the incorporator the ingredients were combined to form a dough mass. The dough mass was extruded into a positive displacement pump and transferred by it to the developer head. The developer head was equipped with a variable speed controller. The dough was developed in the developer head by a combination of retention time and energy employed. The dough was then extruded through a special extruder head built for the production of sheeted sweet dough, Plate III shows a more detailed view of the extruder. The extruded sweet dough was manually collected on plywood boards 21" X 13" for transportation to the dough make-up table.

PLATE III. Detailed View of Dough Extrusion Method

The rate of movement of the board under the extruder was equal to the rate of production, thus a thin sheet 0.25 inches thick and 7-9 inches wide was formed on the board. The sweet doughs were manually cut after a board of dough was collected. The American Machine and Foundry laboratory continuous dough-making unit was designed to produce between 150-300 pounds of dough per hour. In this study, the unit was operated at 225 pounds of dough per hour. The unit was designed to allow from 0 to 50 percent of the total flour in the liquid sponge system. In this study 20 percent of the flour was used in the sponge system.

Formulations and Blending Procedures

A medium formula as presented in Pyler (28) and by Fleishman (31) was chosen as a starting formula. The basic formulas used in this study are presented in Tables III and IV. In the first trial production of sweet dough formula number I (Table III) was used. In all subsequent trials sweet doughs were prepared using formula number II (Table IV).

A. Brew Solution

The brew solution contained 20% of the total flour, 36.1% of the total water and 0.25% shortening in the formula. The yeast, yeast food, emulsifier and oxidant were added to the first mixture in the brew tank. The

Table III. Sweet Dough Formula I

Ingredients	% Flour Base 100	Phase I	Phase II Nutrient	Mixing Phase III
Flour	100.0	20		80
Water	52.6	36.1	16.5	
Yeast	8.0	8		
Yeast food (Arkady)	1.5	1.5		
Sugar	17.0		17.0	
Salt	1.5		1.5	
NFDM	5.0		5	
Whole egg solids	5.0		5	
Liquid shortening	15.0	0.25		15
Emulsifier	0.0045	0.0045		
Oxidation	60 ppm.	1½ tabs		
Flavors (vanilla)	0.10		0.1	

Table IV. Sweet Dough Formula II

Ingredients	% Flour Base 100	Phase I	Phase II Nutrient	Mixing Phase III
Flour	100.0	20		80
Water	52.6	36.1	16.5	
Yeast	8.0	8		
Yeast food (Arkady)	0.75	0.75		
Sugar	17.0		17.0	
Salt	1.5		1.5	
NFDM	5.0		5	
Whole egg solids	5.0		5	
Liquid shortening	15.0	0.25		15
Emulsifier	0.0045	0.0045		
Oxidation	60 ppm.	1½ tabs		
Flavors (vanilla)	0.10		0.1	

brew formulation is expressed in Table II as phase II. The batch size of phase I consisted of 33 kilograms of flour and the proper weight of other ingredients based on the flour weight. The water was placed in the tank and the yeast was added with the high speed agitation continuing to operate. The flour was added and blended in with minimum high speed agitation which took approximately one minute. Agitation was not used during the fermentation period. Following the desired fermentation period, the slow agitation was started and the brew transferred to the constant level tank. The brew delivery pump was then calibrated to the desired rate.

B. Nutrient Solution

The nutrient solution was prepared from 16.5% of the total water and all the sugar, salt, NFDM, whole egg solids and flavoring. All of the dry ingredients were placed in a 20-quart mixing bowl on a Hobart A-200 mixer and blended at low speed until all lumps were dispersed. This required approximately five minutes. On completion of the blending stage, mixing was continued at low speed and the water was gradually added. This slurry was mixed at low speed for fifteen minutes to dissolve the sugar and salt and to completely solubulize the whole egg solids and NFDM. The slurry was then refrigerated until needed for production.

C. Shortening

The shortening was a liquid type used in breadmaking. The type of shortening and emulsifier are critical to the production of quality sweet goods. The basic liquid type bread shortening was modified by the addition of the powdered emulsifier to the brew system or phase I. The shortening was placed in one of the holding tanks for raw ingredients and the delivery pump was calibrated to the proper rate for production.

D. Flour

The flour was placed in the micro feeder produced by Sterwin Chemical, Inc. which was calibrated to proper feed rate. When all delivery pumps for the needed ingredients had been calibrated and the brew had fermented for the desired time, the various ingredients were pumped to the incorporator. The flour was introduced and all dough mass transfer pumps were started. The developer was started and the rotation speed in revolutions per minute (R.P.M.) of the mixing paddles was adjusted to produce a developed sweet dough from the extruder.

Make-up Procedure

The dough was extruded onto a lightly floured plywood board. When the length of the board was covered with dough, the dough was cut. The dough then was transferred to the make-up table. Then the dough sheet was subjected to a normal manual make-up procedure. First the dough was lightly rolled, egg wash was applied, the dough was sprinkled with cinnamon and nuts, curled, sealed, cut to desired size and panned. Nine cinnamon rolls were placed in an Ekco 664 aluminum pan 6 3/4 X 6 3/4 X 1 inch in size. After panning, the prepared dough pieces were placed in the proof cabinet for an additional hour of secondary fermentation. Sweet dough products were given full proof at a temperature of 95^{o}-98^{o}F and a relative humidity of 80% to 85%.

On completion of the secondary proof, the doughs were baked for 20 minutes at 415^{o}F. It has been suggested that sweet doughs be baked as quickly as possible but long enough to insure a thorough bake. The baked sweet dough products were cooled, placed in plastic bags and stored until evaluated.

The baked cinnamon rolls were evaluated after 18 hours (fresh), 3 days, 12 days and 16 days. These products were evaluated for softness by the use of a Precision Penetrometer, Precision Scientific Company. The penetrometer number 73510 was equipped with an A.S.T.M. grease cone number 73526. The American Association of Cereal Chemists (AACC) method 85.1 (32) was used with the exception that the needle and cone was used in place of the 3 cm. cylinder. The plunger was loaded with an additional 150 gm. These modifications were necessary because of the nature of sweet dough products as compared to bread products.

The products were evaluated after 18 hours of storage for product weight per pan, volume per pan, product symmetry, grain, texture and eating quality.

The weight of the product was measured on a Toledo Model 4030 gram scale. The volume was determined by the AACC method 10-20 (33) using rapeseed displacement.

Symmetry is defined as the outside shape of the cinnamon rolls as characterized by a cross section, either lengthwise or through the center. Symmetry is influenced by the contour of the top and sides of the cinnamon rolls.

Grain is the internal physical structure of the cinnamon rolls. It was judged by the visual observation of a freshly cut slice to determine the size, shape and uniformity of the cells and by the thickness of the cell walls.

Texture is the sensation ascribed to the feel of the surface of a cut slice of cinnamon roll. It was determined by pressing the fingers against and rubbing them lightly across a freshly cut surface.

The eating quality was evaluated by a sensory evaluation panel based on a preference decision. The panel members used a paired comparison test. A sample of the score sheet used for acceptance of cinnamon rolls is presented in Figure 2.

ACCEPTANCE SCORES FOR CINNAMON ROLLS

Judge ____________

Date ____________

Rank each roll on acceptability in order of preference as compared to control sample.

Lower in Quality	Equal in Quality	Superior in Quality

Figure 2. Taste Evaluation Sheet

RESULTS AND DISCUSSION

Sweet Dough Characteristics

It was observed that the tendency of the dough to shrink upon extrusion was an indication of underdevelopment. This observation was further substantiated during the dough make-up stage. When the underdeveloped dough was reduced in thickness by rolling, it exhibited a "bucky" characteristic. The dough would not hold its rolled or sheeted shape. It was very hard to curl the dough and to form cinnamon rolls. The curled dough was difficult to cut into uniform pieces because of its rubbery nature.

If the dough had a tendency to flow after extrusion, over-development was indicated. This dough was extremely difficult to handle since it was weak and sticky. Additional dusting flour was required to enable reduction of thickness and curling. It was also observed when dividing the curled dough into pieces for panning, it tended to stick together so that problems in uniform scaling resulted. A properly developed dough upon extrusion maintained its shape and did not shrink or flow. These doughs were easily reduced in thickness on the make-up table. The doughs maintained there reduced shape, were easily curled and cut into cinnamon rolls.

The R.P.M. of the developer head and dough temperature were factors contributing to the development of the dough. At the proper R.P.M. and temperature, a fully developed and easily handled dough was produced. The effect on quality of the baked product was caused by the R.P.M. of the developer head as shown in Plate IV. Underdeveloped dough produced a product with an open grain, harsh texture, low volume and poor symmetry. The properly developed dough produced a baked product with good grain, good texture, good volume and good symmetry. Both overdeveloped doughs yielded products with weak cell structure, rather harsh texture and lower volume and poor symmetry. The highest developed dough gave a somewhat better volume of baked product than the slightly overdeveloped dough. This is not at all unusual in doughs produced by the continuous doughmaking procedure. The dough mass has a tendency to recover and produce a satisfactory product.

The properly developed dough, with good handling characteristics, produced an excellent unbaked and baked product as shown in Plate V.

The results of the specific volume, symmetry, grain, texture and total product score are presented in Tables V through IX.

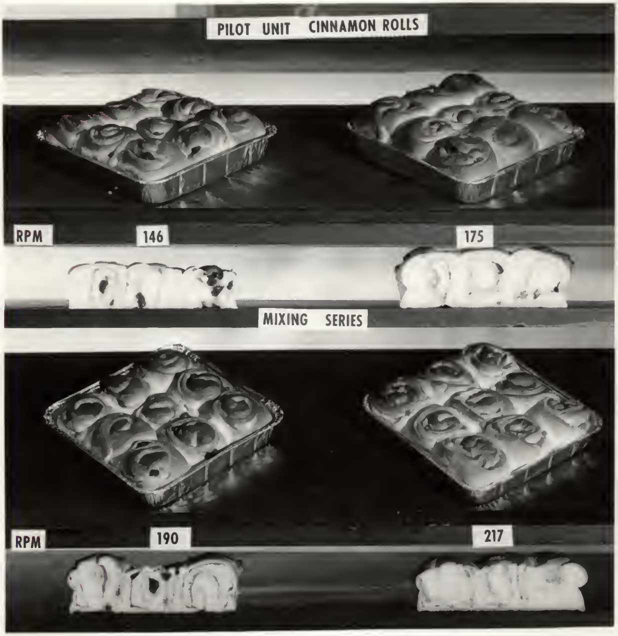

PLATE IV. Mixing Series Comparison of Cinnamon Rolls

PLATE V. Comparison of Unbaked, Baked and Cross Section of Cinnamon Rolls

Table V. Product Score vs. R.P.M. Trial Number One

Sample Number[a]	R.P.M.	Specific Volume[b]	Volume[c]	Symmetry[d]	Grain[e]	Texture[f]	Total Product Score
3	146	2.61	12	9	17	16	54
17	175	4.02	20	13	27	26	86
13	217	3.47	17	11	21	20	69
C-1[g]		2.65	13	12	18	16	59

[a]Sample number designates the products produced from the 3, 13, and 17 plywood transfer boards of doughs collected.

[b]Specific volume was determined by dividing the rapeseed displacement volume by the weight of the product.

[c]Specific volume converted to a numerical score

Specific Volume	Numerical Score
5	25 maximum
4	20
3	15
2	10
1	5

[d]Symmetry, a perfect score equals 15 points maximum

[e]Grain, a perfect score equals 30 points maximum

[f]Texture, a perfect score equals 30 points maximum

[g]Commercial control sample purchased at a local supermarket

Table VI. Product Score vs. R.P.M. Trial Number Two

Sample Number[a]	R.P.M.	Specific Volume[b]	Volume[c]	Symmetry[d]	Grain[e]	Texture[f]	Total Product Score
3	195	2.60	12	11	16	17	56
2	217	4.02	20	12.5	26	25	83.5
14	237	3.63	17	12	21	21	71
C-2		2.85	14	12	17	18	61

[a]Sample number designates the products produced from the 3, 2, and 14 plywood transfer boards of doughs collected.

[b]Specific volume was determined by dividing the rapeseed displacement volume by the weight of the product.

[c]Specific volume converted to a numerical score

Specific Volume	Numerical Score
5	25 maximum
4	20
3	15
2	10
1	5

[d]Symmetry, a perfect score equals 15 points maximum

[e]Grain, a perfect score equals 30 points maximum

[f]Texture, a perfect score equals 30 points maximum

[g]Commercial control sample purchased at a local supermarket

Table VII. Product Score vs. R.P.M. Trial Number Three

Sample Number[a]	R.P.M.	Specific Volume[b]	Volume[c]	Symmetry[d]	Grain[e]	Texture[f]	Total Product Score
4	200	2.50	12	10	18	17	57
9	226	3.99	20	12.5	25	24	81.5
16	246	3.74	18.5	11	23	24	76.5
C-3		3.49	17	11	15	15	58

[a]Sample number designates the products produced from the 4, 9, and 16 plywood transfer boards of doughs collected.

[b]Specific volume was determined by dividing the rapeseed displacement volume by the weight of the product.

[c]Specific volume converted to a numerical score

Specific Volume	Numerical Score
5	25 maximum
4	20
3	15
2	10
1	5

[d]Symmetry, a perfect score equals 15 points maximum

[e]Grain, a perfect score equals 30 points maximum

[f]Texture, a perfect score equals 30 points maximum

[g]Commercial control sample purchased at a local supermarket

Table VIII. Product Score vs. R.P.M. Trial Number Four

Sample Number[a]	R.P.M.	Specific Volume[b]	Volume[c]	Symmetry[d]	Grain[e]	Texture[f]	Total Product Score
3	188	2.61	13	9.5	17	18	57.5
10	217	4.05	20	13	27	26	86
15	240	3.85	18	11.5	25	25	79.5
C-4		3.04	15	12	17	16	60

[a]Sample number designates the products produced from the 3, 10, and 15 plywood transfer boards of doughs collected.

[b]Specific volume was determined by dividing the rapeseed displacement volume by the weight of the product.

[c]Specific volume converted to a numerical score

Specific Volume	Numerical Score
5	25 maximum
4	20
3	15
2	10
1	5

[d]Symmetry, a perfect score equals 15 points maximum

[e]Grain, a perfect score equals 30 points maximum

[f]Texture, a perfect score equals 30 points maximum

[g]Commercial control sample purchased at a local supermarket

Table IX. Product Score vs. R.P.M. Trial Number Five

Sample Number[a]	R.P.M.	Specific Volume[b]	Volume[c]	Symmetry[d]	Grain[e]	Texture[f]	Total Product Score
3	195	2.45	12.5	10.5	19	18	60
8	222	3.98	20	13.5	28	26	87.5
15	239	3.72	18	12	22	23	75
C-5		3.15	16	13	16	17	62

[a]Sample number designates the products produced from the 3, 8, and 15 plywood transfer boards of doughs collected.

[b]Specific volume was determined by dividing the rapeseed displacement volume by the weight of the product.

[c]Specific volume converted to a numerical score

Specific Volume	Numerical Score
5	25 maximum
4	20
3	15
2	10
1	5

[d]Symmetry, a perfect score equals 15 points maximum

[e]Grain, a perfect score equals 30 points maximum

[f]Texture, a perfect score equals 30 points maximum

[g]Commercial control sample purchased at a local supermarket

The cinnamon rolls produced from overdeveloped and properly developed doughs had higher total product scores than the commercial controls in all trials. The cinnamon rolls produced from underdeveloped doughs were lower in total product score than the commercial controls.

The cinnamon rolls prepared from the continuous doughmaking unit exhibited greater specific volumes than the commercial controls. Scarborough (30) reported an increased volume and excellent grain when a brew system is used in conventionally mixed sweet doughs. The results of this experiment indicate that increased volume, excellent grain and texture can be accomplished with continuous doughmaking equipment when the doughs are properly developed.

Further evidence of the superior quality of cinnamon rolls produced by the continuous doughmaking process as compared to commercial controls as shown in Plate VI. The cinnamon rolls produced from this continuous doughmaking process exhibited an internal cell structure similar to bread prepared by this process. There was a definite uniformity to the cell structure.

A preference comparison panel was conducted to determine if continuous doughmaking process cinnamon rolls were lower in quality, equal in quality or superior in quality to commercial cinnamon roll samples. Each panel member was given a sample of

PLATE VI. Cross Section Comparison of Commercial and Experimental Cinnamon Rolls experimental and commercial sweet rolls for evaluation. The panel members were asked to indicate the degree of preference.

The results of the preference panel evaluations of fresh (18 hour) cinnamon rolls are presented in Table X. With the exception of trial number one, the experimental cinnamon rolls were equal or superior in quality to commercial samples.

Rolls used in trial number one were prepared using sweet dough formula I, whereas the remaining trials were conducted using sweet dough formula II. The concentrations of yeast food (Arkady) in sweet dough formula I was twice that of the concentration used in sweet dough formula II. The high level of yeast food in the formula resulted in an undesirable after-taste in the finished product. This undesirable after-taste may explain the panel's rating of the experimental cinnamon rolls at a lower level of quality than the commercial samples in trial number one. The correction of the yeast food level did not cause any detrimental effect on physical quality. This correction also eliminated biased comparisons.

One of the measurements of "shelf-life" of a product is its rate of staling or firmness during storage. The staling rate is determined by the rate of penetration of a needle and cone into the crumb area of a baked product. Samples of commercial and experimental cinnamon rolls were stored for

Table X. Results of Paired Preference Evaluation of Commercial vs. Experimental Cinnamon Rolls

Experiment Number	Lower in Quality to Commercial	Equal in Quality to Commercial	Superior in Quality to Commercial
Trial 1	9	1	-
Trial 2	3	6	1
Trial 3	1	6	3
Trial 4	1	4	5
Trial 5	-	3	7

18 hours (fresh), 3, 12 and 16 days in plastic bags. The results of penetration rates are presented in Table XI.

The determination of staling in cinnamon rolls is difficult because of the presence of nut or raisin pieces. The presence or absence of these pieces can effect the penetration of the needle and cone and, therefore, trends are more significant than actual values.

The experimental samples prepared from overdeveloped and properly developed doughs generally exhibited the highest rate of penetration. This indicated a lower rate of staling. The general trend noted was that the commercial samples exhibited a slightly faster rate of staling than the experimental cinnamon rolls.

The use of a special emulsifier in combination with the liquid bread shortening may account for part of the effect noted.

Presented in Plate VII are some varieties of sweet goods produced from dough made by the continuous doughmaking process.

The results of these studies indicated that it would be feasible to produce sweet dough by the continuous process. The American Machine and Foundry continuous doughmaking unit lent itself very well to experimental sweet dough production with little or no modification. There was adequate tank capacity for

Table XI. Cinnamon Roll Penetrometer Values

Trial No.	Fresh m.m.	3-day m.m.	12-days m.m.	16-days m.m.
1	186	119	93	46
1	220	165	110	55
1	235	168	112	56
C-1	210	148	85	43
2	215	162	108	54
2	192	144	96	48
2	170	127	85	42
C-2	215	145	77	38
3	187	141	94	47
3	250	187	125	62
3	230	172	115	57
C-3	205	138	72	36
4	195	139	93	46
4	220	165	110	55
4	210	156	105	51
C-4	200	130	70	35
5	185	138	92	46
5	240	180	120	60
5	227	169	113	56
C-5	198	135	68	33

PLATE VII. Product Variations Made With Continuous Doughmaking Process Sweet Dough brew and raw ingredients and sufficient auxillary equipment to produce any type of dough that might be desired. Commercial models of continuous doughmaking systems could similarly be utilized for the production of sweet goods. The Dō-Maker Model 36 (Wallace & Tiernan, Inc.) would be very suitable for sweet goods production. The production rate of the Model 36 is 3600 pounds of dough per hour, which would allow efficient continuous feeding of a conventional sweet goods line. The American Machine and Foundry Model 300 is commercially available and could also be used. This unit could be utilized in both retail and wholesale bakeries, because of its production rate of 300 pounds per hour. With the currently available make-up equipment, it would not be practical to use the much larger American Machine and Foundry or Dō-Maker continuous doughmaking units for production of sweet doughs. However, if a multi-unit sweet goods line were in operation, it might be possible to utilize one of the larger units.

There would be a definite economic advantage in the employment of a continuous doughmaking system for making sweet doughs. Economy would be manifested in labor savings, cost of maintenance and ingredients. The labor savings would include elimination of three people: (1) a mixer, (2) an operator for the mechanical extruder, and (3) a baker's helper. In a normal operation this would currently amount to a savings of about $63 per day. Since continuous doughmaking units are complete dough systems, they would require no sponge mixers, dough mixers, sponge troughs, dough troughs, mechanical extruders, hoists and fermentation rooms. Maintenance costs would be reduced with the reduction of equipment, instead of several individual machines to maintain there would be only the continuous mix unit. As to production losses and time, scheduling would be easier and more reliable, since the production would be continuous rather than in small individual batches. Raw dough losses should be reduced as a result of using fewer pieces of equipment.

Product quality, which is always important, would be much more uniform if the continuous doughmaking system of production were employed. Quality attributes which are most important in sweet dough production are volume, grain, texture and eating quality. Of these, the grain and texture were found to be more uniform in products made by the continuous doughmaking procedure.

Product volume was increased by the utilization of the continuous doughmaking procedure. The eating qualities of products produced by the continuous doughmaking system were equal to or better than those of similar products produced by conventional means. The staling quality of 18 hour (fresh), 3-day, 12-day and 16-day old products was superior to that of commercial products of equal age. The method of production or combination of raw ingredients appeared to enhance the quality of products produced.

Continuous doughmaking systems could be operated at uniform rates of production. The desired rate of dough production per hour could be calculated from the formula, thus matching the production rate of finishing equipment. The component parts of the machine could then be calibrated according to the poundage desired and production initiated. The established production rate would not deviate. In conventional systems, the same rate of production may be desired but batching ingredients, mixing single doughs, transferring dough, etc., cause losses in time. The conventional system would appear to lead to larger losses of dough than continuous production. On the basis of these considerations, the actual rate of ingredient utilization could be reduced by 10-15% and the same rate of production maintained as in the conventional system.

Presently variety products such as white, whole wheat, diet and high protein breads can be produced on continuous process equipment. If the baker were to produce sweet goods by this method, he could increase the capital return on the equipment. There are other types of products that could be produced utilizing this process, such as rye and raisin breads, Danish and puff pastry doughs. The technology and ability to utilize this equipment are still in the developmental stages. Producing all varieties of bakery products on the continuous process equipment would certainly enhance the baking industry's profit picture. Sanitation procedures would be reduced in continuous mix systems. Superior cleaning could be accomplished because there would be less equipment to clean. A large share of the continuous system could be cleaned and sanitized in place. This system involves wet process operations. Using the cleaning in place (C.I.P.) process, sanitizers would be pumped through the complete system, which would virtually destroy all harmful bacteria. The keeping qualities of the baked products would be enhanced.

SUMMARY AND CONCLUSIONS

Studies were conducted to determine the feasibility of producing sweet doughs on a continuous basis. The results indicated that such sweet dough production would be possible. Further studies should be made to clarify some details.

It appeared on the basis of the experiments conducted with the American Machine and Foundry laboratory unit that it would be feasible to produce commercial sweet dough on small to medium size production units.

The doughs produced by the continuous doughmaking process exhibited excellent dough handling characteristics. The doughs were pliable and dry and could be handled on bench or production sheeter equipment.

The finished baked products were equal to or better than similar types available on the local market. Eating qualities and external and internal characteristics were superior to those of the commercial products. Shelf-life qualities of the experimental products also were superior to those of commercial products.

Use of the continuous doughmaking process for making sweet doughs should stimulate research on the continuous production of other types of bakery products.

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A STUDY OF THE FEASIBILITY OF PRODUCING SWEET DOUGHS BY THE CONTINUOUS DOUGHMAKING PROCESS

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The American Machine and Foundry laboratory continuous doughmaking unit was used to determine the feasibility of sweet dough production. The feasibility studies were conducted to determine if production of sweet goods could be accomplished without extreme modification of formulas and make-up procedure. The various factors that were studied were dough mixing requirements, shortening systems, levels of dough conditioners and general dough handling characteristics.

The cinnamon roll was used throughout the study as a standard or basis of comparison of factors studied. Cinnamon rolls produced by the American Machine and Foundry laboratory continuous doughmaking process possessed characteristics that were equal to or better than commercially produced cinnamon rolls. The experimentally prepared sweet rolls were compared to samples of commercial products obtained from local supermarkets. The specific characteristics observed were volume, grain, texture, eating qualities and keeping qualities.