THE EFFECTS OF FLOUR STARCH DAMAGE ON PHYSICAL DOUGH PROPERTIES OF CONTINUOUS MIX BREAD

by 683

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Introduction

At the annual meeting of the American Society of Bakery Engineers in 1954, Dr. John C. Baker stated that it was not necessary to ferment flour in order to make bread (1). He proposed a new process---a continuous mix process---for the production of white bread which would result in a greater automation and mechanization of the baking process. He maintained that the process resulted in reduced processing time, space and equipment but increased the production output.

It is estimated that more than 40% of the white bread produced today in the U.S.A. is processed continuously. Since flour is the major ingredient in bread production constituting about 53% of the total weight of dough, it is the single most important variable in the process. There are four factors which have to be considered in selecting a flour:

1) Flour strength
2) Flour uniformity
3) Adaptability of the flour to the process
4) Ability of the flour to produce the desired product

Flour strength and uniformity appear to be the most important characteristics of flour for the continuous production of white bread. Besides the selection of the proper wheat, the milling process influences the flour properties.

During the milling process the starch component of the flour may be damaged to a certain extent. This can cause difficulties in bread production requiring changes in water absorption and mixing speed.

The purpose of this research was to determine the effects of different levels of starch damage on the physical characteristics of the dough in continuous production of white bread.

Literature Review

The technology of continuous mixing of dough was described by Fortmann (2) and Swortfiguer (3). The first stage or premix stage assembles the ingredients. Solids and liquids are incorporated but a dough is not fully developed. The dough is granular and wet at this stage. As mixing continues in the developer, the dough becomes smoother and relatively dry. A peak of power consumption is reached at this stage. The dough reaches the right condition to capture appreciable quantities of air into the mass. When finally developed, the dough is more like a batter than a dough due to the extreme pressure and shearing of the dough in the developer. This dough has a high sensitivity during proofing. The correct melting point of fat (1), the proper prooftime, the correct oxidation (3), and absence of rough handling during oven loading must be observed to produce bread with good external and internal characteristics.

The detrimental effects of starch damage are mentioned by Fortmann (2) and Schiller, et al. (4). Fortmann described the effect of starch damage during mixing as follows: "If damaged starch is present, it will take on water very rapidly. At the same time, the protein portion of flour will compete for water and forms gluten. If the starch is undamaged a continuous gluten structure is formed. If excess starch damage is present it will form a kind of glue. The protein will receive some water, but the dough structure will be largely a starch to starch or starch to gluten bond rather than a continuous gluten structure." Pratt (5) stated that some starch damage is desirable to assure substrate for the fermentation process, but that excessive damage will create an unbalanced condition resulting in a wet crumb, poor loaf volume and inferior grain and texture. Pratt (5) was of the opinion that no chemist is ready to set upper limits for damaged starch in flour. The actual level of damage tolerable in any bakery will probably vary from bakery to bakery depending on formulation, equipment, and processing method.

The effect of damaged starch in bread making was described by Sandstedt (6). Mechanically damaged starch granules were visualized as similar to gelatinized starch granules. These damaged starch granules swell extensively in cold water and are readily digested by amylases. Damaged areas yield about 60% maltose and 40% beta-limit dextrins due to the action of β-amylase. The outstanding characteristic of α-amylase is the ability to dextrinize starch. The action has generally been considered to be random such that a chain of amylase is attacked indiscriminately with the production of shorter chains (7). These in turn are broken down with only small oligosaccharides remaining. The production of reducing and fermentable sugars is relatively slow but may be eventually extensive.

As observed under the microscope, the action of β-amylase on damaged starch causes a shrinkage of the swollen starch, not a disintegration. Beta-limit dextrins hold many times their own weight of water. They are easily disintegrated by the mixer action.

The effects of overgrinding on flour characteristics were studied by Atkinson and Fuehrer (8). They reported that gluten quality does not seem to be adversely affected by overgrinding. Conventional baking tests showed that overgrinding caused no changes in fermentation or mixing, but increased water absorption. Overgrinding caused an increase in maltose and gas production which was in direct relationship to the severity of the treatment. Ponte, et al. (9) found starch damage to be related to the amylase activity, absorption, and baking performance of the flour. They speculated that an optimum degree of starch damage exists for a particular flour, at least for the conventional sponge and dough process. During sponge fermentation, the free sugars of flour are soon exhausted by yeast and production of maltose from damaged starch granules by amylases appears to be necessary for continued fermentation. In conventional baking tests, Ponte et al. (10) found an inverse relationship between loaf volume, the per cent damaged starch, and the relative number of smaller granules. Sullivan et al. (11), overgrinding flour by ball milling, found an increased malt response because of a large increase in damaged starch granules. The same results were also reported by Alsberg et al. (12). Seibel and Zwingelberg separated Australian flour into three fractions---coarse, medium, and fine. They determined damaged starch in each fraction. The coarse fraction showed the lowest amount of damaged starch in each case.

Increased Farinograph absorption, lower bread volume and poorer baking scores were reported by Schlesinger (14) working with ball-milled hard-red-winter wheat flours. He showed by conventional baking methods that starch damage and the increased water absorption requirement rather than gluten damage to be the cause of poor baking results.

Farrand (15) showed that increased mechanical damage correlated with increased water absorption of the starch. He stated that the change in absorption in terms of Brabender consistency could be calculated with a fair degree of accuracy for a given flour in terms of the measured difference in starch damage. Farrand also observed a reduction of the maximum consistency on the Brabender Amylograph by increasing starch damage.

The degree of starch damage is influenced by the type of wheat used as reported by Wolf (16). Soft wheats show only small changes in maltose value during milling while starch from hard wheats is damaged to a higher degree. Wolf (16) also observed an increase in absorption with an increase in starch damage. Farinograph curves showed a narrower band with damaged starch which he interpreted as decreased elasticity of the dough.

Several methods of starch damage determination have been published. Most of these methods are based on the determination of end-products of enzyme action on the starch. Damaged starch differs from normal starch in a number of respects; water absorption, solubility, susceptibility to staining with iodine and certain dyes, birefringence and digestibility by amylases. Damage is not an all or none situation. Rupture occurs from a few intermolecular bonds to extensive rupture of enough bonds to make the starch available to amylase action.

The Sandstedt - Mattern method (17) is based on a higher rate of digestion of damaged starch than of native starch granules by malt amylases. A one gram sample is incubated with 160 SKB units of α-amylase at 30°C. The degree of digestion is measured at the end of the first hour and second hour by determining the maltose values and expressing them as per cent maltose. To correct for the digested native starch, the maltose formed during the second hour is used. This is done graphically or mathematically according to the equation by Ponte and Rosen (18). The per cent damaged starch is obtained by extrapolation back to zero time. The slope of the curve is an indication of the susceptibility of the undamaged starch to digestion.

A rapid method for estimation of damaged starch in soft wheat flours was developed by Donelson and Yamazaki (19). The method is similar to the Sandstedt method, however, the digestion time is reduced to 15 minutes. A one gram sample is used and 0.10g of Rhozyme 33 (fungal amylase enzyme; 5,000 SKB units per gram) is added. Maltose is determined and may be converted to damaged starch by multiplying by the empirical factor 1.64 after correction for the blank.

Whereas both methods above are based on the susceptibility of damaged starch to enzymic degradation, the Hampel method (20) uses the "soluble Amylose" as an index of the condition of the starch. According to this method a flour sample is extracted with saturated ammonium sulfate-formamide solution containing sulfo-salicyclic acid. This extraction step is carried out at 40°C for 10 minutes. After filtration an aliquot is transferred into a test tube, hydrogen peroxide added and the solution is heated for five minutes in a boiling water bath. After cooling, the soluble starch is determined with iodine. The color is expressed as "amylose number" by comparing the color formed with an artificial color standard based on the achromic color obtained with pure amylose.

In 1962, another method for starch damage estimation was published by Sullivan, et al. (21). This method is based on the fact that damaged starch granules are much more susceptible to the action of β-amylase than undamaged granules. The starch damage index (D.S.I.) is the difference in maltose value between flour inactivated by trichloroacetic acid in butanol and the inactivated flour plus an excess of β-amylase. Using ethanol for enzyme inactivation as proposed by Lee and Geddes (22) resulted only in partial deactivation of the enzymes. Complete deactivation was obtained with trichloroacetic acid as reported by Sullivan (21).

Sandstedt and Mattern (17) pointed out that all starch damage methods are empirical, since the complete differentiation of damaged and undamaged starch is virtually impossible.

Kulp and Bechtel (23) compared the Sandstedt method with those of Sullivan and Hampel and found the Sullivan method to be the most satisfactory. The Hampel and Sandstedt methods needed modification. The authors gave analytical data for the three methods for starch damage. They found no quantitative relationship between the values by the three methods which would permit a direct interconversion. For this research project, the Sullivan method was used.

It was the object of this research to establish the effects of starch, damaged to different degrees, on the characteristics of Farinograph and Amylograph curves, on the physical dough properties and the quality of the bread produced by continuous mixing.

Materials and Methods

A baker's patent flour was obtained with a protein content of 12.1% and an ash content of 0.44%.* An unmodified wheat starch was obtained ** and this starch was mechanically damaged by ball milling for 1 day, 2 days, 3 days and 5 days using a small laboratory ball mill (1 lb. samples). A ribbon blendor (100 lbs. capacity) was used to blend 50 lbs. of the flour with 5 lbs. of the damaged starch. Blending time was 20 min. The final protein content of the blends was 11.0% and this protein content was kept constant throughout the project work. Damaged starch was estimated using the Sullivan method. (21) The physical dough properties for the blends were determined with the Brabender Farinograph and Amylograph.

* Rodney Milling Co.

** Hercules Powder Co.

The AMF laboratory model continuous mixer was used in the baking studies (Fig. 1). The system consists of a jacketed brew tank (30 gallon capacity) with high and low speed agitators. The brew which consisted of all the dough ingredients except the flour and shortening was pumped to a holding tank after 2 1/2 hours of fermentation. The holding tank was connected to a variable speed pump that allowed metering of the brew into the incorporator where the flour blends and the shortening were added. From the incorporator, the ingredients entered a positive displacement pump and were pumped to a variable speed developer head. The dough was given full development at this stage and was extruded and cut off at desired weights. Panning was done manually. Proofing was to a height of 2 cm. above the pan. The bread was baked at 425°F for 20 min.

A 5 X 3 X 3 factorial design (5 levels of starch damage X 3 levels of absorption X 3 impeller speeds) was selected. A typical continuous mix white bread formula is listed in Table 1.

Results and Discussion

Starch damage and particle size:

Attempts were made to damage the wheat starch by pin-milling using an Alpine laboratory mill Type 160Z. Particle size was decreased. However, no appreciable starch damage was obtained operating the mill at 16,000 RPM with a feed rate of 178 g/min. Roller-milling proved to be equally unsuccessful. A laboratory mill (Ross) was used at an extremely close setting: Again, only a decrease in particle size resulted. Ball-milling proved to give the desired results. One pound samples were ball-milled with 30 cylindrical porcelain balls. The jars were rotated at 280 RPM. Starch particle size was measured with a Sub-Sieve-Sizer (Fisher Scientific Co.) and is given in Table 3.

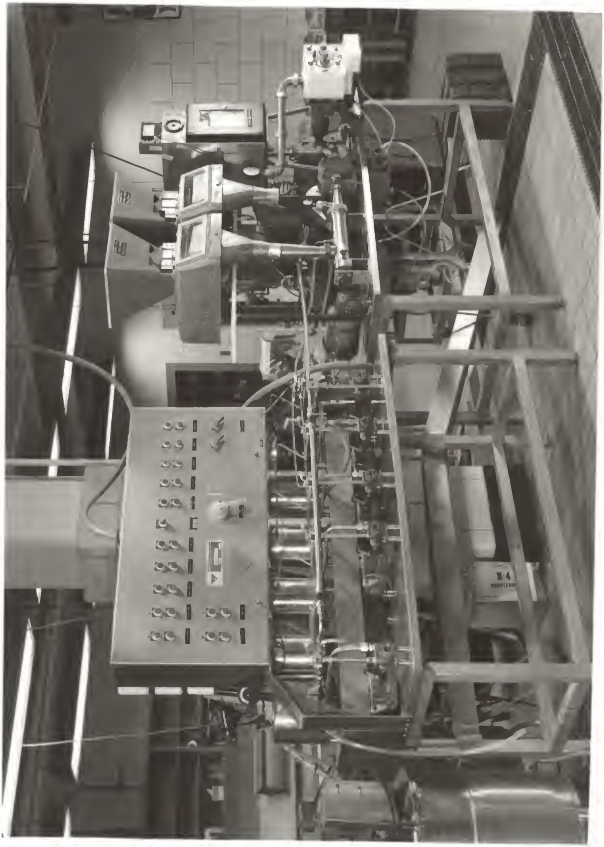

Fig. 1 AMF Unit

TABLE I. WHITE BREAD FORMULA

INGREDIENTS	% ****	PHASE I*	PHASE II**	MIXING PHASE
FLOUR BLEND	100	–	–	100
WATER	VARIABLE	50	10	–
SUGAR	6	2	4	–
YEAST	3	3	–	–
MALT FLOUR	0.5	0.5	–	–
YEAST FOOD ***	0.5	0.5	–	–
SALT	2	–	2	–
MILK	1	–	1	–
LIQUID SHORTENING	3	–	–	3
OXIDATION	65 PPM	–	65 PPM	–

* INITIAL INGREDIENTS OF THE BREW

** INGREDIENTS ADDED TO BREW 1½ HOURS AFTER START OF FERMENTATION

*** ARKADY

**** ALL INGREDIENTS BASED ON FLOUR 100 %

BREW TIME: 1½ HOURS AT 86°F

1 HOUR WITH COOLING SYSTEM CONNECTED

BREW TEMPERATURE AFTER FERMENTATION = 68–70°F

BREW pH = 5.2 ± 0.1

Table 2a. Bread Scoring System

Crust Color	Symmetry	Break	Crumb Color	Grain	Texture	Volume*	
1	1	1	1	9	9		Poor-
3	3	3	3	10	10		Poor
5	5	5	5	11	11		Fair-
6	6	6	6	12	12		Fair
7	7	7	7	13	13		Good-
8	8	8	8	15	15		Good
9	9	9	9	17	17		Very good-
9	9	9	9	18	18		Very good
10	10	10	10	19	19		Excellent-
10	10	10	10	20	20		Excellent

Maximum score possible with this system is 100 points

* For specific volume loaf score conversion see Table 2b

Table 2b. Specific volume loaf score conversion.

Specific volume cc/gm	Loaf score
6.00 or greater	20
5.9	19
5.8	18
5.7	17
5.6	16
5.5	15
5.4	14
5.3	13
5.2	12
5.1	11
5.0	10
4.9	9
4.8	8
4.7	7
4.6	6
4.5	5
4.4	4

Table 3. Particle Size of Study Samples.

Sample	Days ballmilled	Particle size (Microus)
Control starch	0	15.3
Sample No. 1	1	11.0
Sample No. 2	2	11.0
Sample No. 3	3	10.9
Sample No. 4	5	10.8

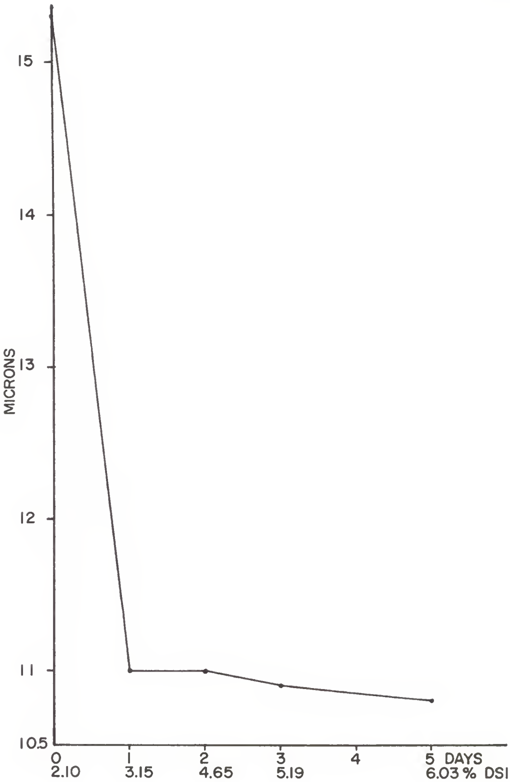

Fig. 2. The Effect of Ball-Milling on Particle Size

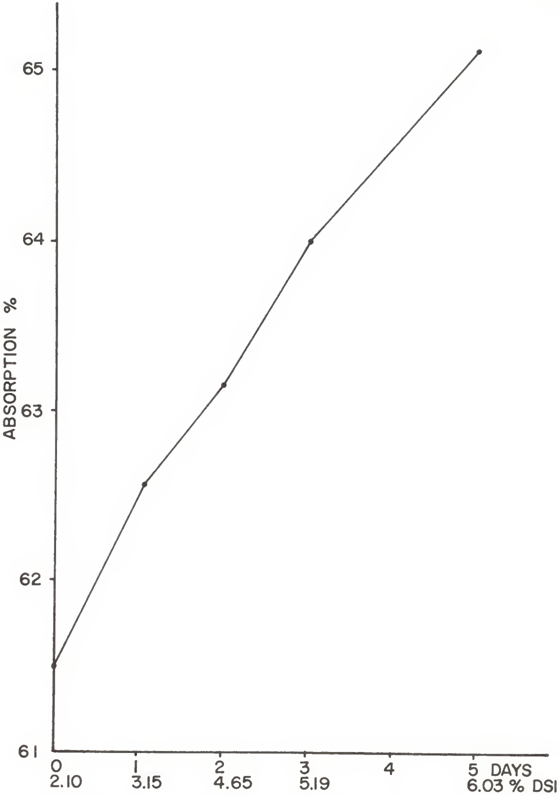

Fig. 3. The Effect of Damaged Starch on Absorption

Starch particle size decreased considerably with 1 day of ball-milling, but showed very little further decrease as the starch was ball-milled up to 5 days. The effect of time of ball-milling on particle size is illustrated in Figure 2.

The ball-milled starch was blended with the flour as described previously and starch damage was estimated by the method of Sullivan (21). The results are summarized in Table 4. The damaged starch index increased with extended time of ball-milling. Water absorption increased by approximately 0.8% for each day of ball-milling. (Fig. 3) Water absorption increased almost directly with length of ball-milling of starch.

The bread scoring system used for this investigation is given in Table 2a. Specific bread volume was determined one hour after baking. Bread scoring was done the day after baking.

Farinograph Studies

While increasing starch damage enables the flour absorption to be increased at constant consistency measured at 30°C, it does not increase the inherent starch absorption at 40° and 50°C. To simulate conditions in the developer of the continuous mixer, the proofbox and the early stages of baking with temperatures of approximately 40°C and 50°C respectively, farinograph studies were conducted at these temperatures with each of the five flour starch blends. (Fig. 4-8) The flour blends and the water were adjusted to the temperature at which the farinograms were recorded. The absorption, determined at 30°C, was first kept constant as the farinograph temperature was raised to 40°C and 50°C respectively. Two more farinograms were recorded at 40°C and 50°C with the absorption adjusted to the 500 Brabender unit line. At 30°C the peak times, the departure times, and the dough mobilities are essentially

TABLE 4. DAMAGED STARCH INDEX (D.S.I.) OF STARCH SAMPLES

SAMPLE	MALTOSE mg/10g	D.S.I. %	FARINOGRAPH ABSORPTION %
FLOUR + 10% WHEAT STARCH (UNTREATED)	210	2.10	61.5
FLOUR + 10% WHEAT STARCH BALL MILLED 1 DAY	315	3.15	62.3
FLOUR + 10% WHEAT STARCH BALL MILLED 2 DAYS	465	4.65	63.1
FLOUR + 10% WHEAT STARCH BALL MILLED 3 DAYS	519	5.19	64.0
FLOUR + 10% WHEAT STARCH BALL MILLED 5 DAYS	609	6.09	65.2

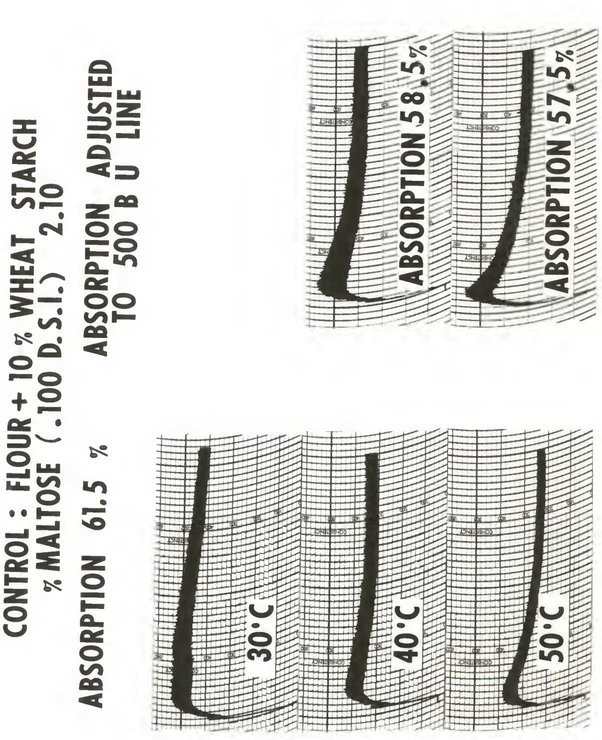
CONTROL : FLOUR + 10 % WHEAT STARCH
% MALTOSE (.100 D.S.I.) 2.10
ABSORPTION 61.5 %
ABSORPTION ADJUSTED
TO 500 B U LINE
30°C
40°C
50°C
ABSORPTION 58.5%
ABSORPTION 57.5%

Fig. 4

FLOUR + 10 % WHEAT STARCH (BALL MILLED 1 DAY)
% MALTOSE (.100 D.S.I.) 3.15

ABSORPTION 62.3 %

ABSORPTION ADJUSTED TO 500 B U LINE

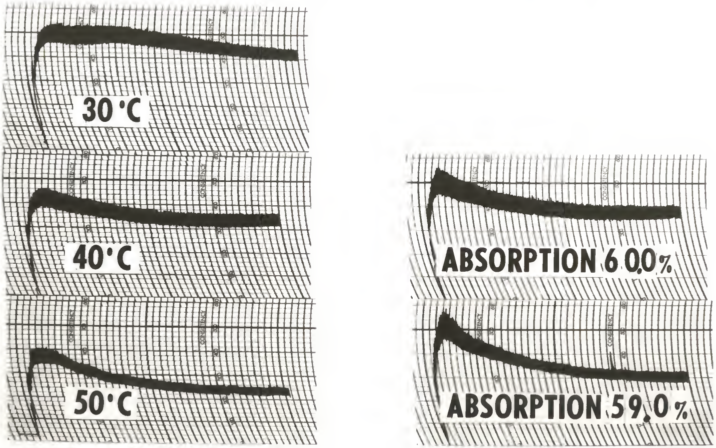

Fig. 5

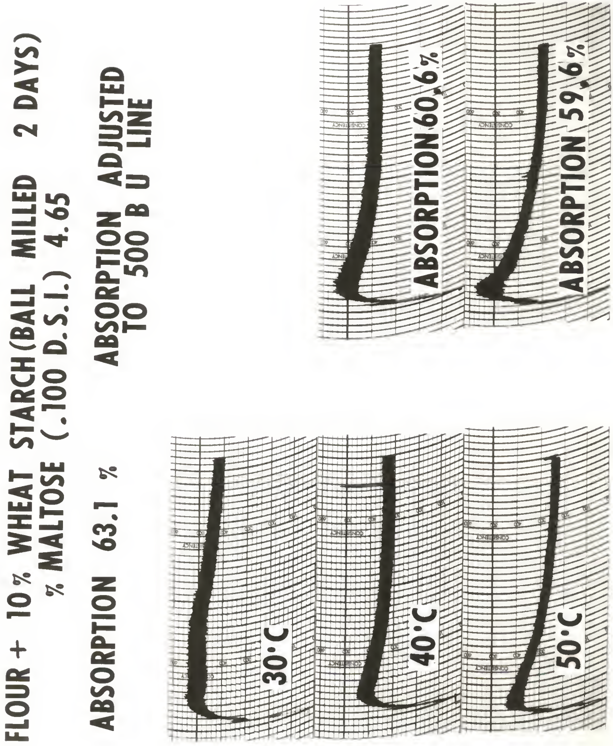
FLOUR + 10% WHEAT STARCH(BALL MILLED 2 DAYS)
% MALTOSE (.100 D.S.I.) 4.65
ABSORPTION 63.1 %
ABSORPTION ADJUSTED TO 500 B U LINE
ABSORPTION 60.6%
ABSORPTION 59.6%
30°C
40°C
50°C

Fig. 6

FLOUR + 10% WHEAT STARCH (BALL MILLED 3 DAYS)
% MALTOSE (.100 D. S. I.)5.19

ABSORPTION 64.0 %

ABSORPTION ADJUSTED
TO 500 B U LINE

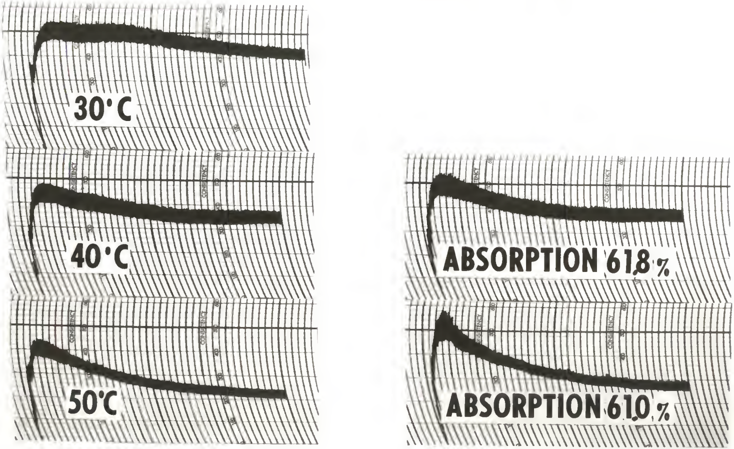

Fig. 7

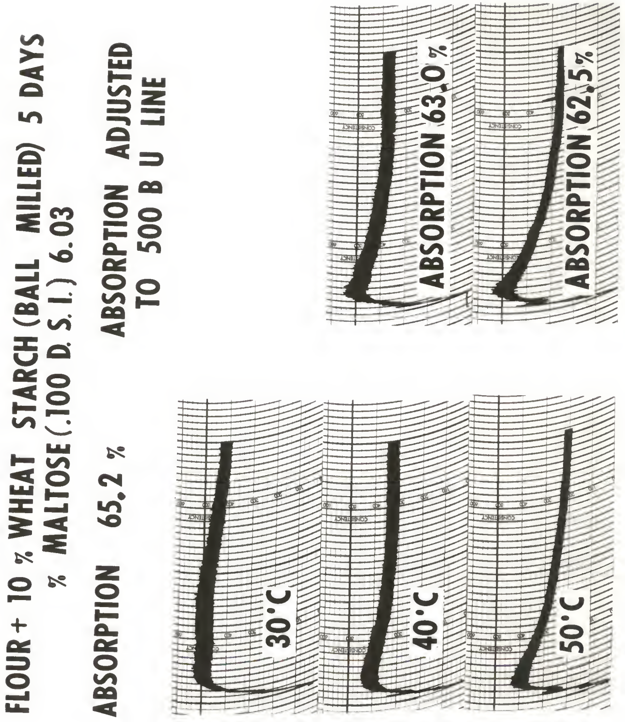
FLOUR + 10 % WHEAT STARCH (BALL MILLED) 5 DAYS
% MALTOSE (.100 D. S. I.) 6.03
ABSORPTION 65.2 %
ABSORPTION ADJUSTED
TO 500 B U LINE
30°C
40°C
50°C
ABSORPTION 63.0 %
ABSORPTION 62.5 %

Fig. 8

the same for the five flour-starch blends which confirms Farrand's (15) results. (Table 5) However, recording at 40°C and 50°C, a gradual decrease in the peak time is observed as the amount of starch damage increased. Departure times also were shorter as starch damage increased resulting in decreased dough stability. The widths of the farinogram bands also become narrower when measured at 20 min. of recording time indicating decreased dough elasticity as the temperature was increased from 30°C to 50°C. This was observed for each of the blends tested. The width of the farinograph band was not affected by starch damage.

Hlynka (24) reported a relationship between temperature and dough mobility in the farinograph and also between temperature and absorption. These relationships were found to be approximately linear. He reported a change in mobility of 12 B.U. at consistency of 500 and 0.52% in absorption per 1°C. The mobility changes as reported by Hlynka could be confirmed with the starch damaged samples, but not the absorption changes. Considering only the control sample with a D.S.I. of 2.10% and the sample with the highest starch damage (D.S.I. = 6.03%) a difference in mobility of 200 BU and 210 BU respectively was observed as the temperature was increased from 30° to 50°C, indicating a mobility change of 10 BU or 10.5 BU respectively per 1°C.

To adjust the absorption to the 500 BU line for the same two samples mentioned above, the absorption had to be changed by 0.2% and 0.15% per 1°C as the temperature was increased from 30°C to 50°C. The dough consistency varied inversely with the temperature. The higher the temperature at which the dough was mixed in the farinograph, the less its absorption at constant consistency, or the softer it becomes at constant absorption.

TABLE 5. FARINOGRAPH DATA OF FLOUR BLENDS

SAMPLE	FARINOGRAPH TEMP.	TIME TO PEAK			DEPARTURE TIME			DOUGH STABILITY		
		30°C MIN	40°C MIN	50°C MIN	30°C MIN	40°C MIN	50°C MIN	30°C MIN	40°C MIN	50°C MIN
1) FLOUR	10% WHEAT STARCH	8.5	7.5	3.0	12.0	11.0	5.0	10.5	9.5	4.0
FLOUR	10% STARCH (BALLMILLED 1 DAY)	8.5	7.0	3.0	11.0	10.0	5.0	10.0	9.0	4.0
FLOUR	10% STARCH (BALLMILLED 2 DAYS)	8.5	5.0	3.0	12.0	7.0	4.0	9.5	6.0	3.0
FLOUR	10% STARCH (BALLMILLED 3 DAYS)	8.5	5.0	2.5	11.0	7.0	3.5	10.5	6.0	2.5
FLOUR	10% STARCH (BALLMILLED 5 DAYS)	7.5	4.0	2.0	11.0	6.0	2.0	9.5	5.0	1.0

To determine the effects of fermentation on physical dough properties when starch damaged samples are used, 300 g flour doughs were mixed at 1st speed for 2 min. in a Hobart N-50 mixer. The doughs were fermented at 30°, 40°, and 50°C for one hour after which they were placed in the farinograph. The results are given in Fig. 9-11.

Farinograph curves recorded after dough fermentation are vastly different than normal farinograph curves. The curves reach a peak instantly and loose their consistency immediately. Fermentation at 30°C resulted in a second peak which became more pronounced as starch damage increased. This second peak was not observed with fermentation at 40°C and 50°C. Generally, at each temperature of fermentation the curves indicated a softer consistency and slightly decreased elasticity after 20 min. of mixing with increasing levels of starch damage.

Farinograph studies suggest that the physical dough properties of doughs from a continuous mixer will be different than those from a conventional mixer.

Amylograph Studies

Amylograph curves changed only slightly with increased starch damage (fig. 12). This might have been expected since only 10% of the starch was modified prior to cooking of the starch in the amylograph. A peak of 740 BU was observed for the control (D.S.I. = 2.10%) while the sample with the highest level of starch damage (D.S.I. = 6.03%) showed a peak of 680 BU. This difference is significant but not phenomenol.

The amylograph measures only gross changes in the starch gel properties. After gelatinization only small differences in the final viscosity can be expected even though the starch was damaged.

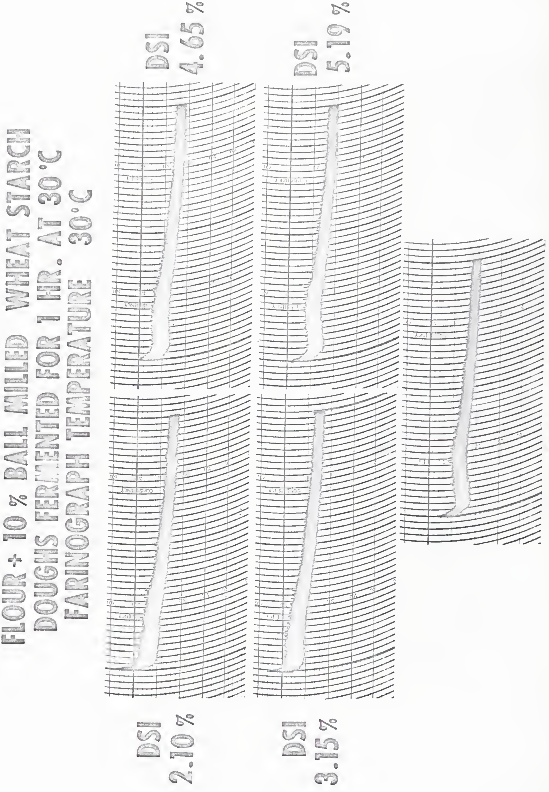
FLOUR + 10 % BALL MILLED WHEAT STARCH
DOUGHS FERMENTED FOR 1 HR. AT 30°C
FARINOGRAPH TEMPERATURE 30°C
DSI 4.65 %
DSI 5.19 %
DSI 2.10 %
DSI 3.15 %
DSI 6.03 %

Fig. 9

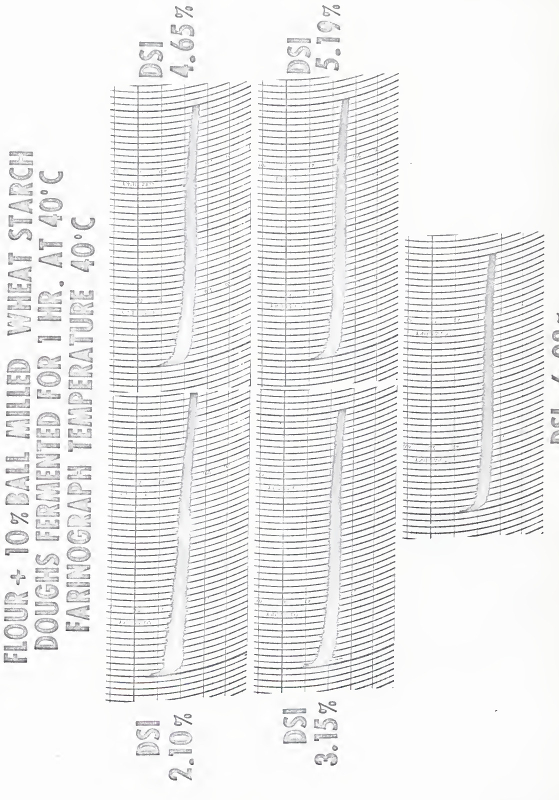
FLOUR + 10% BALL MILLED WHEAT STARCH
DOUGHS FERMENTED FOR 1 HR. AT 40°C
FARINOGRAPH TEMPERATURE 40°C
DSI 4.65%
DSI 5.19%
DSI 2.10%
DSI 3.15%
DSI 6.03%

Fig. 10

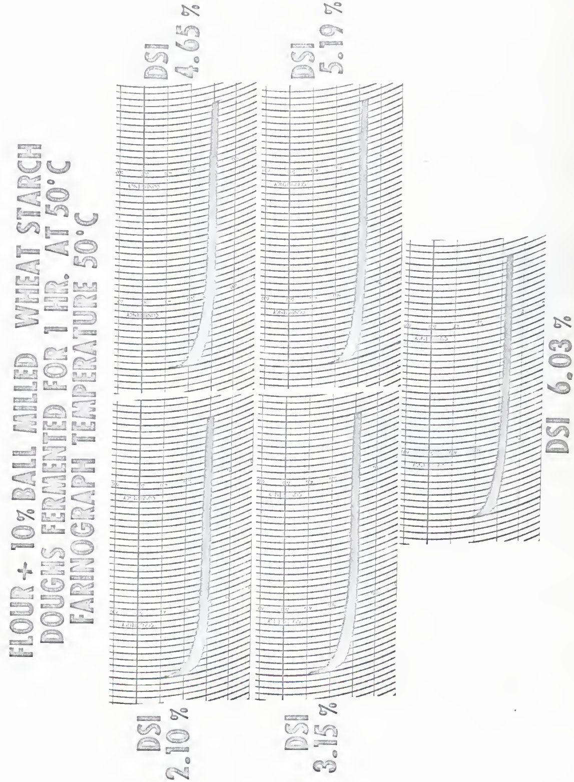
FLOUR + 10% BALL MILLED WHEAT STARCH
DOUGHS FERMENTED FOR 1 HR. AT 50°C
FARINOGRAPH TEMPERATURE 50°C
DSI 4.65 %
DSI 5.19 %
DSI 2.10 %
DSI 3.15 %
DSI 6.03 %

Fig. 11

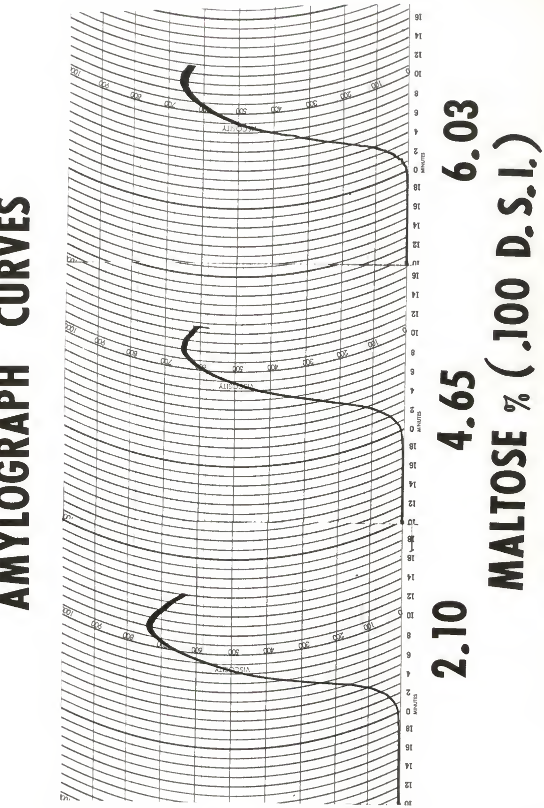

Fig. 12

Baking of Control Formula

To determine baking characteristics of the control flour, absorption level, oxidation requirements and optimum impeller speed, preliminary continuous mix baking tests were conducted. The farinograph absorption for the control flour was 61.5%. Absorption used on the continuous mix unit was 68% to account for the other dry ingredients besides flour in the formulation. The best oxidation ratio was 4 parts of $KBrO_3$ to 1 part of KIO_3. Oxidation requirements were found to be 65 ppm based on total flour. The flour had a good strength and mixing tolerance. The optimum impeller speed was found to be 157 RPM.

Production of Continuous Mix Bread With Starch Damaged Flour Blends

A 5 X 3 X 3 factorial design was selected. This involved 5 levels of starch damage (D.S.I. = 2.10%, 3.15%, 4.65%, 5.19% and 6.03%) 3 absorptions (68% - 70% - 74%) and 3 impeller speeds (143 - 157 - 171 RPM). The results are illustrated in Fig. 13-20. At the lowest level of starch damage (D.S.I. = 2.10%) good quality bread was produced at all 3 levels of absorption, but mixing requirements increased with increasing absorption. Absorptions of 68% and 70% required 143 RPM for optimum bread quality (total scores = 88 and 91 respectively). Increasing the absorption to 74%, 171 RPM produced the best bread (total score = 95). The same trend was noticeable with an increase in starch damage to 4.65%. In each case, good quality bread could be produced provided the impeller speed and absorption were increased. At the starch damage level of 5.19%, only the highest absorption (74%) combined with the lowest impeller speed (143 RPM) produced inferior quality bread. This level of starch damage appears to be critical because just a slight increase in starch damage to 6.03% produced acceptable bread only with an absorption of 68% and 70% with an RPM of 171. Total scores and specific volumes of the breads produced are summarized in Tables 6 and 7. Generally, as starch damage increases, development requirements (RPM) increase and mixing tolerance declines. Total bread scores and specific volumes decrease gradually. The grain of the bread became more open and the texture harsher as the percentage of damaged starch increased. However, at each level of damaged starch acceptable bread could be produced provided the right combination of absorption and developer speed was used. For 2.10%, 3.15%, and 4.65% of D.S.I., the best combination was an absorption of 74% and an impeller speed

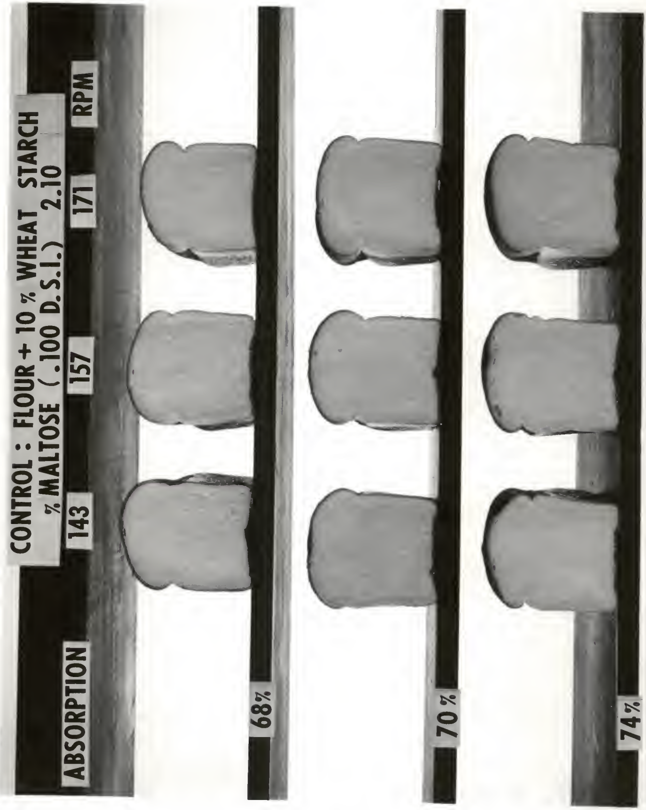
CONTROL : FLOUR + 10 % WHEAT STARCH
% MALTOSE (.100 D. S.I.) 2.10
ABSORPTION
143
157
171
RPM
68%
70 %
74%

Fig. 13

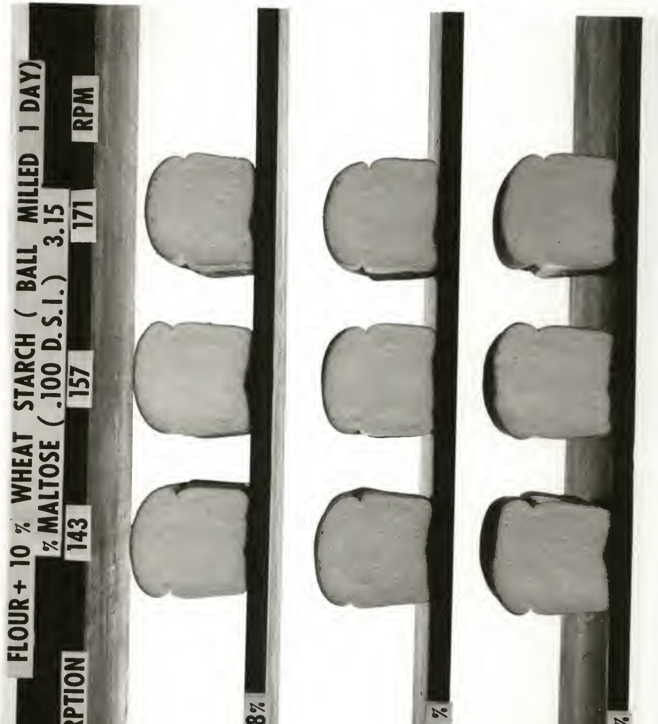
FLOUR + 10 % WHEAT STARCH (BALL MILLED 1 DAY)
% MALTOSE (.100 D.S.I.) 3.15
ABSORPTION
143
157
171
RPM
68%
70%
74%

Fig. 14

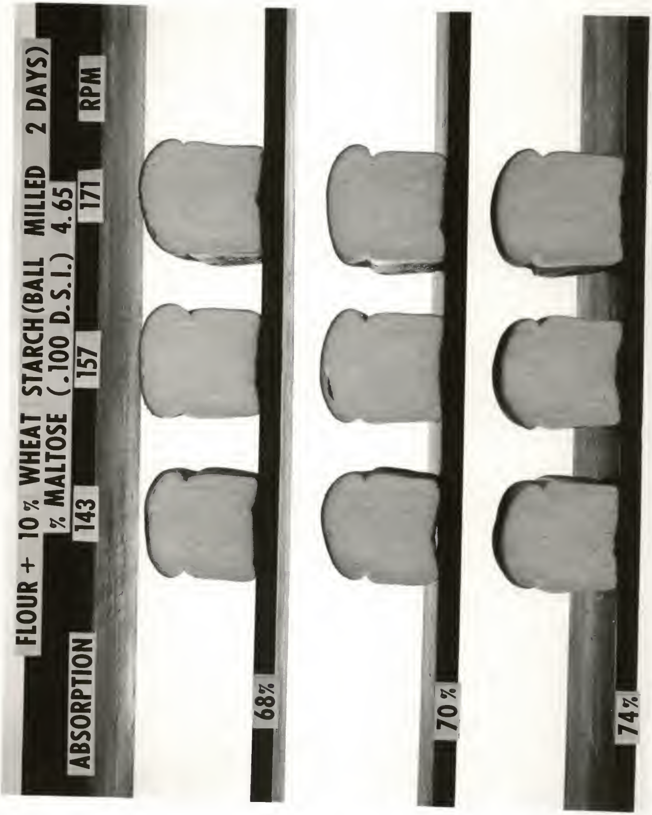
FLOUR + 10% WHEAT STARCH (BALL MILLED 2 DAYS)
% MALTOSE (.100 D.S.I.) 4.65
ABSORPTION
143
157
171
RPM
68%
70%
74%

Fig. 15

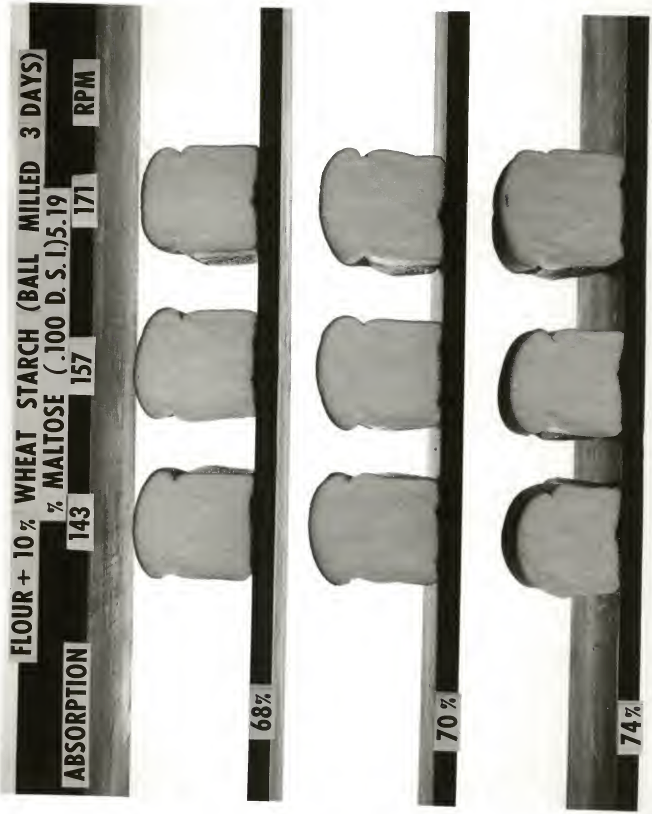
FLOUR + 10% WHEAT STARCH (BALL MILLED 3 DAYS)
% MALTOSE (.100 D. S. I.) 5.19
ABSORPTION
143
157
171
RPM
68%
70%
74%

Fig. 16

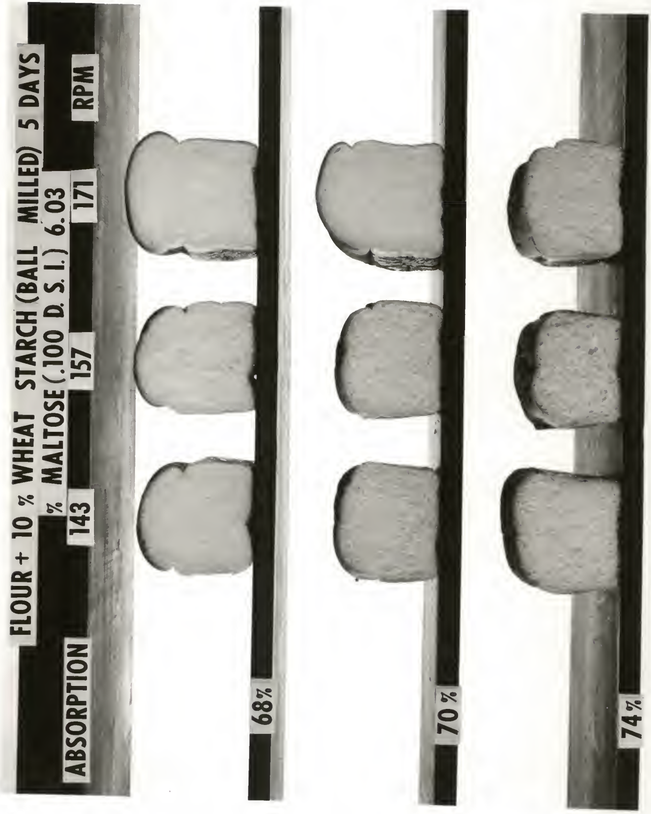
FLOUR + 10 % WHEAT STARCH (BALL MILLED) 5 DAYS
% MALTOSE (.100 D. S. I.) 6.03
ABSORPTION
143
157
171
RPM
68%
70%
74%

Fig. 17

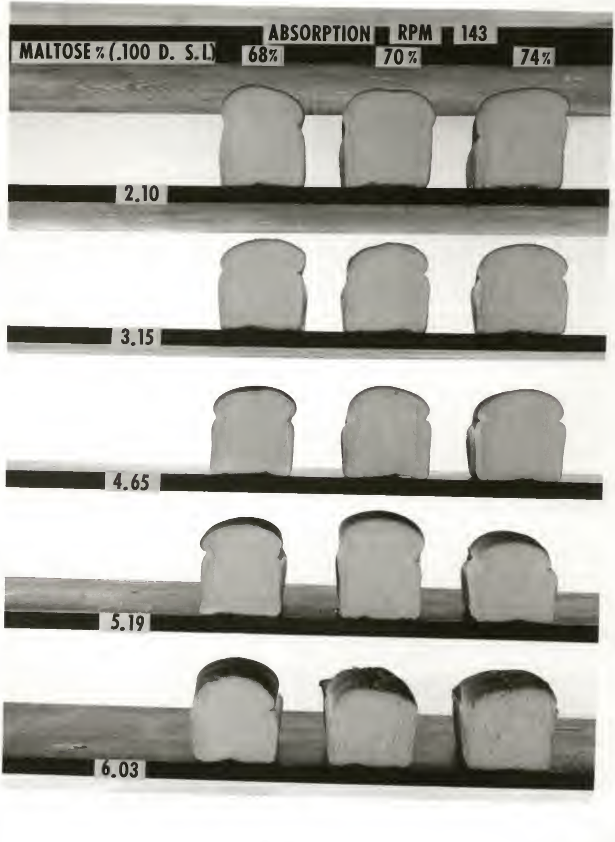
ABSORPTION
RPM
143
MALTOSE % (.100 D. S. L.)
68%
70%
74%
2.10
3.15
4.65
5.19
6.03

Fig. 18

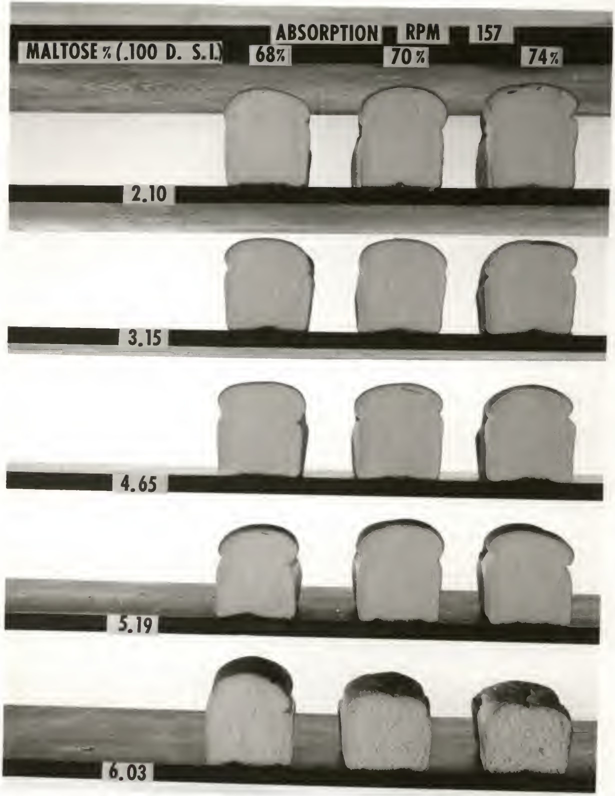
MALTOSE % (.100 D. S.I.)
ABSORPTION RPM 157
68%
70%
74%
2.10
3.15
4.65
5.19
6.03

Fig. 19

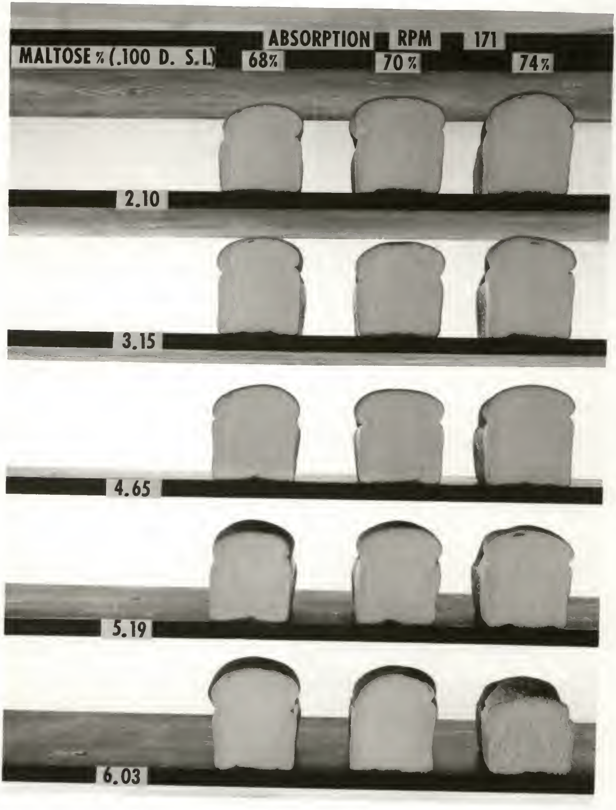
ABSORPTION
RPM
171
MALTOSE % (.100 D. S. L.)
68%
70 %
74%
2.10
3.15
4.65
5.19
6.03

Fig. 20

Table 6. The Effect of Starch Damage, Absorption, RPM on Total Bread Score

		Total Score														
Starch damage		2.10%			3.15%			4.65%			5.19%			6.03%		
Absorption %		68	70	74	68	70	74	68	70	74	68	70	74	68	70	74
	143	88	91	85	78	78	82	77	80	80	84	77	61	76	57	37
RPM	157	85	90	93	78	79	84	79	79	87	86	81	74	84	50	44
	171	75	79	95	79	82	83	78	76	89	80	76	69	87	64	59

Total possible points = 100

Each score based on 4 loaves

Table 7. The Effect of Starch Damage, Absorption and RPM on Specific Bread Volume

		Specific volume cc/g														
Starch damage		2.10%			3.15%			4.65%			5.19%			6.03%		
Absorption %		68	70	74	68	70	74	68	70	74	68	70	74	68	70	74
	143	5.79	5.84	5.92	5.74	5.73	5.89	5.53	5.67	5.71	5.66	5.84	4.89	5.67	4.70	4.44
RPM	157	5.69	5.76	5.90	5.55	5.58	5.75	5.52	5.62	5.92	5.65	5.11	5.06	5.84	4.96	4.58
	171	5.47	5.65	6.07	5.45	5.61	5.75	5.85	5.87	6.10	5.58	5.53	5.67	5.40	5.20	4.59

Specific volume based on 4 loaves

of 171. For a D.S.I. of 5.19% the best combination was 68% absorption and 157 RPM, and for 6.03% D.S.I. this combination was 68% absorption and 171 RPM. The effects of starch damage and absorption on bread volume are illustrated in Fig. 21-23.

With an impeller speed of 143 specific volume increased as absorption increased at a D.S.I. of 2.10%, 3.15% and 4.65%. At a damaged starch level of 5.19% volume increased as absorption was increased to 70% but decreased with a further increase to 74%. A steady volume decrease was observed at the highest level of starch damage (6.03%).

With an impeller speed of 157, bread volume increased steadily as absoprtion increased with starch damage levels of 2.10% - 4.65%. At 5.19% and 6.03% damaged starch, bread volume decreased steadily with increasing absorption. At an RPM of 171 only the highest level of damaged starch (6.03%) exhibited a steady decrease in bread volume with increasing absorption while at other damaged starch levels, bread volume remained essentially constant or increased slightly with higher absorptions.

Dough temperatures at the developer increased about 2-6°F with an increase in impeller speed from 143 to 171. Dough temperatures at 143 RPM averaged 96°F going up to 102°F with an RPM of 171. The doughs were smooth and showed good strength during proofing except for the doughs with the high starch damage (D.S.I. = 6.03%). These doughs were gassy and rather weak during proofing and had to be handled with extreme care in transfer from the proofbox to the oven.

Effect of Different Factors on Baked Products

A statistical analysis was conducted for the data for total loaf score and specific loaf volume. The analysis of variance is given in Tables 8 and 9.

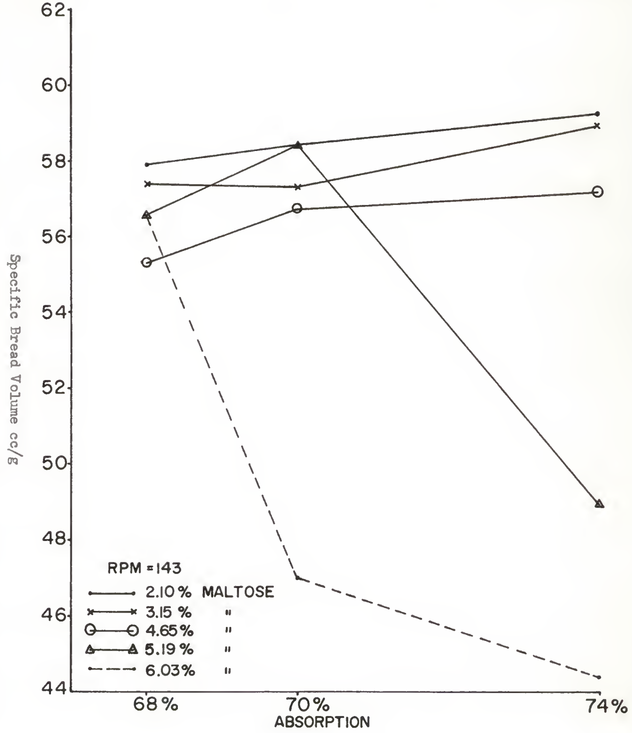

Fig. 21 Effect of Starch Damage and Absorption on Specific Bread Volume

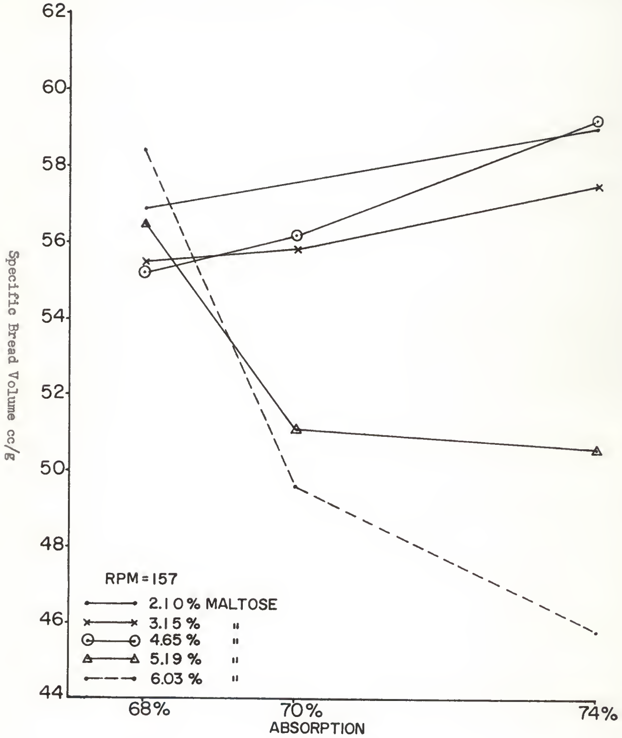

Fig. 22 Effect of Starch Damage and Absorption on Specific Bread Volume

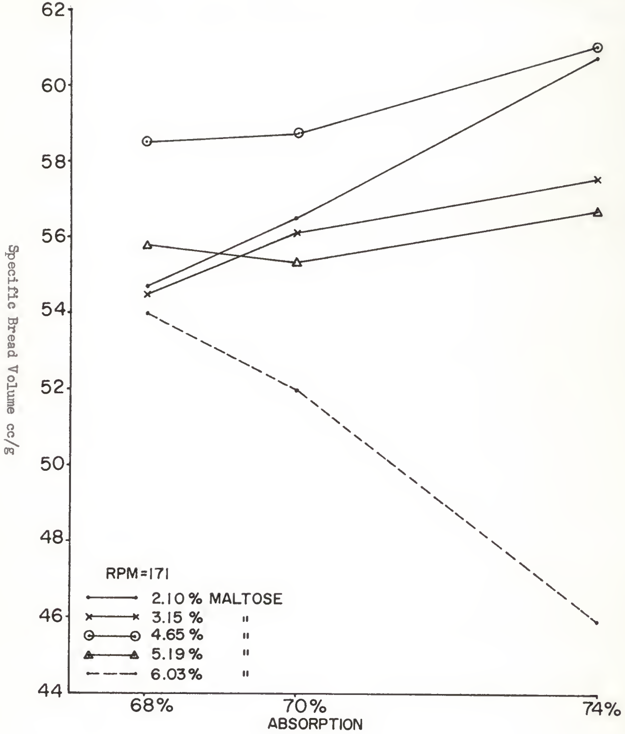

Fig. 23 Effect of Starch Damage and Absorption on Specific Bread Volume

Table 8. Analysis of Variance
(Total Bread Score Data)

Source of variance	Degree of freedom	Mean square	F
Starch damage	4	774.9	73.1 *
Absorption	2	159.8	15.1 *
RPM	2	37.4	3.5 *
Starch damage x absorption	8	288.3	27.2 *
Starch damage x RPM	8	47.2	4.5 *
Absorption x RPM	4	54.0	5.1 *
Error	16	10.6	

Ordered starch damage	Mean
1) D.S.I. = 2.10%	86.8*
2) D.S.I. = 3.15%	80.6
3) D.S.I. = 4.65%	80.3*
4) D.S.I. = 5.19%	76.4*
5) D.S.I. = 6.03%	62.0

in a 3 factor experiment
LSD = 3.3

Ordered absorption	Mean
1) 68%	80.9
2) 70%	75.9*
3) 74%	74.8

LSD = 2.5

Ordered RPM	Mean
1) 143	78.2
2) 157	78.1
3) 171	75.4*

LSD = 2.5

* Difference significant at 5% level

Table 9. Analysis of Variance
(Specific Volume cc/g Data)

Source of variance	Degree of freedom	Mean square	F
Starch damage	4	0.86	29.1 *
Absorption	2	0.09	2.9
RPM	2	0.03	1.0
Starch damage x absorption	8	0.29	9.8 *
Starch damage x RPM	8	0.05	1.7
Absorption x RPM	4	0.07	2.2
Error	16	0.03	

Ordered starch damage	Mean
1) D.S.I. = 2.10%	5.8
2) D.S.I. = 3.15%	5.8
3) D.S.I. = 4.65%	5.7
4) D.S.I. = 5.19%	5.4 *
5) D.S.I. = 6.03%	5.0 *

in a 3 factor experiment
LSD = 0.17

Ordered absorption	Mean
1) 68%	5.6
2) 70%	5.5
3) 74%	5.5

in a 3 factor experiment
LSD = 0.13

Ordered RPM	Mean
1) 143	5.6
2) 157	5.5
3) 171	5.5

in a 3 factor experiment
LSD = 0.13

* Difference significant at 5% level

The effects of damaged starch, RPM, and absorption on total score and on specific volume are given in Tables 10-13. Total scores varied significantly at the lowest level of starch damage (2.10%) as absorption was increased. This is true for all 3 impeller speeds (Table 10). At the intermediate levels of starch damage, significant differences were apparent with an absorption increase from 70% to 74%. At the high levels of D.S.I. (5.19% and 6.03%), every increase in absorption at every impeller speed was found to produce a significant difference in total score indicating that absorption and RPM changes became more critical as the level of damaged starch increased.

Specific volume differences were significant with each increase in absorption at the lowest damaged starch level (2.10%) and an RPM of 143 (Table 11). Increasing the RPM showed a significant effect only at the highest absorption (74%). The intermediate levels of starch damage (3.15% and 4.65%) caused significant volume differences at the highest absorption level (74%). The 6.03% level of damaged starch showed again a significant difference with every increase in absorption at every impeller speed. The effect of impeller speed on total score showed a significance at the lowest absorption and lowest starch damage (Table 10). Only isolated cases of significance were found at D.S.I.'s of 3.15% and 4.65%. At the highest levels of starch damage (5.19% and 6.03%), changes in impeller speed showed a significant difference in nearly every case indicating that impeller speeds became more critical as starch damage increased. The specific volume data (Table 11) confirmed these conclusions.

Table 10. Effect of Damaged Starch, Absorption and RPM on Total Score

Total Score

Starch damage		2.10%			3.15%			4.65%			5.19%			6.03%		
Absorption %		68	70	74	68	70	74	68	70	74	68	70	74	68	70	74
	143	88 *	91 *	85	78 *	78 *	82	77 *	80	80	84 *	77 *	61	76 *	57 *	37
		*		*						*		*	*	*	*	*
RPM	157	85 *	90 *	93	78	79 *	84	79	79 *	87	86 *	81 *	74	84 *	50 *	44
		*				*			*		*	*	*	*	*	*
	171	75 *	79 *	95	79 *	82	83	78	76 *	89	80 *	76 *	69	87 *	64 *	59

Total possible points = 100
Each score based on 4 loaves

LSD = 2.5, 5% level of significance (absorption)

LSD = 2.5, 5% level of significance (RPM)

* = Significantly different from adjacent value

Table 11. Effect of Damaged Starch, Absorption and RPM on Specific Bread Volume.

		Specific volume cc/g														
Starch damage		2.10%			3.15%			4.65%			5.19%			6.03%		
Absorption %		68	70	74	68	70	74	68	70	74	68	70	74	68	70	74
	143	5.79*	5.84*	5.92	5.74	5.73*	5.89	5.53*	5.67	5.71	5.66*	5.84*	4.89	5.67*	4.70*	4.44
					*	*	*			*		*	*	*	*	*
RPM	157	5.69	5.76*	5.90	5.55	5.58*	5.75	5.52	5.62*	5.92	5.65*	5.11	5.06	5.84*	4.96*	4.58
		*						*	*	*		*	*	*	*	
	171	5.47	5.65*	6.07	5.45*	5.61*	5.75	5.85	5.87*	6.10	5.58	5.53*	5.67	5.40*	5.20*	4.59

Special volume based on 4 loaves

LSD = 0.13, 5% level of significance (absorption)

LSD = 0.13, 5% level of significance (RPM)

* = Significantly different from adjacent value

Table 12. Effect of Damaged Starch, Absorption, and RPM on Total Score.

		RPM								
		143			157			171		
Absorption		68	70	74	68	70	74	68	70	74
		%	%	%	%	%	%	%	%	%
	2.10	88 *	91 *	85	85 *	90 *	93	75 *	79 *	95
	3.15	* 78	* 78 *	82	* 78	* 79 *	* 84	* 79 *	82	* 83
DSI	4.65	77 *	80	80	79	79 *	87	78	* 76 *	* 89
	5.19	* 84 *	77 *	* 61	* 86 *	81 *	* 74	80 *	76 *	* 69
	6.03	* 76 *	* 57 *	* 37	84 *	* 50 *	* 44	* 87 *	* 64 *	* 59

Total possible points = 100

Each score based on 4 loaves

LSD = 3.3, 5% level of significance (starch damage)

LSD = 2.5, 5% level of significance (absorption)

* = Significantly different from adjacent value

Table 13. Effect of Damaged Starch, Absorption and RPM on Specific Bread Volume (cc/g).

		RPM								
		143			157			171		
Absorption		68	70	74	68	70	74	68	70	74
					%					
DSI	2.10	5.79	5.84	5.92	5.69	5.76 *	5.90	5.47 *	5.65 *	6.07
	3.15	5.74	5.73 *	5.89	5.55	*5.58 *	5.75	5.45 *	5.61 *	*5.75
	4.65	*5.53 *	5.67	*5.71	5.52	5.62 *	5.92	*5.85	*5.87 *	*6.10
	5.19	5.66 *	5.84 *	*4.89	5.65 *	*5.11	*5.06	*5.58	*5.53 *	*5.67
	6.03	5.67 *	*4.70 *	*4.44	*5.84 *	4.96 *	*4.58	5.40 *	*5.20 *	*4.59

Specific volume based on 4 loaves

LSD = 0.17, 5% level of significance (starch damage)

LSD = 0.13, 5% level of significance (absorption)

* = Significantly different from adjacent value

Summary and Conclusion

It was the purpose of this investigation to study the effects of starch damage on the characteristics of Farinograph and Amylograph curves and on the quality of continuous mix white bread. It was found that starch particle size decreased considerably by ball-milling the starch for 1 day. Further ball-milling up to 5 days caused very little further decrease in particle size. Starch damage, however, increased steadily with duration of ball-milling. Water absorption increased as the percentage of damaged starch increased.

Farinograph curves which were recorded at 30°C, 40°C and 50°C indicated that the consistency of the doughs made with starch damaged flour varied inversely with the temperature. The higher the temperature at which the dough was mixed, the less its absorption at constant consistency, or the softer the dough became.

Amylograph curves changed only slightly due to damaged starch, since only a small percentage of the total starch was actually damaged. For the production of continuous mix bread, an increase in developer speed and a decline in mixing tolerance was observed with increasing amount of damaged starch. Total bread scores and specific loaf volumes decreased, the grain of the bread became more open, and the texture harsher as the percentage of damaged starch increased. Good quality bread, however, could be produced if the proper combination of absorption and impeller speed could be established for each level of starch damage.

Total loaf scores and specific loaf volumes were analyzed statistically. Significant differences were found indicating that absorption and RPM changes became more critical with increasing amounts of damaged starch.

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THE EFFECTS OF FLOUR STARCH DAMAGE ON PHYSICAL DOUGH PROPERTIES OF CONTINUOUS MIX BREAD

by

KLAUS LORENZ

P. H. B. Northwestern University, 1968

An Abstract of

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1969

A flour (12.1% protein) was blended with samples of wheat starch which has been ball-milled for different lengths of time. The final protein content (11.0%) of the blends was constant. Farinograms indicated a direct relationship between Damaged Starch Index (D.S.I.) and flour absorption. Absorption increased as the D.S.I. increased while dough mixing time and dough stability decreased. These effects were most pronounced when the Farinograph was operated at 40°C and 50°C rather than at the normal 30°C. The farinograms also showed a decrease in dough mobility with an increase in D.S.I. Starch damage also affected the characteristics of amylograms. An AMF laboratory model continuous mixer was used to evaluate the flour blends. A 5x3x3 factorial design (5 levels of D.S.I.; 3 absorptions; 3 impeller speeds) was selected for the evaluation. Loaf volume decreased, the grain of the bread became more open and the texture softer but soggy as starch damage increased. Mixing tolerance decreased as the extent of starch damage increased. It was concluded that good quality bread can be produced with levels of damaged starch slightly higher than normal with the proper absorption and impeller speed.