STUDIES ON THE BEHAVIOR OF ACTIVE DRY YEAST IN BREADMAKING[1]

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ABSTRACT

A series of comparative studies was made of active dry yeast (ADY) and compressed yeast which had been suspended, prior to use in doughs, at temperatures from 5° to 50°C. When ADY was rehydrated at 40°C. a minimum (5% of the dry weight) of material was leached from the cells. At this temperature of rehydration, baking performance was optimum and comparable to that of compressed yeast. ADY doughs required a shorter mixing time and higher levels of oxidizing improver than compressed yeast doughs. As the temperature of rehydration of ADY was lowered from 40°C. the amount of material leached from the cell increased to a maximum of 29% of the dry weight of the cells at 5°C. Nitrogenous compounds leached from ADY increased from 3.9 to 11.7 mg. nitrogen per g. yeast and glutathione from 2.2 to 9.9 mg. per g. yeast. No glutathione was found in the compressed yeast supernatants, and nitrogen appeared only in relatively small quantities at all temperatures tested. Two distinct effects resulted as the temperature of rehydration of ADY was lowered. The doughs became progressively more sticky and difficult to handle. Rheological tests showed a marked increase in extensibility and a lessened response to oxidizing agents. Identical results could be obtained by the addition of glutathione to doughs prepared using optimally rehydrated ADY. Gas production by the ADY was progressively decreased as the temperature of rehydration was lowered. This resulted in greatly decreased loaf volumes in the baked bread. This was undoubtedly due to inactivation of the cells as they progressively became more disorganized owing to the loss of cellular constituents. Compressed yeast was quite indifferent to the temperature at which it was suspended, prior to use, at all temperatures up to 40°C. At 50°C. considerably decreased loaf volumes resulted from thermal inactivation of the cells, as was also the case with ADY.

Although active dry yeast (ADY) has been in use by bakers since World War II, there is very little information in the literature concerning its baking properties. Much of the research reported on ADY has concerned its rehydration. Jorgensen (8) observed that significant amounts of glutathione appeared in the supernatant when dried yeast was suspended in water. Peppler and Rudert (10) demonstrated that this was a function of the water temperature and that if the temperature was lowered to 5°C. about one-third of the yeast cells were inactivated and a marked decrease in baking performance re-

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sulted. Herrera *et al.* (5) observed that the suspension of ADY in water at 4.5°C. resulted in the loss of large amounts of yeast solids which included virtually all of the soluble nitrogenous compounds of the cell. Sant and Peterson (11) attempted, without success, to minimize these losses by reconstituting the cells in a concentrated extract of dried yeast. However, if the ADY was first rehumidified to a moisture level of 25% by a process of "vapor rehumidification," the effect of subsequent low-temperature rehydration on nitrogen loss by the cells was eliminated.

Herrera *et al.* (5) postulated that the cell wall of ADY becomes badly disorganized by drying and must be completely rehydrated to resume its function as a semipermeable membrane. The hydration process is probably slow at low temperatures, and a loss of cellular material might be expected before the cell wall begins to function properly.

This paper reports the results of an investigation of some of the properties of ADY in comparison with compressed yeast. Rehydration temperature as it affects the leaching of material from the cells was studied. The subsequent effects of the leached material on dough properties, as well as the loss of this material on the ultimate behavior of the cells, were investigated using baking tests, gassing power studies, and instrumental evaluations of dough rheological properties.

Materials and Methods

Yeast. Active dry yeast (ADY) and fresh compressed yeast manufactured by the Red Star Yeast and Products Co., Milwaukee, were used.[3] The ADY, containing 7.09% nitrogen (dry basis), was vacuum-packed in metal cans which were held at −10°C. prior to use. After a can had been opened the unused yeast was kept at −10°C. in tightly stoppered flasks until needed. Two weeks after a can was opened, any remaining yeast was discarded. The compressed yeast, containing approximately 9.0% nitrogen (dry basis), was obtained commercially and delivered fresh weekly. It was kept under refrigeration and any remaining yeast was discarded at the end of the week.

The active dry yeast (ADY) (5 g. containing 8.42% moisture), or compressed yeast (15 g. containing 69.43% moisture), was suspended in water (100 ml.) at temperatures ranging from 5° to 50°C. for 20 minutes. The suspensions were centrifuged for 15 minutes in an International Centrifuge (size 2) at 3000 r.p.m. and the supernatant liquid decanted and assayed for total solids, ash, nitrogen, and glutathione.

[3] The yeasts were provided by the Red Star Yeast and Products Company as representative of their commercial production.

TABLE I

FORMULAS FOR THE STRAIGHT DOUGH AND SPONGE AND DOUGH BAKING PROCEDURES

INGREDIENTS	STRAIGHT DOUGH	SPONGE AND DOUGH		
		Sponge	Dough	Total
	g	g	g	g
Flour (14% moisture basis)	200.0	130.0	70.0	200.0
Water	as required	as required		
ADY[a]	3.0	1.8	.....	1.8
Compressed yeast[a]	6.0	4.5	.....	4.5
Potassium bromate	0.002	.....	.....	.....
Dough improver[b]				
ADY doughs	.....	1.0		1.0
Compressed yeast doughs		0.75		0.75
Sodium chloride	2.0	.....	4.0	4.0
Sucrose	10.0	.....	8.0	8.0
Nonfat dry milk[c]			8.0	8.0
Shortening[d]			6.0	6.0

[a] Either one or the other yeast was used in individual tests.
[b] A commercial product which contains 0.27% of oxidizing improver (potassium bromate).
[c] A spray-dried product specially prepared for use in baking.
[d] A hydrogenated vegetable shortening containing emulsifying agents.

Flour. A Southwest Bakers' Patent flour (11.3% protein and 0.45% ash, both on a 14% moisture basis) was used in all of the baking, gassing power, and farinograph studies. A Southwest Bakers' Patent flour (10.5% protein and 0.4% ash on a 14% moisture basis) was used for the extensigraph studies.

Total Solids. The AOAC method for determining total solids of milk (2) was employed in estimating the amount of solids leached from the yeasts at various temperatures. This involved pipetting a suitable aliquot of the centrifuged supernatants into tared aluminum moisture dishes, and heating for 3 hours in a forced-draft air oven at 100°C. Results are expressed as mg. total solids per g. yeast (dry weight basis).

Ash. The dried yeast extracts were analyzed for ash by the magnesium acetate method described in *Cereal Laboratory Methods* (1).

Glutathione. The method of Woodward and Frey (12) was used for the determination of glutathione in extracts of ADY and compressed yeast. This titrimetric method involves the oxidation of sulfhydryl groups with potassium iodate using a starch indicator.

Nitrogen. The Kjeldahl procedure (1) was used to determine nitrogen in yeast extracts.

Baking Tests. The formulas for the straight dough and sponge and dough procedures are shown in Table I.

For the straight doughs the ingredients were mixed for 3.5 minutes (unless otherwise indicated) in a Swanson mixer equipped with a McDuffee bowl. Absorption was 66% on a 14% moisture basis. The dough (scaled to 150 g.) was fermented at 30°C. for 95 minutes, punched by passing through the National Dough Sheeter (rolls set at 9/32 in.), rounded, and fermented for an additional 25 minutes. The dough was then passed twice through the sheeting rolls with settings at 9/32 and 5/32 in. respectively. It was then molded on wooden molding rolls, proofed for 55 minutes at 30°C. and baked in a rotary hearth oven for 25 minutes at 227°C. Loaf volumes were measured 1 hour after baking by rapeseed displacement, and the bread was scored the following day.

For the sponge and dough procedure the sponges were mixed at 26°C. in a Swanson mixer with a McDuffee bowl, and fermented for 4 hours at 30°C. The sponges were then returned to the mixer, the remaining ingredients added and mixed from 1.5 to 5.0 minutes using an absorption of 63% (flour basis at 14% moisture). The doughs were fermented 20 minutes at 30°C., punched with the dough sheeter as for the straight doughs, and refermented for 15 minutes at 30°C. The doughs were molded as described for the straight doughs, pan-proofed to a height of 2.4 cm. above the bread pan, and were baked, measured, and scored as described for straight doughs.

Farinograph Studies. Three-hundred grams of flour (14% moisture basis), adjuncts as described later, and distilled water were mixed in the farinograph for 20 minutes at 30°C. Sufficient water was used to center the curve on the 500 Brabender unit (B.u.) line at maximum dough development. Two measurements were made of the farinograms; namely, dough development time, the time in minutes from the start of mixing required to reach a maximum consistency of 500 B.u., and the "drop-off" value, a measurement related to the Tolerance Value, the difference in Brabender units from the 500 B.u. line to the center of the curve 20 minutes after the addition of water.

Gas Production. Gas production curves were made at 30°C. for 6 hours on doughs (150-g.) prepared by the sponge and dough and straight dough procedures, already described, using the Chopin Zymotachygraphe (9). The results are means of duplicate determinations corrected to S.T.P.

Extensigraph Studies. The structural relaxation method described by Hlynka (6) was used to study the effects of various adjuncts including extracts of ADY rehydrated at various temperatures, on the physical properties of the doughs.

Doughs were made with 200 g. flour (14% moisture basis), 1% sodium chloride (flour basis), 55% total absorption (flour basis), and with additives in solution as indicated. The dough additives consisted of yeast extracts prepared at various temperatures as already described, potassium bromate, and glutathione (GSH).

Prior to mixing, the flour was flushed with nitrogen and kept overnight under nitrogen to remove adsorbed oxygen. The doughs were then mixed for 3 minutes under an atmosphere of nitrogen in a specially constructed mixer adapted from a design developed at the Grain Research Laboratory (7), and brought from the mixer at a temperature of 30°C.

After mixing, the doughs were divided into two 150-g. pieces and placed in a humidified (85% relative humidity) fermentation cabinet at 30°C. for periods ranging from 5 minutes to 4 hours (reaction time). They were then shaped on the extensigraph, clamped into cylinders, and returned to the fermentation cabinet for periods ranging from 5 minutes to 3 hours (rest period). Following the rest period, the dough pieces were stretched on the extensigraph and a curve obtained.

Results

Leaching Studies. The effects of suspending ADY and compressed yeast in water at various temperatures on the loss of various constituents from the cells are recorded in Table II. The temperature of rehydration markedly influenced the loss of cell material from ADY, whereas compressed yeast was relatively insensitive to the temperature of the suspension.

The amount of nitrogen leached from ADY increased threefold as the rehydration temperature was lowered from 40° to 5°C., while the total solids lost increased almost sixfold over the same temperature range. A possible explanation for this is that at 40°C. the yeast

TABLE II

EFFECT OF TEMPERATURE OF PREPARATION ON LOSS OF MATERIAL FROM COMPRESSED AND ACTIVE DRY YEAST

Temperature of Rehydration [a]	Material Leached from Cells							
	Solids [b]		Ash [b]		Nitrogen [b, c]		Glutathione [b]	
	ADY	Comp.	ADY	Comp.	ADY	Comp.	ADY	Comp.
°C.								
5	288	8.7	29.5	2.2	11.7	0.7	9.9	0.0
10	258	8.9	26.2	1.4	10.4	0.6	8.0	0.0
20	144	8.3	13.8	1.8	7.5	0.9	5.7	0.0
30	56	10.1	4.2	2.4	4.3	0.7	2.2	0.0
40	51	14.2	3.9	2.7	3.9	0.6	2.2	0.0
50	79	21.9	6.2	6.1	6.2	1.2	3.4	0.0

[a] The cells were in contact with water for 20 minutes prior to centrifugation. Longer extraction was without effect.
[b] All values are mg. per g. yeast (dry basis).
[c] Nitrogen content of intact cells (dry wt. basis). ADY 71 mg. per g., compressed yeast 64.5 mg. per g.

TABLE III

EFFECT OF MIXING TIME ON LOAF VOLUMES[a] OF BREAD MADE FROM STRAIGHT DOUGHS CONTAINING ACTIVE DRY YEAST OR COMPRESSED YEAST

MIXING TIME	LOAF VOLUME[b]	
	Doughs Made with 3% Compressed Yeast[c,d]	Doughs Made with 1.5% ADY[c,d]
minutes	*cc*	*cc*
1.5	604	647
2.0	635	671
2.5	681	701
3.0	717	726
3.5	752	736
4.0	772	712
4.5	762	718
5.0	768	733

[a] Results are means for duplicate doughs of two loaves each.
[b] Least significant difference, 25 cc.
[c] Flour basis.
[d] ADY was rehydrated by suspension in water for 20 minutes at 40°C. Compressed yeast was prepared at 30°C.

cells selectively retain some non-nitrogenous compound such as trehalose, a selectivity which is lost as the rehydration temperature is lowered. Glutathione and ash remained a rather constant percentage of the total material leached over the temperature range studied. Glutathione was not present in measurable amounts in the supernatants of the compressed yeast suspensions.

Baking Studies. Straight dough procedure: Preliminary baking studies indicated that a level of ADY of 1.25 to 1.50% (flour basis) produced a loaf of bread comparable to that made with 3% compressed yeast when a rehydration temperature of 40°C. was used. The doughs made with ADY developed more rapidly than those made with compressed yeast, particularly at the higher levels of ADY. In general, the optimum doughs made with ADY were smoother and more extensible than the doughs made with compressed yeast and produced loaves with a more even break and shred. The loaves with compressed yeast, however, scored higher in crumb grain and texture.

The loaf volumes for different mixing times in Table III show that doughs made with ADY require a shorter mixing time to give optimal loaves than doughs made with compressed yeast. All the doughs, but particularly those made with ADY, became more pliable and extensible as mixing time was increased. However, while the ADY doughs produced a loaf of maximum volume with 3.5 minutes of mixing and began to appear overmixed after that time, the compressed yeast doughs produced bread of a significantly greater volume

TABLE IV

INFLUENCE OF TEMPERATURE OF SUSPENSION AND OF GLUTATHIONE UPON LOAF VOLUMES OF BREAD[a] MADE FROM DOUGHS USING YEAST CELLS AND THE SUPERNATANT OF ACTIVE DRY YEAST SUSPENSION[b]

SUSPENSION TEMPERATURE	(STRAIGHT DOUGH PROCESS) LOAF VOLUMES[c,d]					
	A	B	C	D	E	F
°C.	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*
5	484	505	715	742	631	705
10	573	653	726	746	675	728
20	684	728	752	747	682	721
30	728	729	759	752	724	746
40	741	743	762	751	724	746
50	711	723	755	713	703	732

[a] The results are means of duplicate bakes of two loaves each.
[b] 1.5% and 3.0% ADY and compressed yeast (flour basis) respectively.
[c] Required for significant difference (5% level), 25 cc.
[d] Doughs made with:
A, entire ADY suspension;
B, ADY cells only; rehydration liquid removed;
C, 3% compressed yeast to which were added supernatants from B;
D, entire compressed yeast suspension;
E, ADY rehydrated at 40°C., to which had been added glutathione to bring the level to that of series A;
F, compressed yeast rehydrated at 40°C., to which had been added glutathione to bring the level up to that of series A.

upon longer mixing and appeared to be much more tolerant to overmixing.

The effect of low-temperature rehydration of ADY upon baking behavior was quite marked (Table IV, series A). At rehydration temperatures below 30°C. a highly significant decrease in loaf volume occurred; in addition, these doughs were extremely sticky and difficult to handle. In contrast, the loaf volumes with compressed yeast (series D) were not influenced by the temperature of suspension below 50°C.; at this temperature, however, there was a significant decrease in loaf volume, owing, probably, to thermal killing of the cells.

Removal of the ADY cells from the rehydration liquid and their incorporation into doughs (series B) resulted in the disappearance of the stickiness and a significant increase in loaf volume of the bread baked from ADY suspended at 10° and 20°C. The addition of the suspension liquids obtained from this series to doughs made with compressed yeast (series C) produced a significant decrease in loaf volume only when the supernatant was prepared at 5°C. The stickiness of doughs, observed with ADY rehydrated at 5°, 10°, and 20°C. in series A but which was absent in series B, was again in evidence in series C.

That at least part of the loaf volume depressant effect of low-temperature rehydration was due to glutathione (GSH) present in the supernatant is shown by series E and F. These were breads baked with optimally prepared ADY and compressed yeast, respectively, to which GSH had been added in amounts found in ADY supernatants rehydrated at the indicated temperatures. At temperature equivalents below 30°C., ADY doughs produced loaves whose volumes were significantly depressed. In addition, the doughs were very sticky and difficult to handle. Compressed yeast doughs were much less sensitive to the presence of GSH and it was only at a temperature equivalent of 5°C. that a significant decrease in volume was obtained. As with ADY, however, very sticky doughs were obtained when GSH was present with compressed yeast at temperature equivalents below 30°C.

The loaf volume response of straight doughs baked with ADY or compressed yeast to various levels of potassium bromate and potassium iodate was studied. In both cases (Fig. 1) a higher level of the oxidizing improver was required to obtain the maximum response in bread baked with ADY. With compressed yeast, for example, the maximum loaf volume was obtained using 10 p.p.m. potassium bromate, after which the volumes began to decrease; whereas with ADY the maximum loaf volume was obtained with 30 p.p.m. potassium bromate. There was no significant difference in loaf volumes of bread made with ADY and compressed yeast when optimal bromate levels were used with each yeast.

Similarly, with potassium iodate more of the oxidizing agent was required to produce optimum loaf volume when ADY was employed as the leavening agent; the level of iodate which produced the opti-

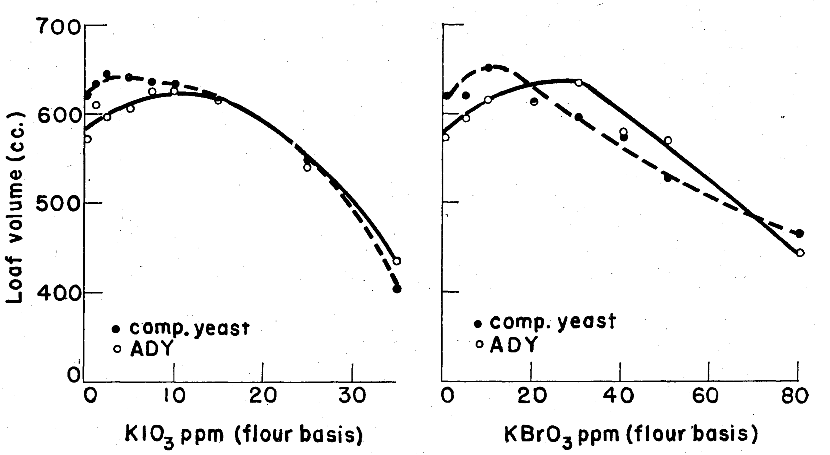

Fig. 1. Effect of potassium bromate and potassium iodate on the loaf volume of bread prepared using compressed yeast and active dry yeast (ADY) by the straight dough procedure. The ADY was rehydrated at 40°C. for 20 minutes.

mum loaf of bread with ADY produced overoxidized doughs when used with compressed yeast.

These results cannot be entirely explained on the basis of glutathione leached from ADY, even when rehydration is carried out at optimum temperatures. To produce optimum loaf volume with ADY an additional 7×10^{-4} meq. potassium bromate per g. flour were required. However, calculations based on the data of Table II show that only about 1×10^{-4} meq. of glutathione per g. flour would appear as a result of the rehydration of the ADY. Again there was no significant difference between the maximum loaf volumes obtained with the two types of yeast.

Sponge and Dough Procedure. The results of baking tests carried out by the sponge and dough method in which dough mixing time was varied are summarized in Table V.

The doughs containing compressed yeast gave bread of somewhat larger volume, and required slightly less time to pan-proof to the same height as the doughs made with ADY.

The doughs employing ADY "picked up" on the mixing hooks after about 2 minutes of mixing time, while those made with compressed yeast required approximately 0.5 minute longer mixing time to reach this stage of dough formation. The doughs made with ADY appeared to be smoother in appearance than those made with compressed yeast. All the bread was of good quality. Better bread was produced over a wider range of mixing time using the sponge and dough method than was obtained by the straight dough procedure.

TABLE V

EFFECT OF VARIATION IN MIXING TIME ON BREAD[a,b] MADE WITH ACTIVE DRY YEAST AND COMPRESSED YEAST USING THE SPONGE AND DOUGH PROCESS

Dough Mixing Time	Loaves Made with ADY		Loaves Made with Compressed Yeast	
	Proof[c] Time	Loaf Volume[d]	Proof Time[c]	Loaf Volume[d]
minutes	*minutes*	*cc*	*minutes*	*cc*
1.5	95	795	92	803
2.0	87	828	81	830
2.5	86	855	82	893
3.0	92	850	82	880
3.5	89	838	83	885
4.0	91	858	78	873
4.5	102	895	82	883
5.0	97	863	77	860

[a] Results with single doughs consisting of two loaves.
[b] Respectively, 0.9% ADY (rehydrated at 40°C.) and 2.25% compressed yeast (suspended at 30°C.), flour basis.
[c] Dough proofed to a constant height of 2.4 cm. above pan.
[d] Least significant difference 25 cc.

TABLE VI
INFLUENCE OF TEMPERATURE OF PREPARATION ON GAS PRODUCTION BY ADY AND COMPRESSED YEAST IN STRAIGHT DOUGHS[a]

YEAST SUSPENSION TEMPERATURE	GAS PRODUCTION FOR 6 HOURS AT 30°C.[b]					
	A	B	C[c]	D	E	F
°C.	cc	cc	cc	cc	cc	cc
5	1,300	1,225	1,985	1,920	1,870	2,040
10	1,455	1,395	1,910	1,930	1,845	2,020
20	1,845	1,805	1,935	1,905	1,930	1,930
30	1,975	1,915	1,925	1,970	1,970	1,945
40	1,985	1,915	1,950	1,920	1,895	1,920
50	1,860	1,840	1,965	1,615	1,620	1,930

[a] 1.5% ADY or 3.0% compressed yeast (flour basis).
[b] Means of duplicate determinations. Least significant difference, 32 cc.
[c] Doughs made with:
A, entire ADY suspension;
B, ADY cells only.
C, ADY rehydrated at 40°C., and with the supernatants from group E.
D, entire compressed yeast suspension.
E, compressed yeast cells only.
F, compressed yeast suspended at 25–30°C., and with supernatants from group B.

Gas Production Studies. The results of gas production studies of straight doughs, summarized in Table VI, help to explain the poor loaf volumes obtained when ADY was rehydrated at temperatures below 30° and above 40°C. Marked decreases in gas production occurred when temperatures above or below this optimum range were used in rehydrating the ADY (series A). When the variously rehydrated ADY suspensions were centrifuged and the cells alone used to prepare doughs, an even greater decrease in gas production occurred (series B). The supernatants thus obtained, however, had no depressant effect on gas production when incorporated into doughs with optimally prepared ADY (series C). As would be expected from the baking experiments, the gas production of compressed yeast doughs was decreased only by suspending it at 50°C. (series D); this may be attributed to thermal killing of some of the cells. When optimally suspended compressed yeast was centrifuged and resuspended in supernatants obtained by rehydration of ADY at various temperatures (obtained from preparation of series B) and incorporated into doughs, the results shown in series F were obtained. No effect on gas production was noted except with the supernatants obtained at 5° and 10°C., in which marked stimulation was observed along with production of sticky doughs. When the compressed yeast cells obtained by suspension at various temperatures were centrifuged and used alone in doughs (series E), however, there appeared to be a slight decrease in gas production by the cells suspended at 5° and 10°C.

The hourly rates of gas production in doughs made with optimally (40°C.) prepared ADY and compressed yeast are shown in Fig. 2,

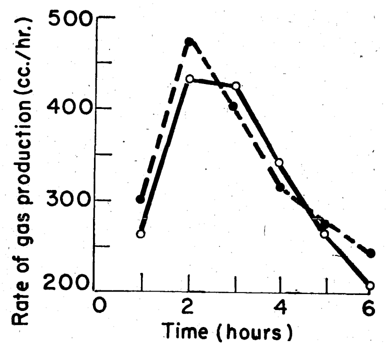

Fig. 2. Rate of gas production in straight doughs containing compressed yeast (open circles) or active dry yeast (solid circles). The ADY was rehydrated at 40°C. for 20 minutes.

which gives the gas production of a straight dough for 6 hours; it is quite obvious that the two yeasts are very similar in rate of gas production, although at the 5% level of significance ADY exceeded the compressed yeast during the first, second, and sixth hours, with the reverse at the third and fourth hour.

Figure 3, which compares the rate of gas production by ADY and compressed yeast during sponge and dough fermentation, shows that although the compressed yeast sponge produced gas at a faster rate during the first 2 hours, the reverse was true for the third and fourth hours of sponge fermentation. During the fourth hour of sponge fermentation the ADY sponge and the compressed yeast sponge produced 436 and 247 cc. respectively. The totals for the sponge

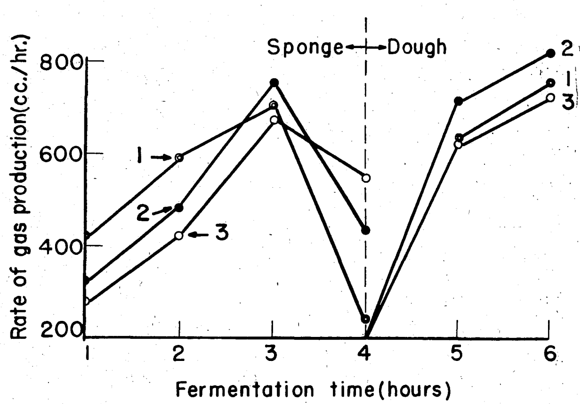

Fig. 3. Rate of gas production in sponge and doughs containing: 1), 2.25% compressed yeast; 2), 1.13% ADY; 3), 0.90% ADY. The ADY was rehydrated at 40°C. for 20 minutes.

fermentation were 1,998 and 1,968 cc. for ADY and compressed yeast doughs respectively.

Since about the same total quantity of carbon dioxide was produced during this period, it would appear that sugar had been depleted to the same extent in both sponges. During the 2-hour dough fermentation, however, 10% more gas was produced by the ADY dough than by the compressed yeast dough. The total gas production for the entire 6-hour sponge and dough fermentations was 3,542 and 3,362 cc. for ADY and compressed yeast respectively; a difference which was not significant.

Farinograph Studies. Farinograph studies were made of doughs containing compressed yeast extracts and ADY extracts obtained by suspension of the yeasts at various temperatures, and also with glutathione in quantities equal to those leached from ADY at the various temperatures used.

Table VII summarizes the results and illustrates the marked similarity between doughs prepared with ADY rehydrated at various temperatures and those with added glutathione. Compressed yeast lost a very small amount of material at all temperatures and, as expected, supernatants from its suspension had no effect on the farinograms. ADY extracts obtained by rehydration of the yeast at temperatures below 30°C. greatly shortened dough development time and lowered the mixing tolerance. Very comparable results were obtained with added glutathione.

Figure 4 illustrates the marked effect of ADY extracts and glutathione on farinograph curves. At all temperatures of rehydration,

TABLE VII

INFLUENCE OF ACTIVE DRY YEAST AND COMPRESSED YEAST EXTRACTS PREPARED AT DIFFERENT TEMPERATURES, AND OF GLUTATHIONE, ON FARINOGRAM CHARACTERISTICS OF FLOUR

Yeast Suspension Temp.	Doughs Made with Compressed Yeast Extracts [a]		Doughs Made with ADY Extracts [b]		GSH per Dough	Doughs Made with Glutathione [b]	
	Dough Development Time [c]	"Drop-off" Value [d]	Dough Development Time [c]	"Drop-Off" Value [d]		Dough Development Time [c]	"Drop-Off" Value [d]
°C	*minutes*	*B.u.*	*minutes*	*B.u.*	*mg*	*minutes*	*B.u.*
5	5.0	60	3.0	100	41.0	3.0	130
10	4.5	60	3.5	110	32.9	3.5	125
20	5.0	55	4.0	90	23.4	4.0	100
30	5.0	55	5.0	85	9.0	4.5	90
40	5.0	55	5.0	80	9.0	4.5	90
50	5.0	55	5.0	90	14.0	4.0	96

[a] Extracts of 1.5% ADY and 3.0% compressed yeast (flour basis) respectively.
[b] Glutathione used in amounts equivalent to that leached from ADY at the temperatures indicated.
[c] Time in minutes for dough to reach maximum peak of 500 B.u.
[d] Decrease in dough consistency from maximum after 20 minutes of mixing.

the doughs containing compressed yeast extracts gave curves which remained on the 500 B.u. line for approximately 10 minutes and were identical to a control curve (not shown). The curves obtained using doughs containing ADY extracts dropped almost immediately after reaching the 500 B.u. line. As the temperature of rehydration was lowered from 40°C. the decrease in consistency became progressively more rapid.

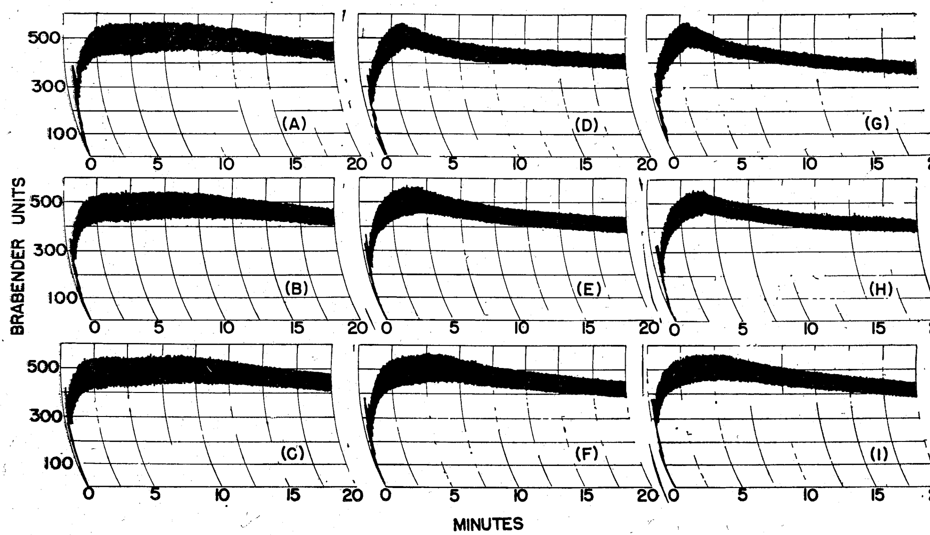

Fig. 4. Farinograms obtained on flour-water-salt doughs containing supernatants of compressed yeast, of ADY, or glutathione.

Compressed yeast supernatants suspended	ADY supernatants rehydrated	Glutathione added
°*C.*	°*C.*	*mg*
A 5	D 5	G 41.0
B 20	E 20	H 23.4
C 40	F 40	I 9.0

Extensigraph Studies. The extensigrams were analyzed by the method described by Dempster *et al.* (3,4). The load, in grams, supported by the dough at a constant deformation of 8 cm. plotted against rest period gave an indication of the extent of relaxation, with time, which the dough had undergone; the curves approximated rectangular hyperbolas. By plotting load times rest period against rest period, straight lines resulted, the intercepts and slopes of which changed with reaction time. The intercepts or "relaxation constants" are a measure of the rate at which a dough relaxes. A large relaxation constant for a dough indicates a "tighter" dough which takes longer to relax than one with a smaller relaxation constant.

When ADY was rehydrated at temperatures below 30°C., a marked increase in extensibility of the doughs, as judged by their handling qualities, had been observed. This effect is shown by the relaxation curves in Fig. 5. Even when ADY was rehydrated at 40°C., a marked softening effect of the extract on the dough occurred (curve 2) when compared with a control dough (curve 1). This was particularly noticeable at rest periods shorter than 40 minutes. As the rehydration temperature was lowered to 20° (curve 3) and 5°C. (curve 4), the dough became exceedingly extensible, offering virtually no resistance to extension. The load supported by the dough given rest periods of less than 40 minutes approached that supported by doughs given a rest period of 120 minutes. It would thus appear that the effect of the ADY extract obtained by rehydration at 5°C. was virtually to eliminate the "high-energy state" condition found in normal newly mixed doughs and causing it to appear in the relaxed state almost at once, as compared to the control dough and the dough containing ADY extract obtained by rehydration at 40°C.

The similarity of the effect of low-temperature rehydrated ADY extracts and of glutathione (GSH) is shown in Fig. 6, which is a plot of relaxation constants versus reaction time. Since a higher relaxation constant indicates a more slowly relaxing and hence tighter dough, a very marked effect of bromate with reaction time is at once seen on the control dough. As reaction time was increased

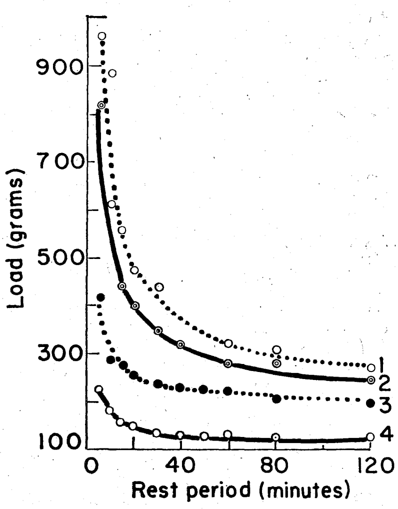

Fig. 5. Structural relaxation in flour-water-salt doughs containing: 1), no addition; 2), supernatant of 1.5% active dry yeast (flour basis) rehydrated at 40°C., 3) at 20°C., 4) at 5°C. Doughs had been allowed 5 minutes' reaction time.

in the unbromated control, the relaxation constant slowly decreased, whereas in the bromated dough (10 p.p.m.) a very great increase in relaxation constant occurred. In contrast, the relaxation constants of the doughs containing 15.6 mg. GSH or ADY extracts prepared at 20°C. remained very low and were virtually identical through-

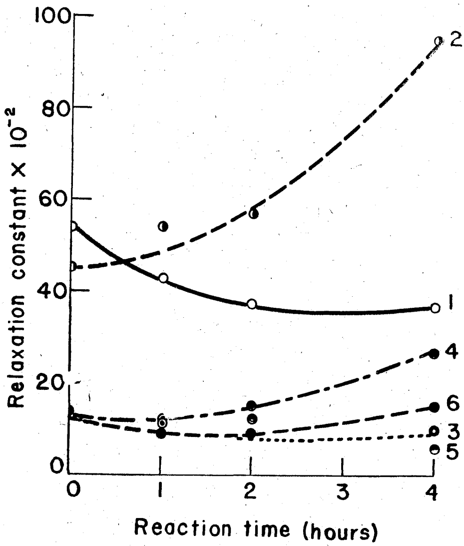

Fig. 6. The effect of active dry yeast (ADY) extracts, potassium bromate, or glutathione on the relaxation constants of doughs. 1) Control; 2) control + 10 p.p.m. potassium bromate; 3) ADY extract prepared at 20°C.; 4) ADY extracts prepared at 20°C. + 10 p.p.m. potassium bromate; 5) 15.6 mg. glutathione; 6) 15.6 mg. glutathione + 10 p.p.m. potassium bromate.

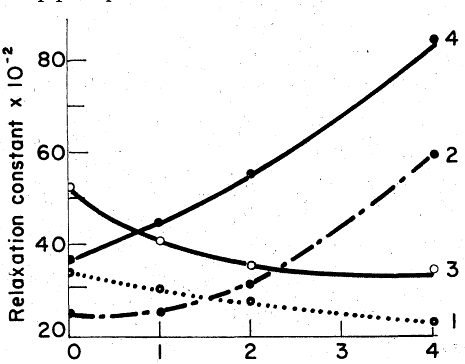

Fig. 7. The effect of active dry yeast (ADY) and compressed yeast extracts on the relaxation constants of doughs. 1) ADY extracts prepared at 40°C.; 2) ADY extracts prepared at 40°C. + 10 p.p.m. potassium bromate; 3) compressed yeast extracts prepared at 30°C.; 4) compressed yeast extracts prepared at 30°C. + 10 p.p.m. potassium bromate.

out the 4-hour reaction times. They were only slightly increased by the addition of 10 p.p.m. potassium bromate with the dough containing ADY extract responding somewhat more than that containing GSH.

The effect of ADY extract, prepared at 40°C., as compared with that of compressed yeast extract, upon the relaxation constants of flour-water-salt doughs is shown in Fig. 7. Again, even at a reaction time of 5 minutes, the dough containing ADY was in a greatly relaxed state and continued to relax further at a rate quite similar to that of the dough made with compressed yeast. The response of the two doughs to 10 p.p.m. bromate was quite similar; the relaxation constants of the ADY doughs were about one-half those of the dough made with compressed yeast during the entire "tightening-up" process as reaction time was increased to 4 hours.

Discussion

These studies show that the temperature of rehydration of active dry yeast exerts a profound influence upon doughs prepared with this leavening agent. These effects are at a minimum when rehydration is carried out at 40°C., the temperature recommended by the manufacturers.

The influence of low rehydration temperatures on doughs made with ADY is twofold: 1) the leaching of glutathione (and other substances) from the yeast cells which has a marked effect on the rheological properties of the doughs; and 2) a decrease in the fermentative power of the yeast as a result of the loss of material from the cells and an accompanying decrease in bread quality.

The result of the first effect is manifested by a shorter mixing time, a marked increase in dough extensibility, and a greater oxidizing improver requirement to obtain the best bread. The higher bromate requirement of ADY doughs results in a greater tolerance to oxidizing agents. The result of the second is a considerable decrease in bread quality. The two effects have been demonstrated by separation of the cells from the rehydration medium. The cells, when incorporated into doughs, produced loaves of inferior volume, grain, and texture. Gas production studies indicated that this was a result of decreased fermentative ability of the yeast. On the other hand, the rehydration medium when incorporated into doughs containing compressed yeast or optimally prepared ADY markedly influenced the rheological properties of the doughs, effects which could be duplicated by the addition of glutathione.

The various criteria used in these laboratory studies showed that

ADY, when rehydrated at the recommended temperature of 40°C., yielded satisfactory bread. Compressed yeast, unlike ADY, was completely unaffected by the temperature of the suspending water over a range of from 5° to 40°C. At 50°C., however, a considerable amount of inactivation occurred, with a resulting decrease in gas production and loaf volume when used in baking.

Acknowledgment

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