EFFECTS OF SUGARS AND CERTAIN FREE AMINO ACIDS ON BREAD CHARACTERISTICS[1]

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ABSTRACT

The effects of adding glycine, lysine, and glutamic acid, alone or in combination with each of 17 sugars, on bread-baking potentialities and crust coloration of bread were investigated. Adding 0.2–0.8 g. of free amino acids or up to 4 g. sugars (per 100 g. flour) had no measurable effects on bromate requirements, mixing time, or water absorption of wheat flour doughs. Glycine had the most adverse effect on loaf volume and it caused pronounced browning of bread crust. The effect of lysine on loaf volume was insignificant, despite increased crust browning. Glutamic acid, generally, improved loaf volume and slightly enhanced browning. None of the amino acids and only ribose among the sugars affected crumb color. Added on an equimolar basis (0.011 g. moles per 100 g. flour), raffinose and the pentoses imparted deepest color to crust; melibiose, sorbose, lactose, and galactose followed in order. The hexoses glucose, levulose, and mannose had little effect and were followed by the disaccharides cellobiose, sucrose, and maltose. The smallest effect was exerted by melezitose and trehalose. The effect of saccharides on loaf volume, except those contributing to the level of fermentable sugars, was small. Adding certain amino acids (0.0026 g. moles per 100 g. of flour) along with sugars augmented the effects of each separately on loaf volume or crust color.

Quality of bread is influenced by several factors, including composition of flour, dough formula, and bread-baking procedure. Zentner (6) recently reported that adding amino acids to wheat flour increased browning of the baked bread crust. Adding glycine and lysine to dough lowered gas production.

Kretovich and Ponomareva (2) found a significant decrease of free amino acid content in wheat and rye bread crusts compared with that in dough and crumb. Amino acids in crust decreased with increase of sugar content in bread. These changes were attributed to the participation of free amino acids in the reaction of melanoidin formation taking place in the crust during bread-baking.

Pomeranz *et al.* (4) followed the rate of browning of 20 sugars or sugar derivatives by reflectance measurements of cookies and spectrophotometric measurements of browning of dilute buffered solutions of the sugars with glycine or lysine heated at 114°C. in an autoclave.

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[1]Manuscript received March 22, 1963. Co-operative investigations of Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, and Department of Flour and Feed Milling Industries, Kansas Agr. Exp. Sta., Manhattan. Contribution No. 435, Department of Flour and Feed Milling Industries.

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Pentoses were most reactive. They were followed by reducing hexoses and disaccharides. Sugars without reducing groups failed to show browning. Menger (3) studied the relation between the soluble carbohydrates of durum wheat and the nonenzymatic browning of wheat pastes. It has been suggested that brown discolorations in pastes prepared from durum wheats were the result of condensation products involving the soluble carbohydrates. Ehle *et al.* (1) have reported that lysine at levels recommended for bread enrichment did not affect the loaf volume of standard white breads, but that browning increased with increasing lysine concentration.

The purpose of this research was to measure the effects of various sugars and certain free amino acids on bread-baking potentialities of wheat flour and on crust color of bread.

Materials and Methods

Untreated flour, used for the experimental baking tests, was experimentally milled from a composite grist of several hard winter wheat varieties grown at a number of locations throughout the Great Plains in 1961 or 1962. Certain chemical and baking properties of the two flour composites on a 14% moisture basis were as follows:

Flour Composite	*Ash*	*Protein*	*Bromate Requirement*	*Water Absorption*	*Mixing Time*	*Loaf Volume*
	%	%	*mg.*	%	*min.*	*cc.*
RBS-61A	0.39	12.6	3	62.5	3	947
RBS-62	0.37	12.9	3	61.5	3⅛	949

Sugars and amino acids used were of analytical grade. Baking properties of the two composite flours were determined by employing a formula which included, in addition to the basic formula, 4 g. sucrose, 0.25 g. 120°L malt syrup, 4 g. nonfat dry milk, and 3 mg. potassium bromate. The basic formula applied in the sugar and amino acid studies included 100 g. flour, 2 g. sucrose, 1.5 g. salt, 3 g. shortening, 2 g. yeast, 1.5 mg. potassium bromate (optimum), and water as needed. An optimum mixing time with the straight-dough procedure and a 3-hr. fermentation at 30°C. were employed. Punching and panning were performed mechanically. Baking time was 24 min. at 218°. Bakings were replicated at least twice. A third replicate was made when loaf volumes differed more than 25 cc. Data for all replicates were averaged. Average loaf-volume differences of 20 cc. were significant at 0.05 level.

Crumb and crust colors were measured with a Photovolt Reflectometer[3], Model 610, equipped with a green filter; the higher the reading, the less the color. Results reported are averages of three measurements rounded off to the nearest 0.5 unit.

Results and Discussion

Adding up to 4.0 g. of sugars or up to 0.8 g. of free amino acids per 100 g. of flour had no significant effect on bromate requirements, mixing time, or water absorption of the wheat flour doughs. The data in Table I show the results for bread containing various levels of

TABLE I

LOAF VOLUME AND CRUST COLOR OF BREADS CONTAINING THE BASIC FORMULA AND LEVELS OF EACH OF THREE AMINO ACIDS WITH 2 G. EACH OF THREE SUGARS

Amino Acid	Glycine: Loaf Volume	Glycine: Crust Color Bottom	Glycine: Crust Color Top	Lysine: Loaf Volume	Lysine: Crust Color Bottom	Lysine: Crust Color Top	Glutamic Acid: Loaf Volume	Glutamic Acid: Crust Color Bottom	Glutamic Acid: Crust Color Top
g.	*cc.*			*cc.*			*cc.*		
				No Sugar					
0.2	650	53.0	31.0	685	60.0	44.0	740	61.5	41.5
				Xylose[a]					
0.0	700	32.0	15.5	700	32.0	15.5	700	32.0	15.5
0.2	645	21.5	12.5	720	26.0	13.5	730	29.5	13.5
0.4	650	19.0	11.0	685	22.0	12.0	705	26.0	12.0
0.8	625	14.5	10.0	720	17.0	10.0	670	22.0	10.5
				Sucrose[a]					
0.0	780	41.5	21.5	780	41.5	21.5	780	41.5	21.5
0.2	750	38.0	18.5	785	42.5	21.0	860	42.5	19.5
0.4	775	33.5	15.0	790	38.5	18.0	795	39.0	16.5
0.8	750	26.0	13.0	740	33.0	16.0	755	38.5	18.5
				Galactose[a]					
0.0	715	33.5	17.5	715	33.5	17.5	715	33.5	17.5
0.2	640	25.5	14.0	750	31.5	16.0	760	36.0	15.5
0.4	665	19.5	11.5	745	27.5	13.5	725	32.0	15.0
0.8	630	17.0	9.5	695	23.0	11.5	685	29.0	13.5

[a] In addition to 2% sucrose in the basic formula.

amino acids with xylose, sucrose, and galactose. These sugars were chosen as representative of the nonfermentable, highly reactive (with amino acids) pentoses, of the readily fermentable sugars, and of the practically nonfermentable hexoses, respectively. The three amino acids selected were the monoamino, monocarboxylic glycine, the monoamino, dicarboxylic glutamic acid, and the diamino, monocarboxylic lysine.

Adding glycine generally reduced loaf volume much more than

[3] Mention in this publication of a trade product, equipment, or a commercial company does not imply its endorsement by the U.S. Department of Agriculture over similar products or companies not named.

did an equal or even equimolar amount of lysine. Actually, loaves containing additional lysine even at a level of 0.8 g., which is far above the levels suggested for supplementation of flour (5), were comparable in loaf volume to breads containing no additional amino acids. On a weight basis, glycine imparted a deeper color to bread crusts than did lysine. The molecular weights of lysine and glutamic acid are approximately twice that of glycine. Therefore, on an equimolar basis, lysine was essentially equal in crust browning to glycine. Glutamic acid had the least effect on crust browning. In practically all cases, adding as little as 0.2 g. glutamic acid gave loaf volumes higher than those without added free amino acids and sugars. High concentrations (0.8 g.) of added free amino acids resulted in darkening of crust color accompanied by a decrease in loaf volume. No clear-cut differences in crumb color could be attributed to added amino acids or sugars.

Varying the concentration of the three types of sugars and employing a uniform addition of amino acids (0.2 g.) at a 1.5-mg. bromate level gave the results shown in Table II.

TABLE II

LOAF VOLUME AND CRUST COLOR OF BREAD BAKED WITH THE BASIC FORMULA AND VARIOUS LEVELS OF EACH OF THREE SUGARS WITH 0.2-G. LEVEL OF THREE AMINO ACIDS

Sugar Level	Glycine			Lysine			Glutamic Acid		
	Loaf Volume	Crust Color		Loaf Volume	Crust Color		Loaf Volume	Crust Color	
		Bottom	Top		Bottom	Top		Bottom	Top
g.	*cc.*			*cc.*			*cc.*		
				No Sugar					
0.0[a]	711	62.5	41.0	711	62.5	41.0	711	62.5	41.0
				Xylose					
0.0	650	53.0	31.0	687	60.0	44.0	740	61.5	42.0
0.5	635	37.5	21.5	705	46.0	25.5	780	43.5	26.0
1.0	645	26.5	16.0	695	34.0	18.0	760	37.0	20.0
2.0	625	20.0	11.5	695	24.0	12.5	715	27.0	12.5
4.0	615	16.0	9.0	685	18.0	8.5	640	19.0	9.0
				Sucrose					
0.0	650	53.0	31.0	687	60.0	44.0	740	61.5	42.0
0.5	635	47.0	26.5	705	52.5	34.0	785	58.0	35.0
1.0	665	46.0	23.5	700	50.5	27.0	825	57.0	29.0
2.0	750	40.0	18.0	750	43.5	21.5	850	40.5	18.0
4.0	800	25.0	10.5	815	34.0	12.5	875	29.0	11.0
				Galactose					
0.0	650	53.0	31.0	687	60.0	44.0	740	61.5	42.0
0.5	645	35.0	22.5	705	45.5	27.0	755	46.5	27.5
1.0	650	30.0	17.0	705	40.5	19.5	750	40.5	20.5
2.0	655	25.0	13.0	730	30.5	14.5	765	30.5	14.0
4.0	705	24.5	10.5	700	24.0	11.5	715	26.5	11.0

[a] No amino acid.

Adding 0.2 g. amino acid to the basic formula caused loaf volume with lysine to decrease from 711 to 687 and that with glycine from 711 to 650; that with glutamic acid increased from 711 to 740 cc. Changes resulting from increased sugar levels depended on the type of sugar added. Sucrose improved the quality and size of the loaf because of its contribution as a readily fermentable sugar; xylose was most detrimental; galactose gave intermediate results. The results of crumb and crust color determinations paralleled those recorded in Table I.

The results summarized in Table III show that under conditions

TABLE III

EFFECT OF 2 G. EACH OF THREE SUGARS OR 0.2 G. EACH OF THREE AMINO ACIDS ON LOAF VOLUME AND BREAD CRUST COLOR

Sugar	Sugar Level	Amino Acid	Amino Acid Level	Loaf Volume	Crust Color	
					Bottom	Top
	g.		g.	cc.		
Basic formula	0	none	0	711	62.5	41.0
Arabinose	2	none	0	700	31.5	13.5
Sucrose	2	none	0	782	47.5	23.0
Galactose	2	none	0	725	36.0	15.0
None	0	glycine	0.2	650	53.0	31.0
None	0	lysine	0.2	685	60.5	44.0
None	0	glutamic acid	0.2	740	61.5	42.0

of panary fermentation, the effects of free amino acids and sugars on loaf volume or bread crust might not be causatively related, but might be two separate, independent reactions. Although adding sugars, at the levels employed and in the absence of added free amino acids, resulted in a pronounced darkening of the crust color, it did not adversely affect the loaf volume. The increase in loaf volume from adding sucrose results from the contribution of additional fermentable sugar. Adding glycine enhanced crust coloration, while lysine and glutamic acid had no effect when added at 0.2-g. level without sugar supplementation. Adding lysine had a small effect (decrease) on loaf volume, adding glycine gave the smallest loaf, and glutamic acid again had a beneficial effect. These results show that whereas amino acids added with sugars might enhance bread crust coloration, the extent of crust browning is primarily a result of the contribution of the sugars added or originally present in the dough.

The effects of 17 sugars on certain bread characteristics (Table IV) were investigated after considering the results of experiments summarized in Tables I to III. In this work the bromate level employed was 1.5 mg. per 100 g. of flour; the level of amino acids added was

TABLE IV

LOAF VOLUME AND CRUST COLOR OF BREADS BAKED WITH EQUIMOLAR CONCENTRATIONS OF EACH OF THREE AMINO ACIDS AND EACH OF SEVENTEEN SUGARS[a]

TYPE AND NAME OF SUGAR	CONTROL			GLYCINE			LYSINE			GLUTAMIC ACID		
	Loaf Volume	CRUST COLOR		Loaf Volume	CRUST COLOR		Loaf Volume	CRUST COLOR		Loaf Volume	CRUST COLOR	
		Bottom	Top		Bottom	Top		Bottom	Top		Bottom	Top
	cc.			cc.			cc.			cc.		
None	711	62.5	41.0	650	53.5	27.0	710	54.5	34.5	705	63.0	44.5
Pentoses												
Arabinose	720	32.0	15.5	650	24.0	13.0	730	23.5	11.5	715	30.0	14.0
Ribose	715	32.0	15.0	655	21.5	11.0	730	23.5	10.5	750	31.5	12.5
Xylose	700	32.0	15.5	635	21.0	11.0	705	21.0	10.0	705	29.5	13.0
Hexoses												
Galactose	715	33.5	17.5	645	21.5	10.5	730	26.0	11.5	715	33.0	13.0
Glucose	750	42.0	21.5	725	33.0	14.5	760	34.0	15.0	795	50.5	23.0
Levulose	780	42.0	20.0	750	31.5	14.0	755	32.0	14.0	795	51.5	21.0
Mannose	775	39.0	19.5	720	28.0	14.5	760	31.5	14.5	785	40.0	19.5
Sorbose	700	33.0	16.0	615	21.0	11.0	650	24.5	11.0	695	32.0	14.0
Rhamnose	720	42.0	23.0	650	29.0	15.0	720	29.0	14.0	720	40.0	18.5
Disaccharides												
Cellobiose	765	38.0	20.0	735	32.0	14.0	735	29.0	10.5	770	39.0	17.0
Lactose	725	37.0	17.0	675	24.0	11.0	745	27.0	10.5	735	35.0	15.5
Melibiose	715	33.0	15.5	685	20.0	11.0	735	24.5	10.0	710	31.5	15.0
Sucrose	780	41.5	21.5	745	29.0	15.5	760	32.5	14.0	790	44.5	17.0
Maltose	745	47.5	25.0	685	35.5	18.0	735	37.5	16.0	755	49.5	21.0
Trehalose	710	55.0	31.0	665	45.0	22.5	735	47.5	25.5	710	57.0	35.0
Trisaccharides												
Melezitose	725	57.0	26.0	670	41.5	20.5	745	50.0	18.0	735	56.5	21.0
Raffinose	765	30.0	12.5	735	25.0	10.0	780	20.0	9.0	790	25.0	10.5

[a] Equimolar concentrations were based on 0.2 g. of glycine for the amino acids and on 2 g. of the hexoses for the sugars.

kept equimolar (0.00266 g. moles per 100 g. of flour), and the level of sugars added was kept equimolar relative to 2 g. of the hexoses employed. The levels of sucrose and maltose added were equal to those of the hexoses, assuming that under conditions of panary fermentation these two sugars are enzymatically hydrolyzed to glucose and levulose and to 2 molecules of glucose, respectively.

The apparent bread-crumb color depends on both crumb texture and crumb color. A properly developed bread has a fine crumb, in which the fine cell walls surrounding small gas cells tend to reflect the light and look much whiter than an improperly fermented bread baked from the same flour. Differences in loaf volume would, therefore, be expected to affect the color of the crumb as measured by the employed reflectance method. No consistent differences in crumb color, as related to loaf volume, could be noted. Loaves containing ribose were distinctly yellow and their crumb color was consistently the poorest among all the tested breads. The effect of adding sugars on browning of the crust is similar to that observed in cookies and dilute solutions (4). Some differences, however, were noted. Raffinose, which in cookies and dilute sugar solutions produced little browning, imparted a deep crust color to bread. This seems to result from the cleavage of the trisaccharide by yeast to fructose and melibiose, both of which darken the crust color. All three pentoses tested imparted a dark brown color to the bread crust. Galactose-containing lactose and melibiose produced a darker crust color than did any of the other disaccharides. Here the picture is more complicated because the enzymatic hydrolysis of sucrose and maltose, subsequent fermentation of the cleavage products, and the amount of residual sugars present at the baking stage may influence the extent of browning. None of the sugars had a detrimental effect on loaf volume or, associated with it, crumb texture, in the absence of added free amino acids. Adding sugars fermentable by yeast consistently increased loaf volume. Under conditions of the experiment, adding sucrose gave the best loaf volumes. Raffinose and sucrose produced comparable increases in loaf volume; loaves containing added maltose were slightly lower in volume than those containing sucrose. Only sorbose of the sugars added in the presence of amino acids reduced loaf volume. Adding glycine resulted in a consistent and pronounced decrease in loaf volume accompanied by enhanced crust coloration. Glutamic acid, in general, slightly increased loaf volume and had little effect on crust color. Adding lysine had little or no effect on loaf volume but imparted a brown color to the crust.

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