THE EFFECT OF VARIOUS SUGARS ON THE FORMATION AND CHARACTER OF GLUTEN[1]

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ABSTRACT

The effects of various sugars added at 4% of flour weight were studied by baking gluten balls prepared in three ways: from gluten developed in a flour-water-sugar dough, from gluten made from a flour-water-sugar dough with the corresponding sugar again added to the gluten after washing, and from gluten made from a flour-water dough with sugars added to the gluten after washing.

In most instances addition of sugars to gluten resulted in no significant changes in volume of baked gluten balls. Tenderness of baked gluten balls was increased significantly over controls only when sugar was again added to gluten developed in the presence of sugar. Sugar added to raw gluten had a dehydrating effect on the raw gluten as shown by extent of drip loss.

In addition, several sugars were added in increasing amounts with constant flour and water to form doughs until no gluten was recovered when the dough was washed. At concentrations varying from 25 to 45% of flour weight, all of the sugars used except the relatively insoluble alpha-lactose interfered severely with gluten formation. Tenderness of baked gluten from these treatments seemed to increase at a greater rate than could be accounted for by decrease in yield alone.

It is commonly accepted that sucrose tenderizes baked products. Most food textbooks which offer an explanation attribute this effect of sugar to a peptizing action on flour proteins, but give no supporting references. Work of Jago and Jago (3,4) in 1911, and again in 1921, showed that the physical condition of a flour-water dough was noticeably affected by the presence of sucrose. As the concentration of the sugar in the dough increased, dough viscosity decreased. They also found that the amount of gluten recovered from a dough made with sucrose, flour, and water was less than that recovered from a flour-water dough. They proposed that the sugar diminished the water-absorptive power of the flour proteins and that it also exerted a solvent action on the flour proteins. In 1958, Baxter and Hester (1) proposed that sucrose interfered with gluten development owing to competition between gluten and the sugar for water, since when sucrose was added after gluten was developed, about the same amount of wet gluten was recovered from the dough as in the control, but the amount recovered was reduced when sucrose was added before gluten

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was developed.

The experiments reported in this paper include studies on the effects of various sugars on gluten formation and character and on the volume and tenderness of baked gluten balls.

Materials and Methods

A commercial, all-purpose, bleached flour containing 12.4% protein (14% moisture basis) was used. The sugars included were D-fructose (C.P.), D-glucose (C.P.), maltose (Tech.), beta-lactose (Tech.), and sucrose. Mixing was done in a Kitchen-Aid mixer, Model 3C.

For Part A, Section I, the gluten was prepared by mixing 1,000 g. flour with 800 g. water, washing by hand until the washwater gave a negative starch-iodine test, and draining. The gluten was divided into 60-g. lots. To a lot of gluten, 7.2 g. of a sugar were added and blended for 10 minutes in the mixer. The amount of sugar was equivalent to 4% of the weight of flour used in the dough. Two lots of gluten were treated in the same way, but with no sugar, to serve as controls. After weighing, each lot of gluten was divided into four equal parts, shaped into balls, baked for 15 minutes at 232°C., and for an additional 35 minutes at 149°C. (5).

For Part B, Section I, the gluten was prepared by mixing 355 g. flour, 288 ml. water, and 7.2 g. of sugar and washing as in Part A. The amount of flour was that estimated from Part A to give 120 g. gluten. The total yield of gluten was weighed, divided into two equal parts of approximately 60 g. each, and to one part (Part B-1) 7.2 g. of the corresponding sugar was added as before on the assumption that it had been lost during washing of the gluten. Gluten for controls for this part of the study was made in the same way, but with no sugar present at any time. Again, each 60-g. lot of gluten was divided into four equal parts, shaped into balls, and baked.

The difference to the nearest 0.1 g. between the weight of prepared wet gluten (or the gluten and added sugar) and its weight after 10 minutes of mixing was designated as drip loss. Volumes, by the rapeseed method, and tenderness of baked gluten balls were measured 1 hour after removal from the oven. A crude method was devised for estimating tenderness by measuring the weight required to crush the gluten ball, as follows: A gluten ball was placed inside a 1-liter glass beaker. A hollow cylinder which fitted exactly inside the beaker was placed on top of the ball. Metal shot was released from a funnel hanging above the cylinder in the beaker, at a uniform rate until the gluten ball was completely crushed. The cylinder and shot were then weighed. In this way the amount of weight needed to crush a gluten ball was measured and the relative tenderness was determined. Since tenderness was expressed as g. required to crush a gluten ball, a lower number indicates a higher relative tenderness.

Section II of the experiment was concerned with the effect of varying amounts of different sugars, expressed as percent of flour weight, on yield of gluten and on volume and tenderness of baked gluten balls. Five percent increments of a sugar were added to form a dough with 30 g. of flour and 24 ml. of water until no gluten was recovered. In addition to the sugars used in Section I, maltose (C.P.) and alpha-lactose (C.P.) were included. The dough was mixed, rested and washed four times, 2 minutes each, in 750 ml. tap water, using the mixer. When the washwater was passed through a wire sieve (20-mesh), the gluten was held in the sieve while starch, solubles, and other finely dispersed material passed through. If the total mixture passed through the sieve, it was assumed that no gluten was formed.

After the washing was completed, the gluten was drained and mixed again in the mixer for 10 minutes. It was then weighed, shaped into a ball, and baked. The baking procedure was the same as that used in Section I. When gluten yields of less than 3 g. were obtained, the mixing times and baking times were shortened.

Volumes and tenderness were determined as in Section I.

Results and Discussion
Section I

The mean volumes and tenderness of baked gluten balls and mean drip losses of raw gluten are shown in Table I. Studentized range (2) was used to test statistical differences among averages when analysis of variance revealed that there were significant differences.

When considered as a group, volumes of baked balls prepared from gluten obtained from a dough containing sugar, 552 ml. (Part B-1), and 594 ml. (Part B-2), were somewhat greater than those made from gluten containing no sugar, 473 ml. (Part A). Gluten for Part B was made in smaller quantities than that for Part A and the control balls from Part A had smaller volumes than control balls from Part B. Therefore these differences between groups were not considered great enough to be significant.

Individual analysis of volumes of gluten balls within Part A (gluten prepared in the absence of sugar) showed that only the gluten balls to which beta-lactose or maltose had been added had significantly smaller volumes than control balls. The maltose was later found to be very impure which probably influenced this result. Lactose should have had a similar effect in Part B-1, but statistical analysis showed that volumes

TABLE 1

INFLUENCE OF 4% LEVELS OF SUGARS AND METHODS OF INCORPORATING SUGARS ON THE DRIP LOSSES OF GLUTEN, AND THE VOLUMES AND TENDERNESS OF BAKED GLUTEN BALLS

SUGARS ADDED TO RAW GLUTEN AND/OR USED IN DOUGH PREPARATION	METHOD OF PREPARATION OF GLUTEN								
	PART A: FLOUR-WATER DOUGH (SUGAR ADDED TO PREPARED GLUTEN)			PART B-1: FLOUR-WATER-SUGAR DOUGH (ADDITIONAL SUGAR MIXED WITH PREPARED GLUTEN)			PART B-2: FLOUR-WATER-SUGAR DOUGH (NO ADDITIONAL SUGAR ADDED TO PREPARED GLUTEN)		
	Drip Loss [a]	Volume [b]	Tenderness [c]	Drip Loss	Volume	Tenderness	Drip Loss	Volume	Tenderness
	g	*ml*	*g*	*g*	*ml*	*g*	*g*	*ml*	*g*
Sucrose	14.0	501	2478	13.4	563	2139	3.8	625	3180
D-fructose	13.7	546	2197	13.9	554	2061	4.5	573	2998
Maltose	12.9	434	2647	11.1	591	2104	5.1	598	3161
Beta-lactose	14.7	420	2633	14.4	518	2520	3.6	580	2870
D-glucose	13.7	464	2558	13.1	533	2142	3.7	595	3285
Group Mean	13.8	473	2503	13.2	552	2193	4.1	594	3099
Control (no sugar)	3.8	546	2602	3.0	623	3352	3.0	623	3352

[a] Mean drip loss of four 60-g. lots of gluten.
[b] Mean volume of the 16 gluten balls obtained from four 60-g. lots of gluten.
[c] Mean weight in g. needed to crush one gluten ball. Smaller number indicates greater tenderness.

for gluten prepared from the dough containing this sugar were not significantly different from those from doughs containing other sugars.

The weight needed to crush gluten balls containing no sugar (3,352 g.) was decreased significantly by treating with a sugar only in Part B-1 (2,193 g.) when the sugar was again added to gluten prepared in the presence of the sugar. Smaller weight was needed to crush gluten balls in Part A (2,503 g.) and Part B-1 (2,193 g.) where sugar was added to prepared gluten than in Part B-2 (3,099 g.) where sugar was present during dough formation only.

Drip losses, which included sugar as well as water and other water-soluble materials, were greater when the sugars were incorporated after preparation of gluten (13.8 g., Part A, and 13.2 g., Part B-1, as compared with 4.1 g., Part B-2); it therefore appears that the presence of sugars decreases the hydration of gluten.

Section II

When sugars were included in increasing amounts (at 5% increments) during dough formation, there was no great change in gluten yield for each sugar at the lower concentrations (Table II). However, a "critical level" was found for each sugar except alpha-lactose where gluten yield dropped off sharply as follows: fructose, glucose, and sucrose, 55–65%; maltose, 45%; and beta-lactose, 35–45%. The alpha-lactose did not affect gluten yield, even at 70%, the highest concentration used.

Data on gluten ball volumes are not presented, since volume

TABLE II

PERCENT CHANGE IN YIELD OF GLUTEN AND TENDERNESS OF GLUTEN BALLS WITH VARIATION IN KIND AND CONCENTRATION OF SUGAR[a]

SUGAR	Decrease in Yield (Y) and Increase in Tenderness (T)											
	Fructose		Glucose		Sucrose		Maltose		Beta-Lactose		Alpha-Lactose	
	Y[b]	T[b]	Y	T	Y	T	Y	T	Y	T	Y	T
%	%	%	%	%	%	%	%	%	%	%	%	%
0	0	0	0	0	0	0	0	0	0	0	0	0
5	9	16	9	16	0	35	0	10	8	14	9	5
15	0	15	0	23	0	26	0	40	17	50	0	29
25	9	23	18	41	0	29	10	56	50	50	9	27
35	18	50	36	62	9	43	60	75	100	..	9	21
45	64	79	82	69	54	70	100	..	100	..	9	13
Control (g.)	11	4165	11	3740	11	4770	10	4333	12	4118	11	3894

[a] Actual figures are given at the bottom of the table for control in g. yield or g. required to crush gluten balls. Each figure was an average of three replications.

[b] Y = yield; T = tenderness.

changes were slight until gluten yields were greatly reduced. Then volumes decreased as expected. In the alpha-lactose series volumes were never reduced significantly. Tenderness increased with increases in sugar. For all sugars except alpha-lactose, a 40 to 50% decrease in weight needed to crush the gluten balls was achieved with a maximum of 18% decrease in gluten yield. Thus when one considers the percent change in tenderness and gluten yield it appears that tenderness increased to a greater extent than could be explained by a decrease in gluten yield alone.

These results indicate that a sugar must be in solution to exert an effect on gluten formation. The alpha-lactose, which is less soluble than the other sugars, exerted no significant effects on gluten yields or volumes of baked gluten balls. Tenderness changes also seem too small to be significant.

It is suggested that all of the sugars except alpha-lactose exerted a solvent or peptizing action on the formed gluten and/or interfered with water absorption by the gluten proteins and thus interfered with gluten formation. Hence, as increasing percentages of sugar were added, less gluten was recovered, and at "critical concentrations" no gluten was recovered.

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