

unsatisfactory to satisfactory. Those data corroborate unpublished data for copper chloride obtained by K. Finney and O. Natsuaki early in 1979. Identical improvements in crumb grains and similar increases in loaf volumes were obtained for 7.45–18.64 ppm of copper as the sulfate and nitrate. The loaf volume of the ascorbic acid control for copper nitrate and copper carbonate was 975 cc, instead of 984 cc. As the concentration of copper (II) carbonate increased from 1.86 to 14.91 ppm, loaf volume responses and improvements in crumb grain were less than the corresponding values for the other three salts. Only at the highest copper level did loaf volume (970 cc) approach the optimum volumes of the other three salts. Thus, copper (II) carbonate is not desirable as an oxidizer in breadmaking.

As little as 7.45 ppm of copper as the chloride, sulfate, and nitrate oxidized bread dough as effectively as 50 ppm of ascorbic acid. Loaf volumes and crumb grains for higher concentrations of those three copper salts essentially remained on plateaus and were not over-oxidized, as has been found for comparably high levels of potassium bromate (Finney 1946).

Zinc chloride and zinc sulfate (2.40–23.98 ppm zinc) did not improve crumb grains or loaf volumes relative to the values for no added salt and no ascorbic acid (data not given).

As the parts per million of the metal in all salts increased, time of dough mixing to the point of minimum mobility gradually increased from 3¹/₄ to 3⁷/₈ min for copper chloride and copper sulfate and to 3⁵/₈ min for copper nitrate, copper carbonate, zinc

chloride, and zinc sulfate.

The data in Table I show that 7.45 ppm of copper gave close to maximum loaf volume when added as the chloride, sulfate, or nitrate. The 7.45 ppm of copper is only 58.5% of Jorgensen's (1945) 12.73 ppm of copper in 50 ppm of copper sulfate.

The Subcommittee on the Tenth Edition of the RDAs (1989) stated that

an FAO/WHO Expert Committee concluded that no deleterious effects can be expected in humans whose copper intake is 0.5 mg/kg body weight per day (FAO/WHO 1971). Usual diets in the United States rarely supply more than 5 mg/day.

The subcommittee also gave estimated safe and adequate daily dietary intakes of up to 1.5 mg for ages 4–6, 2.0 mg for ages 7–10, 2.5 mg for over 11 years, and up to 3.0 mg for adults.

Assuming 300 g of flour in a 1-lb loaf of bread containing 20 slices, there would be 2.235 (0.745 × 3) mg of copper per loaf and 0.112 mg per slice for the 7.45-ppm (0.745-mg) level of copper in Table I. There would be 3.354 (1.118 × 3) mg per loaf and 0.168 mg per slice for the 11.18-ppm (1.118-mg) level of copper. According to Betschart (1988), flour contains 0.62–0.63 mg of copper per kilogram (0.186 mg/300 g). The native copper in flour would increase that in each slice of bread by 0.0093 mg (0.186 ÷ 20), so the above values per slice would increase to 0.121 and 0.177 mg of copper, respectively, and four slices would contain 0.484 and 0.708 mg, respectively. Both values apparently are nutritionally safe and adequate, but using the lower level of 7.45 ppm in Table I, up to no more than 9.31 ppm, would be preferable. Even 13 slices of bread containing 7.45 ppm copper would be nutritionally safe and adequate.

The mechanism of the oxidation and improved loaf volume (gas retention) of wheat flour doughs containing copper (II) salts is unknown. At the end of fermentation, the added copper (II) of the salt may be associated with one or more dough components, thereby affording a research tool for studying the mechanism of dough improvement and possible oxidation.

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TABLE I
Effect on Functional (Breadmaking) Properties of Adding Varying Amounts of Copper (II) Salts at the Mixing Stage^a

Metal in Salt ^b (ppm)	Ascorbic Acid (ppm)	Dough Mix Time (min)	Loaf	
			Crumb Grain ^c	Volume (cc)
Copper chloride				
0	0	3 ¹ / ₄	Q-U	875
1.86		3 ³ / ₈	Q	905
7.45		3 ¹ / ₂	S	975
11.18		3 ³ / ₄	S	990
14.91		3 ⁵ / ₈	S	975
18.64		3 ⁷ / ₈	S	965
	50	3 ¹ / ₂	S	984
Copper nitrate				
0	0	3 ¹ / ₄	Q-U	865
1.86		3 ³ / ₈	Q	900
7.45		3 ³ / ₈	S	970
11.18		3 ¹ / ₂	S	980
14.91		3 ⁵ / ₈	S	968
18.64		3 ⁵ / ₈	S	953
	50	3 ¹ / ₂	S	975
Copper sulfate				
0	0	3 ¹ / ₄	Q-U	875
1.86		3 ³ / ₈	Q	915
7.45		3 ¹ / ₂	S	970
11.18		3 ¹ / ₂	S	975
14.91		3 ³ / ₄	S	960
18.64		3 ⁷ / ₈	S	950
	50	3 ¹ / ₂	S	984
Copper carbonate				
0	0	3 ¹ / ₄	Q-U	865
1.86		3 ³ / ₈	Q-U	888
7.45		3 ³ / ₈	Q	938
11.18		3 ¹ / ₂	Q-S	950
14.91		3 ⁵ / ₈	S	955
18.64		3 ⁵ / ₈	S	970
	50	3 ¹ / ₂	S	975

^aData are on a 14% moisture basis.

^bThe 1.86, 7.45, 11.18, 14.91, and 18.64 ppm of copper are equivalent to 5, 20, 30, 40, and 50 ppm of copper chloride, respectively. The parts per million of the other three copper (II) salts varied with their molecular weights relative to that of copper chloride.

^cS, Q, and U indicate satisfactory, questionable, and unsatisfactory, respectively.

[Received October 30, 1990. Accepted February 5, 1992.]