Defatted Corn-Germ Flour as a Nutrient Fortifier for Bread [1]

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ABSTRACT

Defatted corn germ, rich in minerals and protein with lysine content more than twice that of normal wheat flour, is suitable as a nutrient fortifier for bread. Under optimum conditions, acceptable bread could be made from wheat flour fortified with 12% defatted corn-germ flour. In many countries where loaf volume is not emphasized, the fortified level could be raised to 24%. Defatted corn germ contains fewer sulfhydryl compounds than wheat germ. Accordingly, heat treatment and high dosage of oxidant were not required to improve the baking performance of the corn germ-fortified wheat flour. When ethoxylated monoglyceride, sodium stearoyl-2 lactylate, sucrose monopalmitate, or sucrose tallowate was added, improvement was evident; in fact, no acceptable bread could be made from the fortified flour without the addition of one of these agents.

In corn processing, germ is an important product for oil extraction and expression. After removal of oil, corn germ, often referred to as corn-germ meal, goes into feed. Little information is available concerning the food use of defatted corn germ. Only recently has germ flour been considered as a potential food supplement (1); Blessin et al. (2) evaluated its usefulness for making cookies, muffins, and patties, concluding that acceptable cookies and muffins could be prepared from wheat flour fortified up to 25% with defatted corn-germ flour. Beef patties containing 1 to 10% defatted corn-germ flour reportedly had no objectionable color, odor, or taste after broiling.

Because defatted corn germ is rich in protein and minerals, it is highly suitable as a nutrient fortifier (1–4). Corn germ takes up about 12% of the kernel—a percentage which is much higher than that of wheat (2.5%) or other grain. The world corn production in 1971–72 was estimated to be about 289.1 million tons.[3] In the U.S., approximately 120 million bushels of corn are dry-milled yearly, giving a by-product of about 12 million bushels of germ. The large corn crop, together with the high germ percentage in the corn kernel, would provide an adequate source for the expanded use as food. From both nutritional and economic standpoints it was deemed worth studying the possibility of fortifying wheat flour with defatted corn-germ flour for breadmaking.

Bread, a staple food, is an appropriate vehicle for nutritional fortification. High-protein breads made from wheat flour fortified with soy flour and other protein-rich additives have been successfully developed (5–8). Perhaps a defatted corn germ-fortified bread would be particularly welcomed in Latin American and other countries where corn is a major crop and where wheat and oilseeds are in

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[3]1973 Commodity Year Book.

short supply. Protein malnutrition exists in these countries among peoples with a low income, as it does elsewhere in the world. Their nutrition could be improved by fortifying bread they accept with defatted corn-germ flour.

MATERIALS AND METHODS

Materials

Wheat flour we used was a blend of hard red spring and winter wheat flours milled commercially. Its protein (N X 5.7) and ash contents were 12.5 and 0.39% (on 14% m.b.), respectively.

Defatted corn-germ flour was supplied by the Northern Regional Research Laboratory and processed as described by Blessin et al. (2). Its chemical composition will be presented in the Results and Discussion section.

Sodium stearoyl-2 lactylate (SSL) and ethoxylated monoglycerides (EM); sucrose tallowate (ST), sucrose monopalmitate (SMP), and sucrose distearate(SDS); and sucrose mono- and di stearates (SMDS) are products of C. J. Patterson Company, Colonial Sugar Company, and Dai-Nippon Sugar Manufacturing Company, respectively.

Chemical Analyses

Proximate analyses of wheat and corn-germ flours were made as described in AACC Methods (9), except for fat which was determined by AOCS Method Aa 4-38 using petroleum ether as extracting solvent (10).

Amino acids were determined by procedures of Waggle et al. (11). Germ samples were hydrolyzed in excess of 6N HCl for 22 hr., and 15 amino acids and ammonia were measured in a Beckman 120B amino acid analyzer. Methionine and cysteine were calculated as outlined by Moore (12), with a 24-hr. oxidation period, and hydrolyzed for 18 hr. No corrections were made for possible destruction of labile amino acid.

TABLE I. AMINO ACID COMPOSITIONS OF WHEAT GERM AND DEFATTED CORN-GERM FLOUR[a]

Amino Acid	Amino Acid g./100 g. Kjeldahl Protein	
	Defatted corn-germ flour	Wheat germ
Lysine	5.07	5.71
Histidine	2.70	2.02
Arginine	8.25	7.71
Aspartic acid	7.09	7.40
Threonine	3.37	3.47
Serine	4.13	3.63
Glutamic acid	12.12	11.92
Proline	4.74	3.89
Glycine	5.10	4.83
Alanine	5.64	5.07
Half-cystine	1.88	0.86
Valine	4.38	3.60
Methionine	1.26	1.29
Isoleucine	2.53	2.54
Leucine	5.84	5.17
Tyrosine	2.59	2.29
Phenylalanine	3.17	3.02

[a]Protein content (N X 6.25): 24.29% for defatted corn-germ flour and 36.21% for wheat germ on dry basis.

Sulfhydryl (SH) contents in germ samples were determined by amperometric titration according to Tsen and Hlynka (13).

Baking Test

The K-State Process for making high-protein bread as reported by Tsen and Tang (14) was followed. Loaf weight and volume were measured within 10 min. after bread was removed from the oven and averaged from duplicates. Specific loaf volume (cc. per g.) was then calculated from the average loaf weight and volume. Specific loaf volume is an important parameter of bread's marketability. Generally, in this country, specific volume of marketable bread (1-lb. loaf) should be at least 6.00 or have a volume of 2,722 cc. with acceptable appearance, crumb texture, and grain. Breads were scored 18 hr. after baking. Finished bread scored below 5 was regarded as unsatisfactory. Almost all the baking tests were repeated at least once on a different day to substantiate results.

RESULTS AND DISCUSSION

Composition of Corn-Germ Flour

Proximate composition of defatted corn-germ flour is listed below:

	%
Moisture	5.9
Protein (N X 6.25)	23.6
Ash	10.0
Fat	0.09
Fiber	3.3

This composition is in close agreement with that reported by Blessin et al. (2). The high-protein and ash contents of the corn-germ flour indicate that corn germ should be a good nutrient supplement.

The protein quality of corn germ was evaluated by amino acid analysis and compared with amino acids of wheat germ. Table I shows that the amino acid compositions of the two germs were similar. This finding agrees with that reported by Garcia et al. (3). Comparing the amino acids of germ flour with those of normal corn (15) or wheat flour (16) indicates that the germ flour contains more than

TABLE II. EFFECTS OF INDICATED PROCESSING FACTORS ON THE BAKING PERFORMANCE OF WHEAT FLOUR FORTIFIED WITH 12% DEFATTED CORN-GERM FLOUR WITH 0.5% SSL ADDED

Abs. %	Mix min.	Bromate p.p.m.	Avg. Sp. Loaf Vol. cc./g.	Grain Score
80	4:30	70	6.02	7
82	4:30	70	6.57	9
84	4:30	70	6.69	9
86	4:30	70	6.62	8
82	5:30	70	6.29	8
82	3:30	70	6.41	8
82	4:30	90	6.36	8
82	4:30	110	6.48	7
82	4:30	130	6.55	8

twice as much lysine as corn or wheat flour. In fact, a protein efficiency ratio of 2.19 for corn germ was reported (15). As lysine is the first limiting essential amino acid in corn and wheat flours, corn germ, if used as a fortifier, could effectively balance the essential amino acids and raise protein contents of bread and other cereal products. Of the ash constituents, phosphorus, potassium, and magnesium are the three major elements; sodium, calcium, iron, zinc, and copper are the minor ones in defatted corn-germ flour (3). These elements are important nutritionally in corn-germ supplementation.

Optimizing the Processing Conditions for Making Corn-Germ Bread

Table II shows varied processing conditions for making acceptable corn-germ bread from wheat flour fortifed with 12% corn-germ flour. The optimum condition selected is:

Absorption	84%
Mix	4.30 min.
Bromate	70 p.p.m.

In selecting the optimum condition, we considered both loaf volume and grain score. Typical bread samples are shown in Fig. 1.

Effect of Various Levels of Corn-Germ Flour

As shown in Table III, the specific loaf volume of corn-germ breads lowered steadily with increasing levels of corn-germ flour. Acceptable bread could be prepared from wheat flour fortified with up to 12% corn-germ flour.

The improving action of SSL was evident; no acceptable bread could be made from wheat flour fortified with corn-germ flour without adding 0.5% SSL or a similar agent (Fig. 2).

Effect of Heating

In view of the findings that the baking quality of wheat germ can be improved with heat treatment, as suggested by Sullivan et al. (17) and Pomeranz et al. (18), corn-germ flour was dry-heated at 80°C. for 8 hr. A baking test was then made on wheat flour fortified with 12, 16, and 20% of this heated corn-germ flour as compared to the original corn flour fortified at the same levels. Under those conditions heat treatment did not improve the baking quality of corn-germ flour as measured by loaf volume and crumb grain (Fig. 2).

In another test, various levels (70, 90, 110, 130 p.p.m.) of bromate or 20 p.p.m. azodicarbonamide (ADA) were added to see if higher levels of oxidant would improve the baking quality of wheat flour fortified with corn-germ flour. Negative baking results with bromate levels over 70 p.p.m. and with 20 p.p.m. ADA were also obtained.

To substantiate this finding, a further step was taken to measure the SH groups in the corn-germ flour and raw wheat-germ flour. Amperometric titrations showed that the defatted corn flour contains 9.92 μeq. SH groups per g. as compared to 19.65 μeq. SH groups per g. for wheat-germ flour.

All our baking tests and SH determinations indicate that defatted corn-germ flour contains less SH and other reducing compounds than wheat-germ flour. So for preparing bread from wheat flour fortified with defatted corn-germ flour, neither a heat treatment nor a high oxidant level is required to minimize the deleterious effect of reducing compounds.

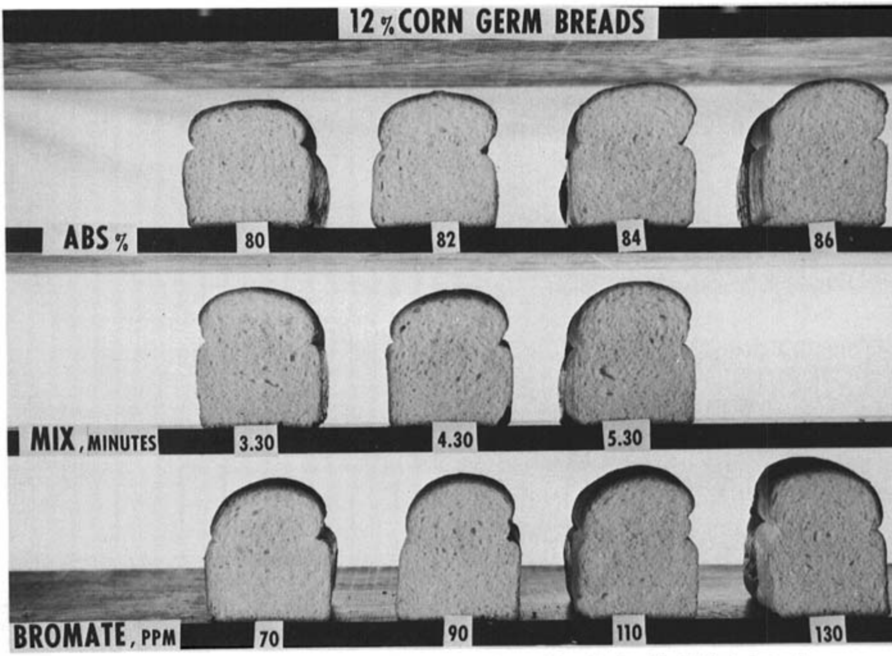

Fig. 1. Typical bread samples prepared from wheat flour fortified with 12% defatted corn-germ flour under various processing conditions.

Effects of Various Additives

Pomeranz et al. (5,6) found that sucroesters improved the baking performance of flour fortified with soy flour. Sucrose monolaurate, added at 0.5%, increased loaf volume of bread baked with 8 g. defatted wheat germ per 100 g. wheat flour; however, sucrose monolaurate was less effective than shortening (3%) in exerting the improving action (18). Later, high levels of sucrose monomyristate were found to have deleterious effects on gassing power, proof height, and loaf volume in bread baked without germ, with defatted wheat germ, and with defatted and heat-treated

TABLE III. BAKING QUALITY OF WHEAT FLOUR FORTIFIED WITH INDICATED LEVELS OF CORN-GERM FLOUR

Corn-Germ Flour %	SSL %	Bromate p.p.m.	Abs. %	Mix min.	Avg. Sp. Loaf Vol. cc./g.	Grain Score
0	0	50	68	9:30	6.65	9
0	0.5	50	68	9:30	7.17	10
12	0	70	84	4:30	4.16	4
12	0.5	70	84	4:30	6.69	8
16	0	76	88	3:30	3.63	3
16	0.5	76	88	3:30	5.58	7
20	0	82	92	3:00	3.19	3
20	0.5	82	92	3:00	5.11	6
24	0	88	96	3:00	2.81	2
24	0.5	88	96	3.00	4.66	5
28	0	94	100	2:30	2.76	2
28	0.5	94	100	2:30	3.65	4

germ. Sucrose monotallowate added at levels of 1.5 to 2.5 g. to doughs made from 100 g. flour and 15 g. wheat germ was much less deleterious to proof height and loaf volume than sucrose monomyristate. Sucrose mono-oleate had a slight improving effect (18). In considering the improving action of sucroesters for making high-protein breads and the diversified effects of sucroesters on wheat germ-enriched bread, effects of various sucroesters were tested on the baking performance of wheat flour fortified with 12% defatted corn-germ flour.

In addition, Tsen et al. (7,8) have shown SSL and EM to be effective as dough conditioners for making high-protein breads. These two dough conditioners were also included in the test.

Fig. 2. Effects of indicated levels of defatted corn-germ flour and heat treatment.

TABLE IV. INDICATED SURFACTANTS' EFFECTS ON BAKING PERFORMANCE OF WHEAT FLOUR FORTIFIED WITH 12% CORN-GERM FLOUR[a]

Surfactant	Avg. Sp. Loaf Vol. cc./g.	Grain Score
0.25% EM	5.16	7
0.50% EM	6.12	9
1.00% EM	6.13	8
0.50% SSL	6.48	8
1.00% SSL	6.55	9
2.00% SSL	6.46	8
0.50% ST	6.32	9
1.00% ST	6.28	8
2.00% ST	7.10	8
0.50% SMP	6.02	8
0.50% SDS	4.96	7
0.50% SMDS	5.06	7
1.00% Lard	5.14	6
2.00% Lard	5.67	7
3.00% Lard	5.77	7
0.5% EM + 1% Lard	6.29	8
0.5% SSL + 1% Lard	6.11	8
0.5% ST + 1% Lard	6.50	9

[a]Absorption, 70%; mix, 4:30 min.; and bromate, 70 p.p.m.

Results, presented in Table IV and Figs. 3 and 4, show that SSL, EM, SMP, and ST each improves the baking quality of wheat flour fortified with 12% defatted corn-germ flour. Different sucrose esters vary greatly in their improving effects: SDS is least effective; ST, most effective. The varied effects of sucrose esters agree with the finding of Pomeranz et al. (18) despite corn germ being substituted for wheat germ. Adding 0.5% SSL, EM, or ST, together with 1.0% lard, enhanced the improving effect more than does individual additive, except SSL.

GENERAL DISCUSSION

Cereal germs have long been known for their high nutritive value. Westerman et al. (19) reported both wheat germ and soy flour, added at 3% to wheat flour, significantly improved growth in rats. However, no significant differences occurred in rats receiving enriched wheat flour plus wheat germ as against those on enriched wheat flour plus soy flour (19). Rand and Collins (20) found that supplementing cereals, including wheat and rice, with 10 to 15% defatted wheat germ greatly improved their nutritive value. Likewise, Rohrlich and Bruckner (21) reported that from 8 to 10% wheat germ was required to upgrade effectively bread's nutritive value.

Although corn germ contains less protein than wheat germ, the amino acid compositions of the two are similar (Table I). Conceivably, the protein quality of corn germ would equal that of wheat germ.

An acceptable bread can be prepared from wheat flour fortified with 12% defatted corn-germ flour by adding 0.5% EM, SMP, SSL, or ST. Although no systematic organoleptic test was conducted on corn germ-enriched bread, reactions

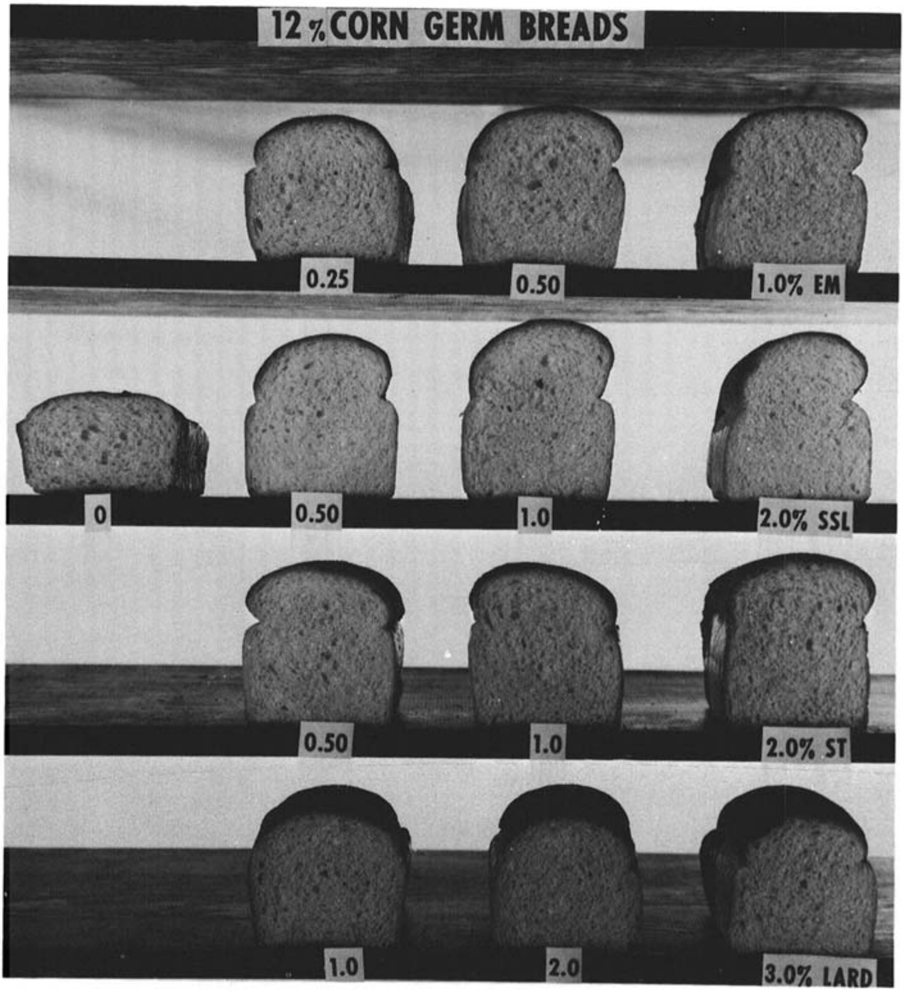

Fig. 3. Effects of EM, SSL, ST, and lard on the quality of breads prepared from fortified flour.

of those who tasted the breads were favorable. No objectionable odor or flavor was reported.

In our study, bread is rated acceptable if its specific volume is more than 6.00 (cc. per g.) and it has normal appearance, crumb texture, and grain, to be marketable by the U.S. baking industry. The rating is, of course, arbitrary. In fact, breads with a specific volume more than 4.50 are considered acceptable in many countries. With that standard, the fortification of defatted corn germ can be raised as high as 24% (Table II). Furthermore, in Latin America where hard rolls, such as bolillo, are commonly consumed, the germ fortification could go even higher than 24%. So breads of various types can be fortified with enough corn germ to ensure the nutritive improvement in breads for human consumption in many countries.

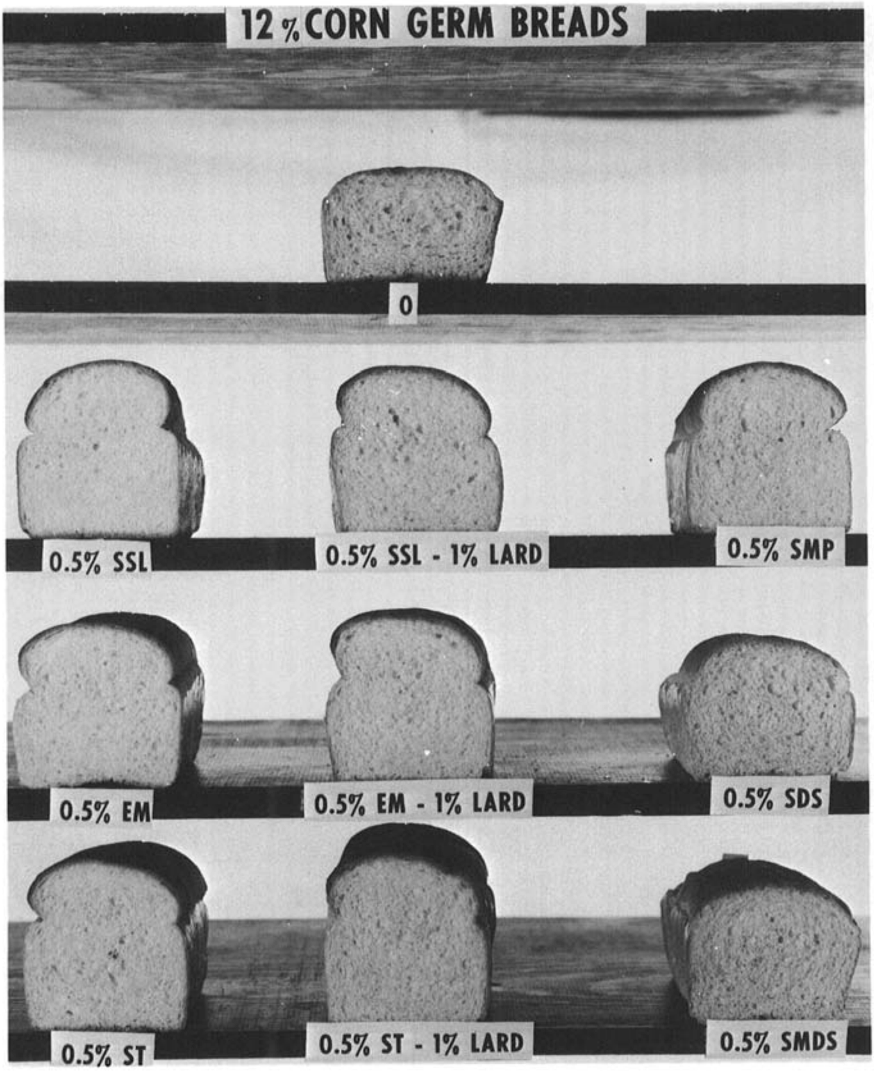

Fig. 4. Effects of 0.5% SSL, EM, ST, SMP, SDS, SMDS, and 0.5% SSL-1% lard, 0.5% EM-1% lard, or 0.5% ST-1% lard on the quality of breads prepared from fortified flour.

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