CORN GERM BREAD: PROCESSING, NUTRITIONAL, AND FLAVOR ASPECTS

BY

SUSAN N. BOERO

B. S., California Polytechnic State University, 1974
San Luis Obispo, California

A Master's Thesis submitted in partial fulfillment
for the degree of

MASTER OF SCIENCE
FOOD SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

Approved by Cho C. Bern
Major Professor

TABLE OF CONTENTS

		Page
LIST OF TABLES		iv
LIST OF FIGURES		vi
Chapter		
1.	INTRODUCTION	1
2.	REVIEW OF LITERATURE	3
	Nutritional Aspects	3
	Composition	3
	Nutrition studies	4
	Processing Aspects	12
	Flavor Aspects	14
	Conclusion	16
3.	MATERIALS AND METHODS	17
	Materials	17
	Baking studies	17
	Nutrition studies	19
	Methods	19
	Processing aspects	19
	Farinographic studies	19
	Baking studies	19
	Combination of surfactants	20
	Staling study	22
	Crumb and crust color analyses	24
	Nutrition study	24
	Diets	24
	Rats	25
	Protein efficiency ratio	25
	Digestibility	29
	Flavor aspects	29
	Flavor profile analysis	30
	Consumer acceptability test	31

Chapter		Page
4.	RESULTS AND DISCUSSION	33
	Processing	33
	Farinographic studies	33
	Baking studies	33
	Combination of surfactants	37
	Additional ingredients	39
	Staling	41
	Crumb and crust colors	45
	Nutrition	45
	Protein efficiency ratio	45
	Digestibility	51
	Flavor	54
	Flavor profile	54
	Consumer acceptability	56
5.	CONCLUSION	57
LITERATURE CITED		58
APPENDIXES		
A.	MINERAL CALCULATIONS	62
B.	ANALYSIS OF VARIANCE TABLES	64
	1. Surfactants singly or in combination	64
	2. Twelve percent corn germ breads	64
	3. Staling study	64
	4. Rat initial weight	65
	5. Rat weight gain	65
	6. Rat feed intake	65
	7. Rat PER	65
	8. Rat digestibility	66

LIST OF TABLES

Table		Page
1.	Composition of Defatted Corn Germ Flour	5
2.	Amino Acid Composition of Corn Germ Flour Compared to Hen's Egg Proteins	6
3.	Amino Acid Patterns for High Quality Proteins and Corn Germ Flour	7
4.	Analytical Data for White Flours and Corn Germ Flours	18
5.	Baking Ingredients	21
6.	Formula Levels of Surfactants Singly or in Combination in 12% Corn Germ Bread	23
7.	Vitamin Premix	26
8.	Mineral Premix	27
9.	Diet Formulations	28
10.	Consumer Acceptability Form	32
11.	Farinograms of White Flour and Flour Supplemented With Corn Germ Flour	34
12.	Mixing Specifications and Baking Characteristics For White Bread Supplemented With Corn Germ Flour	36
13.	Results of Surfactants Singly or in Combination	38
14.	Twelve Percent Corn Germ Breads	40
15.	Staling Rates of 12% Corn Germ Breads and White Bread	42

Table		Page
16.	Crumb and Crust Colors	46
17.	Analytical Data For White Bread And Corn Germ Breads	47
18.	Rat Protein Efficiency Ratio Data	49
19.	Rat Digestibility Data	52
20.	Flavor Profile of 12% Corn Germ Bread	55

LIST OF FIGURES

Figure		Page
1.	Histograms of Effect of Surfactants Singly or in Combination on Specific Volume	43
2.	Staling Regression Plot	44
3.	PER Regression Plot	50
4.	Digestibility Plot	53

ACKNOWLEDGMENTS

The writer wishes to thank her major professor, Dr. Cho C. Tsen, for his encouragement and support throughout these studies. Also giving help to the writer during this research were members of her committee, Dr. Jean Caul and Dr. Robert Robinson. This help was very much appreciated. Special thanks to Dr. Caul for her help in the flavor studies.

The writer also is grateful to her husband for all his help and encouragement during these studies.

Chapter 1

INTRODUCTION

Recently, much concern has been focused on the world food problem. Of major interest is how to use the available food supply most efficiently to feed the rapidly expanding human population. This problem has no simple solution but is very complex, involving many interrelating factors such as politics, economics, education, agriculture, nutrition, and culture. One small part of the solution is to make existing human food products more nutritious by substituting a portion of the product with a food source that is both nutritionally rich and physically compatible with the food product. This food source could be a product which has been traditionally used as animal feed. Corn germ bread is an example of a fortified food product which uses defatted corn germ flour, usually fed to animals, as a partial replacement for which flour in bread. This thesis will explore the effects of corn germ fortification on the nutritional, processing, and flavor aspects of bread.

The objectives of this investigation were to produce acceptable corn germ bread using high-protein defatted corn germ flour and white flour of average-protein content and then study the nutritional and flavor aspects of that bread. From past research (Tsen, Mojiban, and Inglett, 1974 and Tsen, 1975), it was found that acceptable bread, in terms of specific loaf volume and grain, could be obtained at a 12% fortification level but no higher. These studies used a high-protein white flour as opposed to the average-protein white flour used in this study. Fortification levels of 12%, 24%, and 36% corn germ flour are explored in this work not only to study the effects of defatted corn germ flour on bread quality but also to examine the nutritional value of corn germ flour in bread. The flavor properties of acceptable 12% corn germ bread are also studied.

If 12% corn germ bread could be produced having acceptable loaf properties, significantly higher nutritional value than white bread, and flavor acceptance, then corn germ bread would be an excellent example of a food product fit for human consumption which had been upgraded by an animal feed.

Such a product would warrant production and sale in the United States and possibly overseas wherever a typically "American" type of bread is consumed.

Chapter 2

REVIEW OF LITERATURE

Nutritional Aspects

The germ portion of the corn kernel is approximately 12% by weight (Blessin, Inglett, Garcia, and Deatherage, 1972). Corn oil production is the major use of germ. The by-product of this process is defatted corn germ meal, used predominantly as livestock feed. In recent years, there have been studies on the use of defatted corn germ flour in food products. Due to the nutritive composition of defatted corn germ flour and its performance in animal feeding studies, defatted corn germ flour could be used to increase the nutritional value of a compatible food product.

Composition

Defatted corn germ, produced through the corn dry-milling process, is screened, flaked, defatted with hexane, dried to remove residual hexane, and ground into flour (Blessin, Garcia, Deatherage, and Inglett, 1971). On a dry basis, Blessin et al. (1972) reports such defatted corn germ flour to contain approximately 25% protein (N x 6.25), 4.2% fiber, 24.7% starch, 13.8% sugars, 11.7% pentosans, 10.3% ash, and 0.5% fat. The National Academy of

Sciences (1971) reports solvent extracted ground corn germ meal to contain 19.5% protein (N x 6.25), 3.8% ash, and 12% fiber on a dry basis. Corn germ flour functions as a complete protein because it contains adequate levels of both lysine and tryptophan, two essential amino acids found limiting in whole kernel corn (Blessin et al., 1972). The major minerals in corn germ flour include phosphorus, potassium, and magnesium. Minor minerals include calcium, sodium, and iron (Blessin et al., 1972). Corn germ flour is rich in thiamine (Mitchell and Beadles, 1944). Detailed analyses of corn germ flour are given in Tables 1, 2, and 3.

Defatted corn germ flour, being high in protein, vitamins, and minerals, can be used to fortify certain foods and improve their nutritional qualities (Stare and Hegsted, 1944).

Nutrition Studies

Both full-fat and defatted corn germ flours have been used in many animal feeding studies to determine protein efficiency ratio (PER), digestibility, and biological value (BV). The nutritive value of a dietary protein depends upon the pattern and quality of essential amino acids supplied to the body after absorption by the intestine (National Academy of Sciences-National Research Council, 1963). Animal assays including PER, digestibility, and BV measure the nutritive value of a dietary protein. PER is the ratio of weight gain per gram of protein intake (NAS-NRC, 1963). Digestibility, measured

Table 1

Composition of Defatted Corn Germ Flour

Element	Unit	Blessin *et al.*, 1972	NAS, 1971
Dry Matter	%	100.0	100.0
Fat	%	0.5	-
Fiber	%	4.2	12.0
Protein (N x 6.25)	%	25.3	19.5
Starch	%	24.7	-
Sugars	%	13.8	-
Pentosans	%	11.7	-
Ash	%	10.3	3.8
Calcium	%	0.15	0.03
Copper	mg/kg	-	14.3
Iron	%	0.02	0.035
Manganese	mg/kg	-	18.2
Phosphorus	%	2.74	0.55
Potassium	%	2.36	-
Magnesium	%	1.02	-
Sodium	%	0.14	-
Choline	mg/kg	-	2132.0
Niacin	mg/kg	-	46.3
Pantothenic acid	mg/kg	-	3.6
Riboflavin	mg/kg	-	4.1
Alpha-tocopherol	mg/kg	-	95.8

Table 2

Amino Acid Composition of Corn Germ Flour Compared to Hen's Egg Proteins (g/100 g protein)

Amino Acid	Normal Mertz, 1970	Defatted Blessin et al., 1973a	Hen's Egg Blessin et al., 1973
Lysine	6.1	5.9	6.4
Histidine	2.9	-	-
Arginine	9.1	-	-
Asparagine	8.2	-	-
Glutamine	13.1	-	-
Threonine	3.9	4.1	5.1
Serine	5.5	-	-
Proline	4.8	-	-
Glycine	5.4	-	-
Alanine	6.0	-	-
Valine	5.3	5.6	7.3
Cystine	1.0	1.4	2.4
Methionine	1.7	2.1	3.1
Isoleucine	3.1	3.4	6.6
Leucine	6.5	7.2	8.8
Tyrosine	2.9	3.3	4.2
Phenylalanine	4.1	4.1	5.8
Tryptophan	1.3	1.2	1.6

Table 3

Amino Acid Patterns For High Quality Proteins
And Corn Germ Flour (mg amino acid/g protein)

Amino Acid	Recommended NAS-NRC, 1963	Corn Germ Flour Blessin et al., 1973a
Isoleucine	42	34
Leucine	70	72
Lysine	51	59
Total S-containing amino acids	26	35
Total aromatic amino acids	73	86
Threonine	35	41
Tryptophan	11	12
Valine	48	56

as percent, is the proportion of food nitrogen absorbed in body tissue (NAS-NRC, 1963). BV is defined as the proportion of absorbed nitrogen retained in the body for maintenance and/or growth (NAS-NRC, 1963). Values for BV range from 1 to 100, the higher values indicating higher quality proteins (NAS-NRC, 1963).

Mitchell and Beadles (1944) studied digestibility and BV of defatted corn germ flour which contained 21.2% protein (N x 6.25) on a 7% moisture basis. The digestibility of defatted corn germ was 85% compared to 99.5% for beef round steak. The BV of defatted corn germ was 77.6 while beef round steak was 76.9. They concluded that defatted corn germ could be used as a protein supplement to the American diet because of its good digestibility and high biological value.

Hove, Carpenter, and Harrel (1945) studied corn oil meal consisting of 24% protein (N x 6.25) and 9.8% moisture. The PER of non-fat-dry-milk solids was 2.84 while corn oil meal resulted in a PER of 2.56. Patent flour yielded a PER of 0.84. By mixing 10% corn oil meal with 90% patent flour, the PER increased to 0.93. A mixture of 20% corn oil meal and 80% patent flour resulted in a PER of 1.52. Forty percent corn oil meal combined with 60% patent flour further increased PER to 2.09. They concluded corn oil meal contained high-quality protein about equal to non-fat-dry-milk solids or low-fat wheat germ in its supplemental value.

Using human subjects, Murlin, Edwards, Fried, and

Szymanski (1946) reported the BV of corn germ to be 75.5 and its digestibility to be 77%.

The PERs of defatted corn germ and other protein sources were reported by Jones and Widness (1946). Defatted corn germ contained 21.3% protein (N x 6.25). The PER of casein was reported to be 2.41 and whole egg powder to be 3.25 while the PER of defatted corn germ was 2.11. They concluded animal proteins were more efficient than plant proteins in growth promoting value. Wheat germ and soy flour gave higher PERs than corn germ (2.54 and 2.32 respectively).

The growth promoting value of low-fat corn germ was studied by Beeson, Lehrer, and Woods (1947). The PER of whole egg was 2.5 while corn germ yielded a PER of 2.01. They concluded low-fat corn germ was significantly less efficient in promoting growth when compared to whole egg powder.

In two studies Schulz and Thomas (1949a and 1949b) reported the digestibility and BV of defatted corn germ. The first study (Schulz and Thomas, 1949a) utilized experimentally milled ether-extracted corn germ. Digestibility ranged from 79% to 85% while the BVs ranged from 65 to 72. Storage effects on digestibility and BV, using commercially milled ether-extracted corn germ, were reported in a second study (Schulz and Thomas, 1949b). Corn germ stored three months did not change its digestibility or BV, 72% and 83 respectively. After two years of storage, corn germ increased its digestibility to

81% but decreased its BV to 79.

Reussner and Thiessen (1957) studied high-oil and regular corn germ. On a dry basis, the high-oil corn germ contained 13.1% protein (N x 6.25) and 27.5% fat. The regular corn germ contained 14.6% protein (N x 6.25) and 20.7% fat. The PER of high-oil corn germ was 1.74 while regular corn germ gave a PER of 2.15. Digestibility of high-oil corn germ was 91% as compared to 87% for regular corn germ. They concluded high-oil corn germ was significantly more efficient in growth promoting value than regular corn germ.

Wall, James, and Cavins (1971) studied the nutritive value of corn germ processed in three different ways: air-dried, solvent-extracted corn germ containing 23% protein (N x 6.25) and 8.2% moisture; heat-dried, solvent-extracted corn germ containing 23% protein (N x 6.25) and 4.2% moisture; and heat-dried, expeller-processed corn germ containing 21.4% protein (N x 6.25) and 6.8% moisture. The corrected PER of casein was 2.5. The corrected PER for air-dried, solvent-extracted corn germ was 2.29 while the heat-dried sample yielded a corrected PER of 2.04. The expeller-processed germ gave a corrected PER of 1.54. Their work showed protein quality was better retained by solvent extraction as opposed to expeller processing.

Sutescu, Zaharia, Rufinski, Septataenum, and Gontea (1972) increased the nutritive value of bread by adding corn germ consisting of 16.25% protein (N x 6.25) and 29.7% fat. They used 78% extracted white flour. The PER of wheat bread was 1.05. Adding 6% corn germ significantly increased the PER to 1.22.

Using the relative protein value (RPV) method, Canolty, Schoenborne, Gregg, and Haring (1977) studied defatted corn germ flour consisting of 20% protein (N x 6.25) and 2% fat on a dry basis. Protein value is defined as the slope of the regression line relating weight gain to protein intake. The RPV is the protein value expressed as a percentage of the protein value obtained for lactalbumin. The RPV obtained for casein was 0.71 while the RPV for corn germ flour was 0.62. The results concluded corn germ flour contained high-quality protein.

No reports in the literature state corn germ contains anti-nutritional factors as are found in other cereal grains. Two reports show raw corn to contain a bound form of niacin, possibly resulting in niacin deficient rats (Pearson, Stempfel, Valenzuela, Utley, and Darby, 1957). Niacin deficiency was reduced by steeping the corn in lime water, then neutralizing and drying it (Laguna and Carpenter, 1951) or by heat-treatment (Pearson <u>et al.</u>, 1957). Because corn germ is heat-treated, a bound form of niacin should not be present.

Wall <u>et al.</u> (1971) found in comparing air-dried, solvent-extracted corn germ with heat-dried, solvent-extracted corn germ no evidence for heat-labile anti-nutritional factors.

Clearly, defatted corn germ flour has been proven to be nutritionally desirable in terms of its composition and results obtained from animal feeding studies. Most studies concluded defatted corn germ flour contains good-quality protein and would be an acceptable protein supplement to food products.

PROCESSING ASPECTS

The use of defatted corn germ flour as a nutritional supplement to bread was studied by Tsen, Mojiban, and Inglett (1974) and Tsen (1975). Acceptable bread, in terms of specific volume and grain, could be obtained at a 12% fortification level by optimizing mixing time, bromate requirement, water absorption, and with the addition of a surfactant. In the United States the specific volume (cc/g) of acceptable bread must be above 6.0. A grain score below 5 on a scale from 1 to 10 is unsatisfactory. The composition of white flour in these studies was 12.5% protein (N x 6.25) and 0.39% ash on a 14% moisture basis. The corn germ flour was 5.9% moisture, 23.6% protein (N x 6.25), 10% ash, 0.09% fat, and 3.3% fiber (Tsen et al., 1974).

The use of defatted corn germ flour in bread decreased mixing time and increased water absorption and bromate requirement (Tsen et al., 1974). White bread required a mixing time of 9½ minutes, 50 ppm bromate, and 68% water absorption. Fortifying white flour with 12% corn germ flour decreased mixing time to 4½ minutes and increased bromate requirement to 70 ppm and water absorption to 84%. When corn germ flour was added at a level of 28%, the mixing time decreased to $2\frac{1}{2}$ minutes, the bromate requirement increased to 95 ppm, and water absorption increased to 100%. Under optimum conditions, the specific volume obtained for white bread was 6.65 with a grain score of 9. With the replacement of 12% corn germ flour, the specific volume dropped to 4.16 and the grain score decreased to 4. Increasing the corn germ level to 28% decreased the specific volume to 2.76 and grain score to 2.

Only with the addition of a surfactant can acceptable bread be obtained. Surfactants act by improving shelf life, increasing mixing tolerance, increasing dough strength, and increasing loaf volume (Newbold, 1976). Tsen and Hoover (1971) report that one surfactant, sodium stearoyl-2 lactylate (SSL), imparts strength to dough to increase the loaf volume. SSL is more dispersible in a dough system than shortening. Thus, it is more effective in forming complexes with gluten to strengthen dough structure. Tsen, Hoover, and Phillips (1971) report the addition of SSL or calcium stearoyl-2 lactylate (CSL) to high-protein breads yields acceptable bread that could not be otherwise obtained. Surfactants are thought to improve shelf life by retarding the rate of crumb firming which is a function of the slow crystallization of amylopectin (MacDonald, 1968).

With the addition of the surfactant, SSL, the specific volume of 12% corn germ bread is 6.69 with a grain score of 8 (Tsen et al., 1974). Even with the addition of SSL, acceptable bread could only be obtained at a 12% level of fortification. Increasing the amount of corn germ flour decreased the specific volume to below 6.0.

Other surfactants, including ethoxylated monoglycerides, sucrose monopalmitate, sucrose tallowate, sucrose distearate, and sucrose mono- and di-stearate, also improved 12% corn germ bread with acceptable results (Tsen, 1975).

Corn germ flour was also added to hot dog buns (Tsen, 1975); beef patties (Anon, 1975 and Blessin, Garcia, Deatherage, Cavins, and Inglett, 1973b); muffins (Blessin et al., 1973b and Anon, 1975); and cookies (Anon, 1975; Blessin et al., 1973b; and Tsen and Weber, 1977) with acceptable results.

FLAVOR ASPECTS

Flavor work has been conducted on corn germ fortified cookies, beef patties, muffins, and hot dog buns, but not bread. Also, corn germ protein isolate has been studied in relation to its flavor aspects.

In taste panel tests on beef patties to which 10% corn germ flour had been added, no objectionable color, odor, or taste was reported (Anon, 1975). Acceptable taste, odor, and color resulted from panel work performed on muffins with 25% corn germ flour supplementation (Anon, 1975). Twenty-five percent corn germ cookies were found to noticeably differ from the control in terms of color and flavor, but were not considered objectionable (Anon, 1975).

Hot dog buns were acceptable in appearance, texture, grain, crumb color, flavor, and taste with up to 18% corn germ supplementation. The appearance, texture, and grain were acceptable in 24% corn germ hot dog buns, but flavor, crumb color, and taste were considered unsatisfactory (Tsen, 1975).

Texture, flavor, and taste were all considered acceptable in oatmeal and chocolate chip cookies fortified with up to 48% corn germ flour (Tsen and Weber, 1977).

Nielsen, Inglett, Wall, and Donaldson (1973) and Nielsen, Wall, Mueller, Warner, and Inglett (1977) studied corn germ protein isolate containing 74% protein (N x 5.4), 4.2% ash, 0.08% fiber, and 8% fat (Nielsen et al., 1973). The isolate was reported to be mild in flavor, a light tan color, soluble at neutral and low pH, and able to stabilize in an oil-water emulsion. By washing the protein isolate with 80% ethanol, most of the bound lipid was removed (Nielsen et al., 1977), reducing the lipid content to 0.15% and the phosphorus content from 1.7% to 0.9% (probably because the phospholipids were removed). Flavor profile analyses were done on these two compounds (Nielsen et al., 1977). The odor of corn germ protein isolate was described as being cereal-grainy and stale-musty. The flavor was reported to be bitter, astringent, grassy-beany, and stale-musty. After washing the corn germ protein isolate with 80% ethanol, the odor was described as being cereal-grainy. Bitter and grassy-beany were the flavor notes. Nielsen et al. (1977) concluded that removing the bound lipid from the corn germ protein isolate significantly reduced the number and intensity of the off-flavors.

CONCLUSION

From a nutritional standpoint, defatted corn germ flour would be a beneficial supplement to bread. It is rich in vitamins and minerals and high in protein. The quality of protein in corn germ is such that it performs well in PER studies.

Defatted corn germ flour has been used in baking studies as a supplement to high-protein white flour. After optimizing baking conditions and adding a surfactant, 12% corn germ bread was judged to be acceptable in specific volume and grain.

No research has been done on the flavor aspects of corn germ bread. However, flavor work has been reported on corn germ flour in cookies, hot dog buns, muffins, and beef patties. The flavor in all these products was judged acceptable. A flavor profile analysis on corn germ protein isolate, a refined product from corn germ flour, indicated the flavor of corn germ protein isolate was improved by removing the bound lipids.

Chapter 3

MATERIALS AND METHODS

The objectives of this investigation were to determine the processing, nutritional, and flavor aspects of corn germ bread. This section will discuss the materials and methods used to study these aspects.

MATERIALS

Baking Studies

Two hard red winter wheat flours were mixed to produce a bread flour of average protein content. Ross Milling Company, Wichita, KS, supplied a high-protein bread flour which was combined in a 1:1 ratio with a low-protein bread flour supplied by the Department of Grain Science and Industry at Kansas State University. The resulting protein content was 11.6% (N x 5.7). Lauhoff Grain Company, Danville, IL, supplied three defatted corn germ flours used for supplementation. Analytical data of flour and germ samples are given in Table 4. These samples were analyzed for protein, moisture, and ash according to AACC methods and fat which was analyzed according to AOCS methods.

Three surfactants were used in the baking studies: sodium

Table 4

Analytical Data For White Flours And Corn Germ Flours

Flour	Moisture %	Protein %	Crude Ash %	Crude Fat %
Defatted corn germ flour #1 (baking studies)	7.0	21.6 (N x 6.25)	8.7	2.2
Defatted corn germ flour #2 (baking studies)	7.1	19.8 (N x 6.25)	7.6	1.1
Defatted corn germ flour #3 (baking, nutrition, and flavor studies)	3.2	24.6 (N x 6.25)	7.2	1.6
White flour #1 KSU:Ross, 1:1 (baking studies)	12.2	11.7 (N x 5.7)	0.53	1.2
White flour #2 KSU:Ross, 1:1 (baking studies)	11.0	11.6 (N x 5.7)	0.5	0.80
White flour #3 KSU:Ross, 1:1 (baking and nutrition studies)	9.9	12.0 (N x 5.7)	0.51	0.90
White flour #4 KSU:Ross, 1:1 (baking and flavor studies)	11.0	11.5 (N x 5.7)	0.50	0.80
White flour #5 Ross (baking studies)	11.8	13.4 (N x 5.7)	0.54	0.70
White flour #6 KSU (baking studies)	13.0	10.2 (N x 5.7)	0.47	0.70
Vital wheat gluten	7.9	71.4 (N x 5.7)	0.86	1.1

stearoyl-2 lactylate (SSL) and ethoxylated mono-glycerides (EMG) from C. J. Patterson Company, Kansas City, MO, and polysorbate-60 from ICI United States Incorporated, Wilmington, DE.

Other baking ingredients were as follows: Red Star yeast, C & H sugar, Crisco shortening, and vital wheat gluten.

Nutrition Studies

Male weanling rats 3 to 4 weeks old, of the Charles River Strain were supplied through Animal Resources Facility, College of Veterinary Medicine, Kansas State University. Initial weights ranged from 57 to 68 grams.

METHODS

Processing Aspects

Farinograph

The C. W. Brabender Farinograph aids in determining optimum dough development time, stability, and optimum water absorption as described by AACC Method 54-21. This study utilized the constant weight procedure with the 50-gram bowl.

Farinograms were obtained for the following samples: KSU and Ross (1:1) white flour; Ross white flour; KSU white flour; and white flour fortified with 12%, 24%, and 36% corn germ flour. Water absorption, stability, and dough development time were determined.

Baking Studies

The K-State process for making high-protein breads (Tsen and

Tang, 1971) was used in this study. Ingredients, including basic and additional, are shown in Table 5. Batches included 700 grams flour plus additional ingredients to make two loaves of bread. Ingredients were premixed at speed 1 for 1 minute; mixed at speed 2 for optimum dough development time; divided into 500 gram pieces and rounded; fermented at 84°F and 86% R. H. for 40 minutes; molded and placed into loaf pans; proofed to height at 92°F and 96% R. H.; and baked at 425°F for 20 minutes. Volume (cc) and weight (g) were measured immediately after baking. Specific volume was calculated as cc/g. Grain scores were taken after the bread had cooled.

Machinery utilized were as follows: bread mixer with jacketed bowl from Hobart, ferment and proof cabinets from National Manufacturing Company, Molder from Moline, and revolving oven from Despatch.

The following types of bread were studied: KSU and Ross (1:1) white bread, 12% corn germ bread, 24% corn germ bread, and 36% corn germ bread. Results were statistically analyzed by one-way analysis of variance (Snedecor and Cochran, 1967).

Combination of Surfactants

Combinations of three different surfactants at five different levels were calculated. Because the maximum surfactant allowed by law (0.5%) is necessary to obtain optimum corn germ bread, combinations totalling more than or less than 0.5% were not used. Therefore, of

Table 5

Baking Ingredients
(based on baker's percentage)

Basic Ingredients	%
Flour	100.0
Yeast	3.0
Salt	2.0
Sugar	5.0
Water	optimum
Bromate	optimum
Corn germ	as desired
Additional Ingredients	
Surfactant	0.5
Shortening	3.0
Vital wheat gluten (replaced 3% of white flour)	3.0
Calcium propionate	0.25

125 possible combinations, only 15 were used. The three surfactants and levels of use are shown in Table 6. The purpose of combining surfactants was to determine the effects of surfactants singly or in combination on physical bread properties in 12% corn germ bread using basic ingredients. EMG, SSL, and polysorbate-60 were chosen over other surfactants for their superior baking performances. The results were statistically analyzed by one-way analysis of variance (Snedecor and Cochran, 1967).

Staling Study

The Bloom Gelometer detects changes in crumb firmness (Pyler, 1971). A freshly cut one-inch thick slice of bread was placed on a platform. Lead shot was released which depressed a one-inch thick plunger into the slice. Degree of firmness is expressed by grams of shot required to compress the slice 4 mm.

Three loaves of bread were baked according to the K-State process and individually packaged 1 hour after removal from the oven. Readings were taken 1 day, 3 days, and 5 days after wrapping, using one loaf of bread per day. From each loaf, three slices were taken, equidistant from each other. Readings were taken in the top, middle, and bottom portions of the slice. Results were statistically analyzed by two-way analysis of variance (Snedecor and Cochran, 1967).

Breads studied were as follows: KSU and Ross (1:1) white bread; 12% corn germ bread with 0.5% SSL; 12% corn germ bread with

Table 6

Formula Levels of Surfactants Singly or in Combination in 12% Corn Germ Bread

Treatment	% SSL	% EMG	% Polysorbate-60
1	0.125	0.375	-
2	0.375	0.125	-
3	0.125	0.125	0.25
4	-	0.125	0.375
5	0.375	-	0.125
6	-	0.375	0.125
7	0.25	0.25	-
8	-	0.25	0.25
9	-	0.5	-
10	0.125	-	0.375
11	0.125	0.25	0.125
12	0.5	-	-
13	0.25	0.125	0.125
14	-	-	0.5
15	0.25	-	0.25

0.5% SSL, 3% gluten, and 3% shortening; and 12% corn germ bread with 0.25% SSL, 0.25% EMG, 3% gluten, and 3% shortening.

Crumb Color

Crumb color was determined by an Agtron Multi-Chromatic Abridged Reflectance Spectrophotometer Model M-300A. The spectral modes and monochromatic wavelengths were as follows: red, 640 mu; green, 546 mu; yellow, 585 mu; and blue, 436 mu. Round, black construction paper with a two-inch square opening in the middle was placed in the sample viewing area to restrict color analysis to the center portion of a one-inch thick slice. Crust sample was prepared by removing as much crumb from the crust of a three-inch square sample as possible. Three crust and crumb samples were taken from KSU and Ross (1:1) white bread with 0.5% SSL and 12% corn germ bread with 0.25% SSL, 0.25% EMG, 3% gluten, and 3% shortening.

NUTRITION STUDY

Diets

Six diets were tested to determine PER (NAS-NRC, 1963 and Reddy, 1975) and digestibility (NAS-NRC, 1963): casein, white bread, 12% corn germ bread, 24% corn germ bread, 36% corn germ bread, and 100% corn germ flour.

Breads were prepared according to the K-State process except for standardizing proof time to 80 minutes. Basic ingredients were used plus SSL. When cooled, the breads were mechanically sliced and air dried in an oven at 23°C for 24 hours. After drying, the samples were ground in experimental mills into meals which passed through a 20-mesh wire screen. Samples were analyzed for moisture, protein, fat, and ash (AACC and AOCS).

Diets were calculated to contain: approximately 10% protein (N x 6.25 for casein and 100% corn germ diets and N x 5.7 for others); 2% vitamin premix, Table 7 (Reddy, 1975); 3% mineral premix, Table 8 and Appendix (Reddy, 1975); 5% oil; 2% fiber (casein diet only); and carbohydrate (3:1 ratio of cornstarch and sucrose) to equal 100%. Specific diet formulations are found in Table 9.

Rats

Rats, six per diet, were randomly placed in individual cages in rooms having temperature, humidity, and light control, located in the Veterinary Medicine Complex, Kansas State University. They were fed and given water ad libitum. Waste products were removed every other day. Grams feed intake were measured and spilled feed (very minimal) was measured and subtracted from intake. Rats were weighed weekly. Initial weights, weight gain, and feed intake were statistically analyzed by one-way analysis of variance (Snedecor and Cochran, 1967).

Protein Efficiency Ratio

PER was individually calculated as grams weight gain/grams

Table 7

Vitamin Premix

Vitamin	g/100 g diet
Vitamin A 10,000 IU/g	0.2
Vitamin D 15,000 IU/g	0.062
Alpha-tocopherol succinate (25%)	0.035
Menadione sodium bisulphate	0.0056
Thiamine HCl	0.00125
Pyridoxine	0.0012
Riboflavin	0.0025
Niacin	0.015
Calcium pantothenate	0.008
Choline chloride	0.8
Vitamin B_{12}	0.005
Cornstarch (carrier)	0.9088

Table 8

Mineral Premix (g/100 g diet)

Diet	Calcium carbonate	Dicalcium phosphate	Potassium chloride	Sodium chloride	Magnesium sulfate	Trace minerals	Cornstarch
Casein	0.42	1.60	0.332	0.4	0.2	0.05	-
White bread	0.303	1.65	0.170	0.1	0.075	0.05	0.652
12% Corn germ bread	0.44	1.41	0.16	0.1	-	0.05	0.84
24% Corn germ bread	0.54	1.22	0.15	0.1	-	0.05	0.94
36% Corn germ bread	0.63	1.05	0.15	0.1	-	0.05	1.5
100% Corn germ flour	1.25	-	0.10	0.1	-	0.05	1.5

Table 9

Diet Formulations (g/100 g diet)

Diet	Meal to provide 10% protein	Vitamin premix	Mineral premix	Fiber	Oil	Sucrose 1:3	Cornstarch
Casein	12.20	2	3	2	5	19.95	56.84
White bread	80.65	2	3	-	5	2.36	7.08
12% Corn germ bread	76.34	2	3	-	5	3.44	10.31
24% Corn germ bread	71.94	2	3	-	5	4.54	13.61
36% Corn germ bread	70.42	2	3	-	5	4.92	14.75
100% Corn germ flour	55.24	2	3	-	5	8.71	26.14

protein intake (NAS-NRC, 1963) over a period of four weeks. Corrected PERs were obtained by adjusting the PER of casein to 2.5 and multiplying the other PERs by that adjustment constant. Results were statistically analyzed by one-way analysis of variance (Snedecor and Cochran, 1967).

Digestibility

Feces were collected and weighed twice weekly during the last two weeks of the four week study. They were air dried, ground in a Stein mill, and analyzed for protein (AACC). Digestibility was individually calculated as grams protein intake - grams protein in feces/grams protein intake (NAS-NRC, 1963). This number is multiplied by 100 to obtain percent digestibility. Results were statistically analyzed by one-way analysis of variance (Snedecor and Cochran, 1967).

FLAVOR ASPECTS

Acceptable (in volume and grain) 12% corn germ bread was subjected to flavor profile analysis and consumer acceptability testing. The flavor profile (Caul, 1957) describes odor, flavor, aftertaste, and amplitude of a product. Odor and flavor notes are described and intensities assigned to them. Aftertaste notes are described and duration estimated. Amplitude attempts to define how well a product is blended. Consumer acceptability tests attempt to judge consumers' response to a food product (Larmond, 1971).

Flavor Profile Analysis

Five trained tasters participated in the flavor profile analysis. Sessions were held twice weekly at 9:30 A.M. The first four sessions were devoted to describing the odor and flavor components in white bread in order to acquaint the panel members with bread. The fifth and sixth sessions were spent in becoming familiar with corn germ bread. Samples of white flour, white flour in solution, toasted white flour, toasted white flour in solution, corn germ flour, corn germ in solution, yeast solution, and watery caramel syrup were introduced as references to aid the panel members in describing odor and flavor components. Actual profile analysis began in the seventh session. Panel members were given uniform slices of 12% corn germ bread and individually determined odor and flavor notes and intensities and aftertaste. Discussions were held after individual analysis to clarify each person's conclusions. The final profile analysis, including amplitude was obtained in the fifth week.

White bread was made according to the K-State process and included the basic ingredients plus 0.5% SSL. The K-State process was followed to make 12% corn germ bread which included the basic ingredients plus 0.25% SSL, 0.25% EMG, 3% gluten, and 3% shortening. Breads were packaged 1 hour after baking in two thick plastic bags and frozen. They were thawed at room temperature the night before analysis.

Consumer Acceptability Test

Twelve percent corn germ bread, prepared with basic ingredients plus 0.25% SSL, 0.25% EMG, 3% gluten, 3% shortening, and 0.25% calcium propionate according to the K-State process, was judged by consumers. These consumers included 15 untrained American graduate students and their spouses in Grain Science, Food Science, and Agronomy. They were given the questionnaire (Table 10) and a loaf of bread baked the previous afternoon. They consumed and evaluated the bread at home, then returned the questionnaire. Results are reported. Questions 2 and 3 were statistically analyzed by the chi-square test (Snedecor and Cochran, 1967).

Table 10

Consumer Acceptability Form

This study is being run to determine the consumer acceptability of this bread by graduate students and their spouses in the departments of Grain Science, Food Science, and Agronomy. This bread is made according to conventional formulas and contains no harmful ingredients. Take the loaf of bread home and eat it as you normally would. Please answer the questions below. The questionnaire can be returned to either Susan Boero (Shellenberger 215) or George Boero (Waters 107A). Thank you for your cooperation.

1. In what way did you use this bread?

   husband: toast sandwich bread & butter other________

   wife: toast sandwich bread & butter other________

2. Was this bread acceptable to you in terms of flavor and texture?

   husband: yes______ no______

   wife: yes______ no______

3. Would you buy this bread at the grocery store?

   husband: yes______ no______

   wife: yes______ no______

4. Any comments you would like to make about this bread?

Chapter 4

RESULTS AND DISCUSSION

Processing

Farinographic Studies

Farinograms, Table 11, indicated approximate water absorption, dough development time, and stability of white flours and white flour supplemented with corn germ flour. Adding 12% corn germ flour increased water absorption and decreased stability. Further increasing supplementation to 24% and 36% increased water absorption, decreased dough development time, and decreased stability. According to the farinograms, corn germ supplementation weakens the dough structure. Less mixing time would be needed as compared to white flour for optimum dough development.

KSU flour exhibited low water absorption, dough development time, and stability as compared to Ross flour. Mixing the two flours produced a flour with average water absorption, dough development time, and stability.

Baking Studies

Mixing time, bromate requirement, water absorption, specific volumes, and grain scores for white bread and corn germ bread are shown in Table 12. Mixing time was decreased from approximately 7

Table 11

Farinograms of White Flour and Flour Supplemented With Corn Germ Flour

Flour	Absorption %	Dough development minutes	Stability minutes
White flour #1 KSU: Ross, 1:1	60.8	5.0	13.25
+ 12% Corn germ flour #1	77.2	5.0	5.0
+ 24% Corn germ flour #1	89.0	2.0	5.25
+ 36% Corn germ flour #1	98.2	2.0	5.25
White flour #2 KSU: Ross, 1:1	65.0	2.5	6.5
White flour #3 KSU: Ross, 1:1	65.4	8.5	16.0
White flour #4 KSU: Ross, 1:1	62.6	5.5	16.0
White flour #5 Ross	66.0	7.5	13.5
White flour #6 KSU	59.0	2.0	5.0

minutes for KSU: Ross (1:1) white flour to 4 minutes for 12% corn germ supplementation. Supplementing with 24% and 36% corn germ flour further decreased mixing time. The decrease in mixing time with corn germ supplementation indicated a weakened dough structure; therefore, less time was needed for optimum dough development.

Bromate requirement was increased from 35 ppm to 75 ppm (legal limit) for 12%, 24%, and 36% corn germ breads. Optimum bromate requirements in 24% and 36% corn germ breads are probably higher than 75 ppm. Because that would exceed legal limits, additional bromate was not added. Bromate acts by oxidizing some reducing agents in flour to improve its baking performance. Corn germ flour contains some reducing agents, so more bromate is required.

Water absorption was increased with corn germ flour supplementation. The increases in water absorption and bromate requirement and decrease in mixing time with corn germ flour supplementation are supported by Tsen (1974).

Specific volume was reduced from 6.51 for white bread to 5.52 for 12% corn germ bread. Using a flour of average-protein content failed to produce acceptable specific volume, even with the addition of SSL. Grain score dropped from 9 to 7, still acceptable. Further increasing corn germ supplementation produced unacceptable bread.

Using Ross high-protein flour to make 12% corn germ bread slightly increased water absorption and mixing time and significantly ($p = .05$) increased specific volume although still below acceptable

Table 12

Mixing Specifications and Baking Characteristics for
White Bread and Bread Supplemented with Corn Germ Flour

Flour	Mixing time minutes	Bromate ppm	Water absorption %	Specific volume cc/g	Grain
White flour #1 + SSL	7.0	35	66	6.51	9
+ 12% Corn germ flour	4.0	75	75	5.52	7
+ 24% Corn germ flour	2.0	75	80	3.12	4
+ 36% Corn germ flour	3.0	75	87	2.11	2
White flour #2 + 12% corn germ flour + SSL	4.0	75	75	5.14	7
White flour #3 + 12% corn germ flour + SSL	4.0	75	80	5.14	7
Ross flour #5 + 12% corn germ flour + SSL	4.5	75	84	5.88	7
KSU flour #6 + 12% corn germ flour + SSL	3.0	75	76	5.44	8

levels. KSU flour, a weak flour, lowered mixing time and water absorption in 12% corn germ bread, although specific volume was not significantly ($p = .05$) different from 12% corn germ bread made with KSU and Ross (1:1) white flour (Table 12).

Combination of Surfactants

Table 13 and Appendix B show differences among means ($p = .01$) due to surfactants added to 12% corn germ bread. Even with surfactant combinations, acceptable 12% corn germ bread was not obtained. Treatment 7 (0.25% SSL and 0.25% EMG) produced the highest mean but was not significantly ($p = .05$) different from treatments 3, 4, 5, 8, 9, or 14. Treatment 12 (0.5% SSL) was among the lowest means but not significantly ($p = .05$) different from treatments 1, 2, 6, 10, 11, 12, 13, or 15.

These results do not seem to show any definite pattern (Figure 1), although polysorbate-60 and EMG singly or in combination seem to give consistently higher specific volumes than either SSL and polysorbate-60 or SSL and EMG. It cannot be conclusively stated that with increasing amounts of one surfactant and decreasing amounts of another surfactant there is a predictable specific volume response. It is not known whether the lack of predictable responses is due to random error in the experiment or the effects of surfactants combining with each other. Because previous unpublished results have shown the combination of 0.25% SSL and 0.25% EMG to give consistently

Table 13

Results of Surfactants Singly or in Combination

Treatment*	Specific Volume (mean ± standard error)	Grain
1	5.11 ± 0.07 E	8
2	5.19 ± 0.02 BCDE	8
3	5.31 ± 0.06 AB	8
4	5.31 ± 0.02 A	8
5	5.29 ± 0.09 ABCD	8
6	5.25 ± 0.04 BCDE	8
7	5.43 ± 0.07 A	8
8	5.31 ± 0.08 AB	8
9	5.31 ± 0.06 ABC	8
10	5.16 ± 0.04 BCDE	8
11	5.15 ± 0.04 CDE	8
12	5.14 ± 0.07 DE	8
13	5.13 ± 0.02 E	8
14	5.31 ± 0.06 ABC	8
15	5.16 ± 0.04 BCDE	8
LSD, .05	0.159	

-like means are indicated by same letter

*See Table 6

high volume and grain score and produced the highest specific volume in this study, this combination was chosen to be used for the rest of the baking studies.

Additional Ingredients

By adding gluten or shortening or both to 12% corn germ bread and using a combination of surfactants, 12% corn germ bread became physically acceptable (Table 14 and Appendix B). Adding 3% shortening in addition to 0.5% SSL significantly increased (p = .05) specific volume from 5.14 to 5.46. The addition of 3% gluten significantly increased (p = .05) specific volume from 5.14 to 5.70, although the specific volumes resulting from the addition of 3% gluten or 3% shortening were not significantly (p = .05) different from each other. When both 3% gluten and 3% shortening were incorporated in 12% corn germ bread (in addition to 0.5% SSL), specific volume increased to 6.08, a significant (p = .05) improvement over each separate ingredient. By using a combination of surfactants, 0.25% SSL and 0.25% EMG, in addition to 3% shortening and 3% gluten, specific volume significantly (p = .05) increased to 6.47.

Although SSL is said to have a shortening-sparing effect (Tsen and Hoover, 1971), both SSL and shortening seem necessary in 12% corn germ bread made with an average-protein flour to obtain physically acceptable bread. Gluten gives added strength to the structure of 12% corn germ bread. Even though the addition of gluten,

Table 14

Twelve Percent Corn Germ Breads

Ingredients	Specific volume (mean ± standard error)
White flour #3 + 0.5% SSL	6.72 ± 0.11
+ 12% Corn germ flour #2 + 0.5% SSL	5.14 ± 0.06
+ 12% Corn germ flour #2 + 0.5% SSL + 3% Gluten	5.70 ± 0.08 A
+ 12% Corn germ flour #2 + 0.5% SSL + 3% Shortening	5.46 ± 0.04 A
+ 12% Corn germ flour #2 + 0.5% SSL + 3% Gluten + 3% Shortening	6.08 ± 0.05
+ 12% Corn germ flour #2 + 0.25% SSL + 0.25% EMG + 3% Gluten + 3% Shortening	6.46 ± 0.07

-like means are indicated by same letter

shortening, and SSL to 12% corn germ bread produced acceptable bread, a combination of the surfactants SSL and EMG produced a specific volume nearer to that of white bread.

<u>Staling</u>

The analysis of variance table shows interaction to be significant ($p < .01$), therefore, variation due to treatment or day becomes irrelevant (Appendix B). Table 15 shows white bread made with 0.5% SSL not significantly ($p = .05$) different from 12% corn germ bread made with 0.25% SSL, 0.25% EMG, 3% shortening, and 3% gluten on day 1, day 3, or day 5. It can be concluded these two breads stale at the same rate.

The staling rates of 12% corn germ bread made with 0.5% SSL and that made with 0.5% SSL, 3% shortening, and 3% gluten were significantly ($p = .05$) different from each other and the other two treatments. Staling rate was increased in 12% corn germ bread made with 0.5% SSL because of lower specific volume, therefore, denser crumb. As the crumb becomes less dense, staling occurs at a slower rate. These results conclude when crumb denseness is approximately equal, corn germ flour has no adverse effect on staling rate.

Staling rate occurs linearly for each treatment (Figure 2). High correlation coefficients indicate actual data to be very close to the estimated regression line.

Table 15

Staling Rates of 12% Corn Germ Breads and White Bread
(mean grams shot ± standard error)

	Treatment			
	12% corn germ flour #2 + 0.5% SSL	12% corn germ flour #2 + 0.5% SSL + 3% shortening + 3% gluten	12% corn germ flour #2 + 0.25% SSL + 0.25% EMG + 3% shortening + 3% gluten	white flour #4 + 0.5% SSL
Day 1	183.3 ± 11.45	111.2 ± 4.97	90.4 ± 1.87 A	85.8 ± 4.08 A
Day 3	283.7 ± 16.66	161.4 ± 3.92	140.4 ± 3.19 B	152.3 ± 4.03 B
Day 5	394.0 ± 11.98	198.1 ± 9.89	177.9 ± 2.50 C	187.9 ± 6.71 C

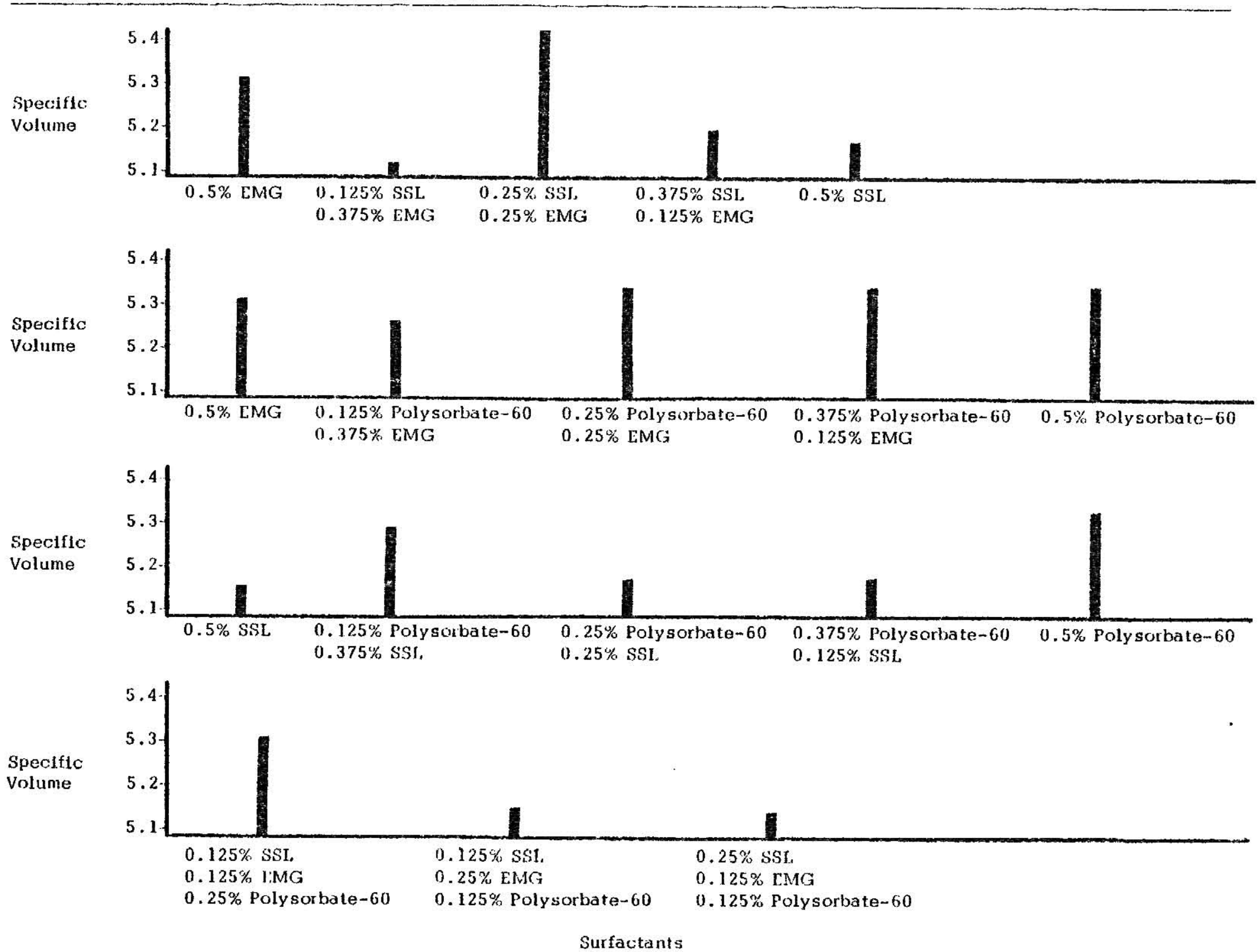
-like means are indicated by same letter

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

Figure 1

Histograms of Effect of Surfactants Singly or in Combination On Specific Volume



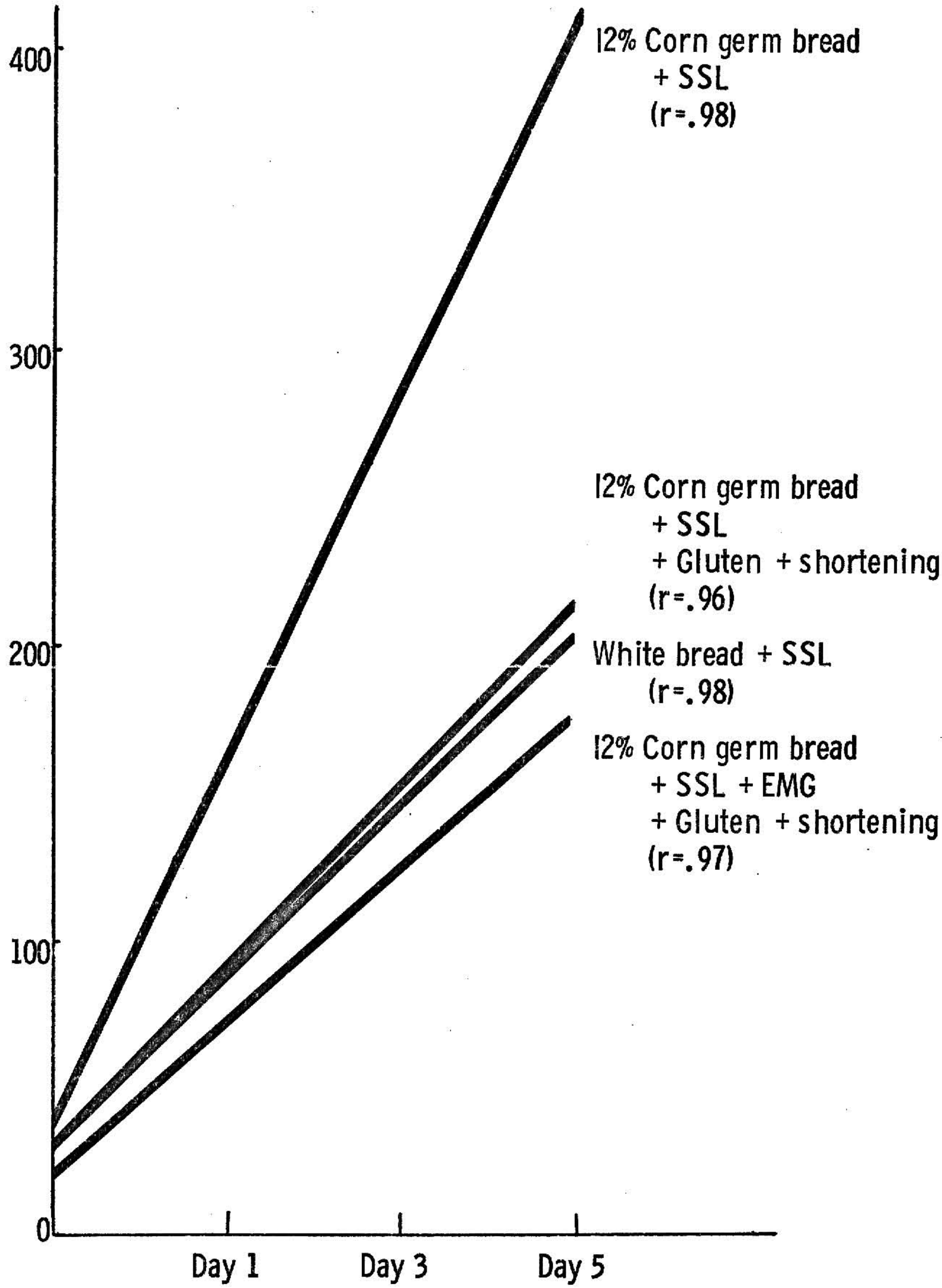


FIGURE 2 - STALING REGRESSION PLOT

Crumb and Crust Colors

Results from the Agtron Multi-Chromatic Spectrophotometer indicate 12% corn germ bread made with 0.25% SSL, 0.25% EMG, 3% gluten, and 3% shortening absorbs more blue, yellow, green, and red color in the crumb and crust than does white bread made with 0.5% SSL (Table 16). Because 12% corn germ bread is higher in protein than white bread, the crust of 12% corn germ bread should be darker due to increased browning reaction. The crumb of 12% corn germ bread is gray yellow which would exhibit more color than white bread.

NUTRITION

PER Studies

As stated, diets including sources of protein from casein; white bread; 12%, 24%, and 36% corn germ breads; and 100% corn germ flour were studied for their PER values. Analytical data of these breads are given in Table 17. In addition to PER data, initial weights, weight gain, and feed intake were statistically analyzed.

Appendix B depicts analysis of variance results for initial weights. No differences are seen among the means. For accurate results from PER studies, no significant differences in initial weights should be detected.

Analysis of variance table, Appendix B, show differences in weight gain for rats on different diets. Casein and 100% corn germ flour diets show no significant ($p = .05$) difference in weight gain.

Table 16

Crumb and Crust Colors
(% absorbance)

Treatment	Color							
	Blue		Yellow		Green		Red	
	discs 00-68		discs 00-75		discs 00-75		discs 00-75	
	crumb	crust	crumb	crust	crumb	crust	crumb	crust
White Bread	74.7	4.7	92.7	13.9	90.1	9.5	99.9	24.9
12% Corn germ bread + 0.25% SSL + 0.25% EMG + 3% Gluten + 3% Shortening	50.4	3.8	76.2	8.9	74.2	6.3	87.8	16.4

Table 17

Analytical Data for White Bread and Corn Germ Breads
(dry basis)

Bread (+ SSL)	Protein (N x 5.7) %	Ash %	Fat %
White bread	13.0	2.42	0.44
12% Corn germ bread	13.9	2.85	0.44
24% Corn germ bread	14.6	3.36	0.56
36% Corn germ bread	14.9	3.68	0.89

Also showing no difference in weight gain were: white bread and 12% corn germ bread diets; 12% and 24% corn germ bread diets; and 24% and 36% corn germ bread diets. Differences should be detected in weight gain. PER measures growth promoting value of protein sources. Sources containing high-quality protein should result in higher weight gains than low-quality protein. Table 18 shows with increases in weight gain, PER increases.

Differences are also seen among feed intake means (Table 18 and Appendix B). Casein and 100% corn germ flour diets are not significantly ($p = .05$) different. Rats on these two diets ate much more than rats on other diets, possibly because of the high-quality protein of casein and corn germ flour which would contribute to healthier rats. White bread, 12% corn germ bread, and 24% corn germ bread diets show no differences in feed intake ($p = .05$). Table 18 depicts with increasing feed intake, PER increases. Because PER measures grams weight gain per gram protein intake, feed intake should not make any difference in PER, only the quality of feed intake should affect PER.

The analysis of variance table for PER data (Appendix B) shows differences among means; 100% corn germ flour is equally effective as casein in promoting growth ($p = .05$) (Table 18). White bread is significantly ($p = .05$) less effective in promoting growth than 12% corn germ bread. With increasing amounts of corn germ supplementation, 24% and 36%, there are significant ($p = .05$) increases in PERs. Figure 3 illustrates the linear relationship of PER to increasing amounts of

Table 18

Rat Protein Efficiency Ratio Data
(mean ± standard error)

Diet	Protein in diet, %	Initial weight, g	Weight gain, g	Feed intake, g	PER	Corrected PER
Casein	11.4	60.3 ± 0.56	154 ± 10.56 A	404 ± 29.39 A	3.35 ± 0.04 A	2.50
White bread	10.3	60.7 ± 0.80	28 ± 3.33 B	216 ± 13.09 B	1.20 ± 0.08	0.90
12% Corn germ bread	10.1	61.5 ± 1.61	35 ± 3.05 BC	224 ± 9.82 B	1.55 ± 0.09	1.16
24% Corn germ bread	10.3	62.2 ± 1.35	52 ± 2.33 CD	264 ± 8.41 BC	1.92 ± 0.03	1.43
36% Corn germ bread	10.1	62.2 ± 0.87	65 ± 5.69 D	283 ± 13.70 C	2.32 ± 0.10	1.73
100% Corn germ flour	11.8	61.0 ± 0.73	163 ± 12.4 A	403 ± 22.15 A	3.42 ± 0.16 A	2.55
LSD, .05			21.209	51.139	0.268	

-like means are indicated by same letter

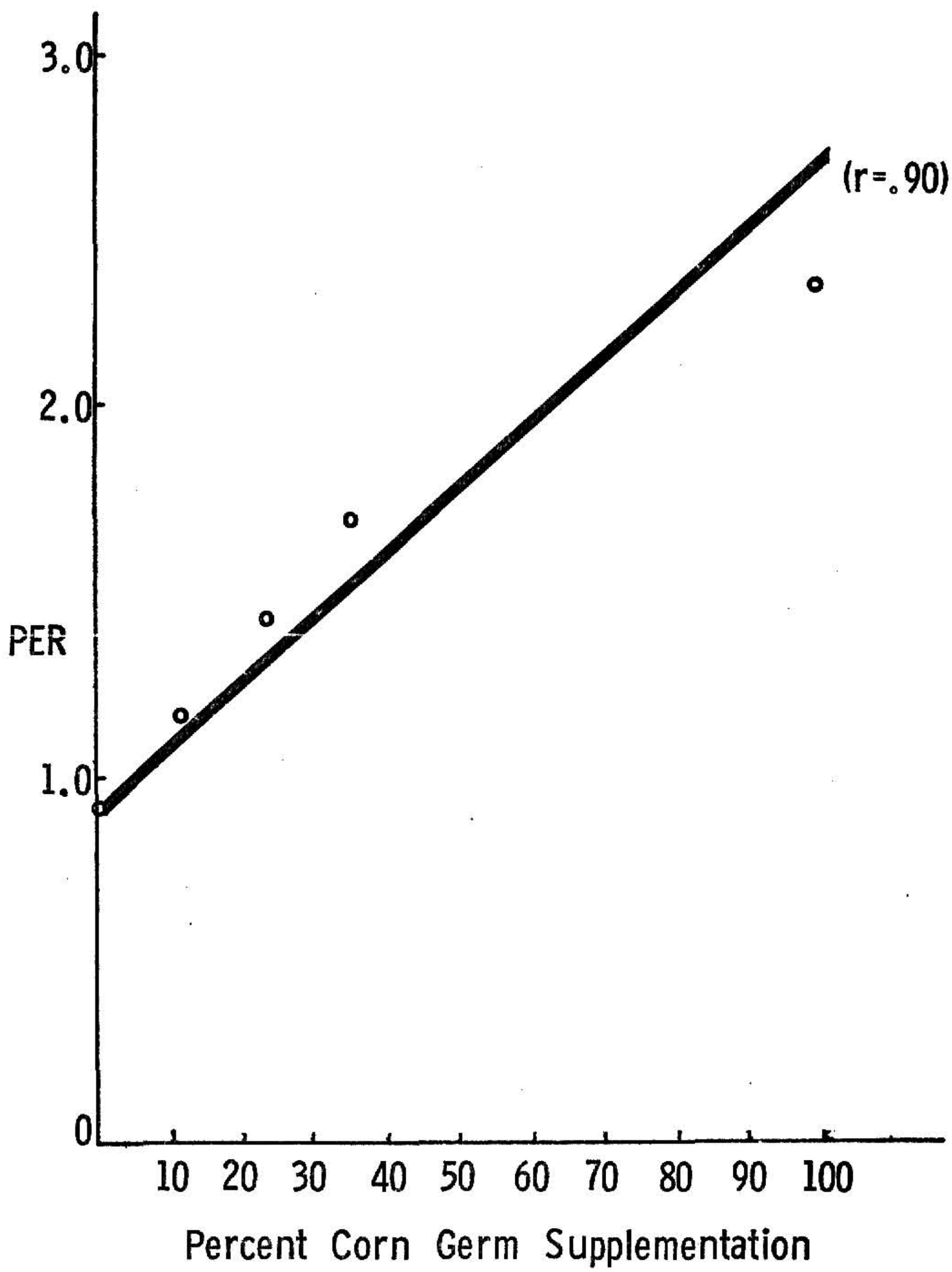


FIGURE 3 - PROTEIN EFFICIENCY RATIO REGRESSION PLOT

corn germ supplementation (r = .90).

Literature well supports the performance of 100% corn germ flour in this study. Other studies have found 100% corn germ flour to contain high quality protein, but none relate to growth promoting value of defatted corn germ flour in bread.

Digestibility

Differences were detected among digestibility means of the different diets (Table 20 and Appendix B). Casein showed the highest digestibility, 92%. 100% corn germ flour gave the lowest digestibility, 76%. White bread yielded a digestibility of 82%. The digestibility of 12% corn germ bread, 88%, and 24% corn germ bread, 86%, were not significantly different (p = .05). Also not significantly different (p = .05) were 24% corn germ bread and 36% corn germ bread, 85%.

Digestibility for 100% corn germ flour corresponds well to what has been reported in the literature. This study indicates corn germ flour to increase the digestibility of white bread, 82%, to 88% in 12% corn germ bread. With increasing amounts of corn germ supplementation, digestibility is decreased (Figure 4).

The low digestibility of 100% corn germ flour could be due to its high pentosan and fiber content. These materials are not easily digested. Matter in the intestine may pass through more quickly allowing less nitrogen to be absorbed. It is noticed (Table 19) that rats on 100% corn germ flour diet ate approximately the same amount

Table 19

Rat Digestibility Data
(mean ± standard error)

Diet	Protein in diet %	Feed intake g	Feces weight g	Protein in feces %	Digestibility
Casein	11.4	269 ± 13.79	14.43 ± 0.87	17.23 ± 0.77	0.92 ± 0.0025
White bread	10.3	96 ± 11.63	6.30 ± 0.65	27.94 ± 1.28	0.82 ± 0.01
12% Corn germ bread	10.1	110 ± 7.90	5.90 ± 0.34	22.94 ± 0.81	0.88 ± 0.0048 A
24% Corn germ bread	10.3	130 ± 4.34	8.30 ± 0.46	22.30 ± 0.33	0.86 ± 0.0025 AB
36% Corn germ bread	10.1	146 ± 3.57	10.9 ± 0.23	20.77 ± 0.70	0.85 ± 0.0025 B
100% Corn germ flour	11.8	207 ± 31.56	37.7 ± 6.46	16.00 ± 0.75	0.76 ± 0.0025
LSD, .05					0.20

-like means are indicated by same letter

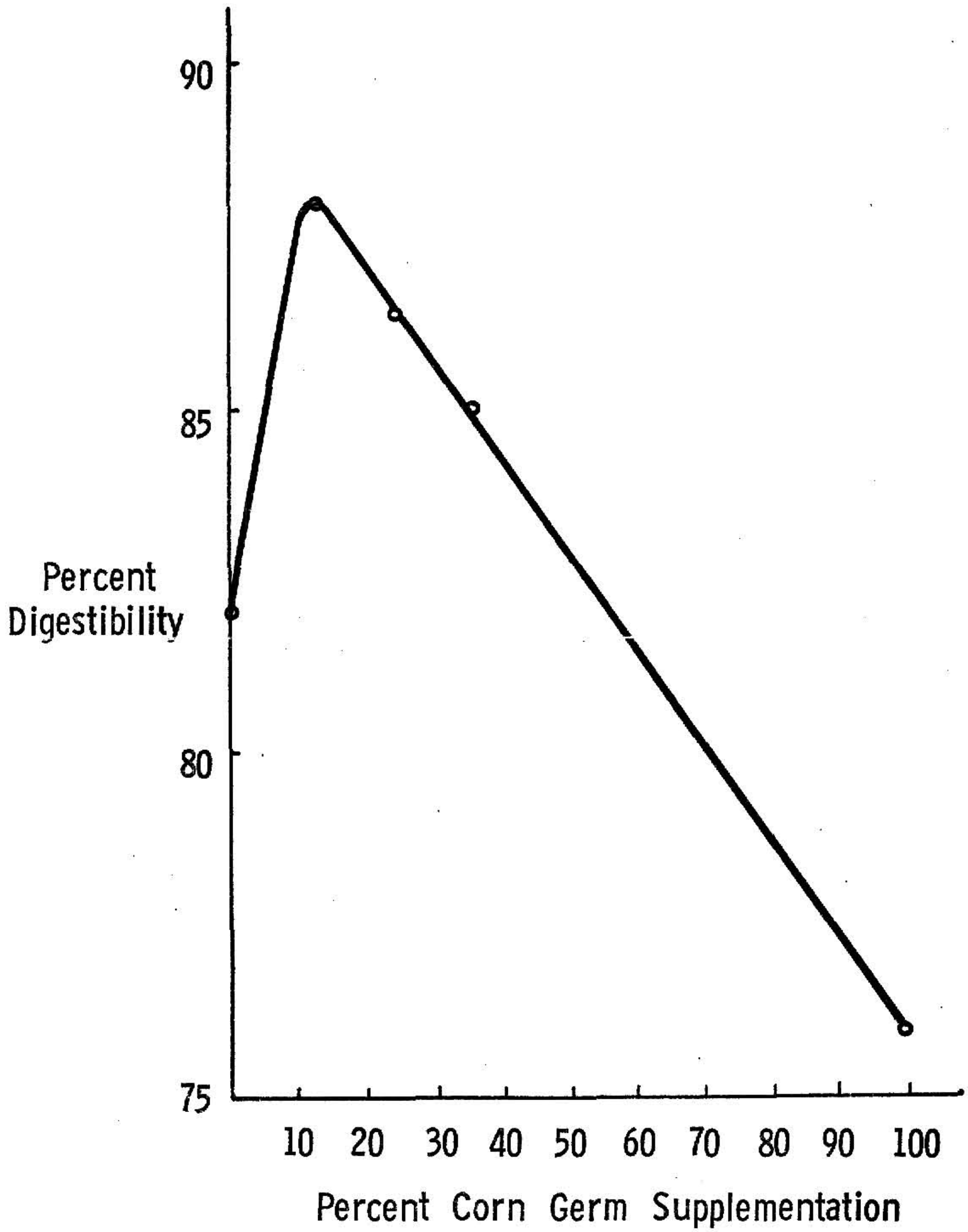


FIGURE 4 - DIGESTIBILITY PLOT

as rats on the casein diet, but the amount of feces were more than twice as much.

The increase in digestibility as 12% corn germ flour is added to white bread may be due to the fiber from corn germ flour. The white bread diet was possibly low in fiber, resulting in rats not as healthy as those on the 12% corn germ bread diet. Further increases in corn germ flour increased the amount of indigestible material, possibly decreasing nitrogen absorption.

FLAVOR

Flavor Profile

Flavor profile findings for 12% corn germ bread are shown in Table 20. In both crumb aroma and flavor, doughy (including yeasty, sweet, flour-starch, and alcohol) and corn germ notes were detected at the same time and at approximately the same intensities. A slight sweetness was detected in the crumb. No bitterness was detected. Both crust aroma and flavor were described as slightly browned to burnt and had a coffee note present. Slight bitterness was detected in the crust flavor.

The crumb aroma and flavor were fairly well blended. Amplitude ratings were 2 and 2+ respectively. Crust aroma and flavor were not well blended.

The crumb aftertaste was of short duration and consisted primarily of a corn germ note. Bitter and a browned to burnt flavor were

Table 20

Flavor Profile of 12% Corn Germ Bread

		Note	Intensity	Amplitude
AROMA				
	Crumb	Doughy	1	2
		Corn germ	1-	
		Others		
		Sweet	)(	
		Alcohol	1+	
	Crust	Browned to burnt	1+	1
		Coffee	)(	
		Bitter	1	
FLAVOR				
	Crumb	Slight lag		2+
		Doughy	1-	
		Corn germ	1	
		Sweet	1-	
		Others		
		Alcohol	)(	
		Sour	)(+	
	Crust	Bitter	1	1
		Browned to burnt	1	
		Coffee	)(	
AFTERTASTE				
	Crumb	Short duration		
		Corn germ		
		Others		
		Doughy		
		Sweet		
	Crust	Moderate duration		
		Bitter		
		Browned to burnt		

Intensity scale:)(threshold; 1 slight; 2 medium; 3 strong

Amplitude scale: 1 poorly blended; 2 fairly blended; 3 well blended noted in the crust aftertaste which were of moderate duration.

The profile analysis attempts to describe the flavor of a food product, not judge it. After undergoing a profile analysis, 12% corn germ bread was judged by consumers.

Consumer Acceptability

Of thirty consumers who judged 12% corn germ bread, twenty-four found it to be acceptable and six found it not acceptable in flavor and texture. A chi-square test found 12% corn germ bread to be definitely acceptable ($p = .05$).

When asked if they would buy it at the store, eighteen responded yes and twelve no. A chi-square test found this significant ($p = .05$), concluding consumers may not buy 12% corn germ bread even though they find it acceptable.

When asked to comment about 12% corn germ bread, many liked the crumb flavor but found the crust flavor to be objectionable. Those who said they would not buy the bread gave the reason that they normally bought wheat bread. Two said they would buy it only if it were cheaper than white bread.

Because this group of consumers is not a representative sample of the bread-buying public, it is possible the results may be biased, but impossible to say how much or in which way the biasing occurs.

Chapter 5

CONCLUSION

The goals of this research were to produce 12% corn germ bread, using average-protein white flour and defatted corn germ flour, which was acceptable in loaf volume and grain, nutritionally superior to white bread, and acceptable in flavor and texture. If this goal were met, 12% corn germ bread would be an excellent example of a product that makes use of a nutritional food source traditionally used as animal feed.

The specific volume of 12% corn germ bread made with basic ingredients plus 0.25% SSL, 0.25% EMG, 3% gluten, and 3% shortening was 6.47 with a grain score of 8, both acceptable by United States standards. In animal nutrition tests, corn germ flour was found to be equal to casein in growth promoting value and inferior in digestibility. White bread made from average-protein white flour was found to be significantly ($p = .05$) less nutritious than 12% corn germ bread. The flavor and texture of 12% corn germ bread were judged acceptable, but a significant ($p = .05$) amount of consumer testers said they would not buy the product for various reasons. Essentially the goals were met, except that these consumers preferred not to buy 12% corn germ bread, although some liked it.

LITERATURE CITED

AACC. 1962. Approved Methods. American Association of Cereal Chemists. St. Paul, Minn.

Anon. 1975. New 18-25% cereal protein to become commercially available. Food Prod. Dev. 36:19.

AOCS. 1971. Official and Tentative Methods. 3rd ed. American Oil Chemists Society. Chicago, Ill.

Beeson, W. M., W. P. Lehrer, E. Woods. 1947. Peas, supplemented with wheat germ or corn germ as a source of protein for growth. J. Nutr. 34:587.

Blessin, C. W., W. J. Garcia, W. L. Deatherage, J. F. Cavins, and G. E. Inglett. 1973b. Updates applications of corn germ flour. Food Engineering. 45:78.

Blessin, C. W., W. J. Garcia, W. L. Deatherage, and G. E. Inglett. 1971. An edible defatted germ flour from a commercial dry-milled corn fraction. Cer. Sci. Today. 19:224.

Blessin, C. W., G. E. Inglett, W. J. Garcia, and W. L. Deatherage. 1972. Defatted germ flour --food ingredient from corn. Food Prod. Dev. 6:34.

Bloksma, A. H. 1971. Rheology and chemistry of dough. In Y. Pomeranz, ed. Wheat Chemistry and Technology. American Association of Cereal Chemists. St. Paul, Minn.

Canolty, N. L., B. M. Schoenborne, V. A. Gregg, and R. V. Haring. 1977. Relative protein value of defatted corn germ flour. J. Food. Sci. 42:269.

Caul, J. F. 1957. The profile method of flavor analysis. In E. M. Mrak and G. F. Stewart, eds. Advances in Food Research, Vol. 7. Academic Press.

Hove, E. L., L. E. Carpenter, C. G. Harrel. 1945. The nutritive quality of some plant proteins and the supplemental effect of some protein concentrates on patent flour and whole wheat. Cereal Chem. 22:287.

Jones, D. B. and K. D. Widness. 1946. The comparative growth promoting value of the proteins of wheat germ, corn germ, and of some other protein foods of plant and animal origin. J. of Nutr. 31:675.

Laguna, J. and K. J. Carpenter. 1951. Raw versus processed corn in niacin deficient diets. J. Nutr. 45:21.

Larmond, E. 1970. Methods for sensory evaluation. Publ. 1284. Food Research Institute. Central Experiment Farm, Ottawa. Canadian Dept. of Agriculture.

MacDonald, J. 1968. The functional properties of various surface active agents. Baker's Dig. 42:24.

Mertz, E. T. 1970. Nutritive value of corn and its products. In G. E. Inglett, ed. Corn: Culture, Processing, Products. AVI Publishing Co., Inc.

Mitchell, H. H. and J. R. Beadles. 1944. Corn germ: A valuable protein food. Science 99:129.

Murlin, J. R., L. E. Edwards, S. Fried, T. A. Szymanski. 1946. Biological value of proteins in relation to the essential amino acids which they contain. III. Comparison of proteins with mixtures of amino acids. J. Nutr. 31:715.

NAS. 1971. Atlas of Nutritional Data on United States and Canadian Feeds. National Academy of Science. Washington, D. C.

NAS-NRC. 1963. Evaluation of Protein Quality. Publ. 1100. Food and Nutrition Board. National Academy of Science-National Research Council. Washington, D. C.

NAS-NRC. 1974. Recommended Dietary allowances. Food and Nutrition Board. National Academy of Science-National Research Council. Washington, D. C.

Newbold, M. W. 1976. Crumb softeners and dough conditioners. Baker's Dig. 50:37.

Nielsen, H. C., G. E. Inglett, J. S. Wall, and G. L. Donaldson. 1973. Corn germ protein isolate - preliminary studies on preparation and properties. Cereal Chem. 50:435.

Nielsen, H. C., J. S. Wall, J. K. Mueller, K. Warner, and G. E. Inglett. 1977. Effect of bound lipid on flavor of protein isolate from corn germ. Cereal Chem. 54:503.

Pearson, W. N., S. J. Stempfel, J. S. Valenzuela, M. H. Utley, and W. J. Darby. 1957. The influence of cooked versus raw maize on the growth of rats receiving a 9% casein ration. J. Nutr. 62:445.

Pyler, E. J. 1973. Baking Science and Technology. Seibel Publishing Co. Chicago, Ill.

Reddy, P. R. K. 1975. High-protein breads from wheat flour fortified with peanut flour and peanut-soy blends and their nutritive values. Master's Thesis. Dept. of Grain Science and Industry, Kansas State University, Manhattan, Kansas.

Reussner, G. and R. Thiessen. 1957. Studies on the protein quality of high-oil, high-protein corn. J. Nutr. 62:575.

Schulz, J. A., and B. H. Thomas. 1949a. The biological value of the proteins of corn germ and endosperm wet milled experimentally. Cereal Chem. 26:67.

Schulz, J. A. and B. H. Thomas. 1949b. The biological value of some commercial corn protein fractions. Cereal Chem. 26:60.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods, 6th ed. The Iowa State University Press. Ames, Iowa.

Stare, F. J. and D. M. Hegsted. 1944. The nutritive value of wheat germ, corn germ, and oat proteins. Fed. Proc. 3:128.

Sutescu, P., I. Zaharia, A. Rujinski, A. Septetaenu, I. Gontea. 1972. Increasing nutritive value of bread by maize germ addition. Igiena. 21:647.

Tsen, C. C. 1975. Defatted corn germ flour, a nutritive ingredient for breadmaking. Baker's Dig. 49:42.

Tsen, C. C. and W. J. Hoover. 1971. The shortening-sparing effect of sodium stearoyl-2 lactylate and calcium stearoyl-2 lactylate in breadbaking. Baker's Dig. 45:38.

Tsen, C. C., W. J. Hoover, and D. Philips. 1974. High-protein breads. Use of sodium stearoyl-2 lactylate and calcium stearoyl-2 lactylate in their production. Baker's Dig. 45:20.

Tsen, C. C., C. N. Mojiban, and G. E. Inglett. 1974. Defatted corn germ flour as a nutrient fortifier for bread. Cereal Chem. 51:262.

Tsen, C. C. and R. T. Tang. 1971. K-State process for making high-protein breads. I. Soy flour bread. Baker's Dig. 45:26.

Tsen, C. C. and J. Weber. 1977. Corn germ flour a nutritive ingredient for cookies. Food Prod. Dev. 49:22.

Wall, J. S., C. James, and J. F. Cavins. 1971. Nutritive value of protein in hominy feed fractions. Cereal Chem. 48:546.

Watt, B. K. and A. L. Merrill. 1963. Composition of Foods. Agriculture Handbook No. 8. Agriculture Research Service. United States Department of Agriculture. Washington, D. C.

APPENDIX A

Mineral Calculations

A. Mineral content of flours:

Sample	Calcium mg/100 g	Phosphorus mg/100 g	Potassium mg/100 g	Magnesium mg/100 g
Corn germ flour[1]	14	510	130	280
White flour[2]	16	95	95	25

1. NAS (1971)
2. Watt and Merrill (1963)

B. Requirements for rat (g/100 g): .5 grams calcium; .4g phosphorus; .18 grams potassium; and .2 grams magnesium.

C. Contents
   1. Calcium phosphate contains 18% phosphorus, 22% calcium.
   2. Calcium carbonate contains 40% calcium, 60% carbonate.
   3. Molecular weight of potassium chloride is 75.5, 39 potassium and 36.5 cloride.

D. Example - In 12% corn germ bread there is 10.7% corn germ and 89.3% white flour.

$$\frac{100\%\ \text{corn germ}}{14\ \text{mg calcium}} = \frac{10.7\%\ \text{corn germ}}{X\text{mg Ca}}$$

$$\frac{100\%\ \text{white flour}}{16\ \text{mg calcium}} = \frac{89.3\%\ \text{white flour}}{Y\text{mg calcium}}$$

X + Y = A (total mg calcium in 12% corn germ bread)
.5g - A = B (calcium needed to meet requirements)

If phosphorus needed to meet requirements = C, then:

$$\frac{18.5g}{100\ g} = \frac{C}{R}$$

R = Ca P to add to give C mg phosphorus

To check calcium:

$$\frac{22}{100} = \frac{S}{R}$$

S = mg calcium present in X amount Ca P

If S is larger than B, don't worry. If S is smaller than B, add $CaCO_3$.

If phosphorus contest is all right, then use $CaCO_3$ to supplement Ca.

$$\frac{B\ (100)}{.40} = T$$ (grams $CaCO_3$ to give B amount of calcium)

Potassium calculations-

$$\frac{39}{75.5} = \frac{D}{E}$$

D = mg potassium to meet requirements

E = amount KCl needed to give D amount of potassium

Note: The writer would not recommend this method. It would be better to prepare a premix that meets rat requirements. Slight excess amounts of minerals will not be harmful.

APPENDIX B

1. Surfactants Singly or in Combination

Source of variation	Degrees of freedom	Mean square	F value
Treatment	14	0.0540	2.82
Error	75	0.0191	
Total	89		

2. Twelve Percent Corn Germ Breads

Source of variation	Degrees of freedom	Mean square	F value
Treatment	5	2.842	77.89
Error	35	0.037	
Total	40		

3. Staling Study

Source of variation	Degrees of freedom	Mean square	F value
Treatment	3	138176.875	233.918
Day	2	133754.938	226.433
Treatment x day	6	8344.453	13.938
Error	96	590.705	
Total	107		

4. Rat Initial Weight

Source of variation	Degrees of freedom	Mean square	F value
Treatment	5	3.561	0.53
Error	30	6.661	
Total	35		

5. Weight Gain

Source of variation	Degrees of freedom	Mean square	F value
Treatment	5	21653.074	66.91
Error	30	323.627	
Total	35		

6. Feed Intake

Source of variation	Degrees of freedom	Mean square	F value
Treatment	5	43198.188	22.96
Error	30	1881.533	
Total	35		

7. PER

Source of variation	Degrees of freedom	Mean square	F value
Treatment	5	5.149	99.68
Error	30	0.052	
Total	35		

8. Digestibility

Source of variation	Degrees of freedom	Mean square	F value
Treatment	5	0.01180	65.35
Error	18	0.00018	
Total	23		

CORN GERM BREAD: PROCESSING, NUTRITIONAL, AND FLAVOR ASPECTS

BY

SUSAN N. BOERO

B. S., California Polytechnic State University, 1974
San Luis Obispo, California

An Abstract of a Master's Thesis submitted in partial fulfillment for the degree of

MASTER OF SCIENCE
FOOD SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

ABSTRACT

Average-protein white flour was supplemented with defatted corn germ flour to make corn germ bread. Processing aspects, nutritional quality, and flavor aspects were studied.

After mixing time, bromate requirement, and water absorption were optimized and with the addition of 0.25% SSL, 0.25% EMG, 3% gluten, and 3% shortening, corn germ bread of acceptable baking quality was prepared at the 12% level of supplementation. Average specific volume of this bread was 6.47 as compared to 6.51 for white bread. The grain score was 8 for 12% corn germ bread as compared to 9 for white bread.

Diets made from the following protein sources were studied for protein efficiency ratio and digestibility: casein, white bread, 12% corn germ bread, 24% corn germ bread, 36% corn germ bread, and 100% corn germ flour. Respective corrected PER and digestibility values are given: casein, 2.5 and 92%; white bread, 0.90 and 82%; 12% corn germ bread, 1.16 and 88%; 24% corn germ bread, 1.43 and 86%; 36% corn germ bread, 1.73 and 85%; and 100% corn germ flour, 2.55 and 76%.

It was concluded defatted corn germ flour was equal to casein in its growth promoting value but digestibility was inferior. Twelve

percent germ bread was significantly better ($p = .05$) in growth promoting value than white bread. Significant improvements ($p = .05$) were also seen in 24% and 36% corn germ bread. Digestibility was significantly improved ($p = .05$) over white bread with the addition of 12% corn germ flour. Increasing levels of corn germ flour decreased digestibility, but all were still significantly better ($p = .05$) than white bread.

Flavor profile analysis and a pilot consumer acceptability test were performed on acceptable 12% corn germ bread. A profile analysis attempts to describe the flavor of a product. Crumb aroma was described as being slightly doughy and corn-germy with occasional sweet and alcohol notes. Slightly burnt and bitter notes were detected in the crust aroma in addition to a threshold coffee note. The crumb flavor exhibited a slight initial lag and was described as being slightly doughy, corn-germy, and sweet. Other notes detected were alcohol and sour at threshold levels. The crust was described as being slightly burnt and bitter with a threshold coffee note present. The crumb aftertaste was of short duration and described as corn-germy. Bitter and burnt notes were present in the crust aftertaste, which was of moderate duration. Amplitude describes how well the product is blended. The crumb aroma and flavor were judged to be fairly well blended while the crust aroma and flavor were poorly blended.

Of the thirty consumers who participated in the consumer acceptability test, twenty-four judged 12% corn germ bread acceptable in flavor and texture. When asked if they would buy the product at the store, twelve said no, a significant number ($p = .05$). Reasons given were they did not like the product or they normally bought whole wheat breads.

The purpose of this study was to prepare acceptable 12% corn germ bread nutritionally superior to white bread and acceptable in flavor and texture. Essentially, these goals were achieved except consumers said they liked the product but would not buy it.