THE EFFECT OF PROTEIN CONTENT AND ALPHA-AMYLASE ACTIVITY ON THE BAKING PROPERTIES OF TRITICALE FLOUR.

A Thesis

Presented to

The Faculty of Graduate Studies

of

The University of Manitoba

by

Beverly Anne Fyfe

In partial fulfillment of requirements

for the degree of

Master of Science

June, 1985

THE EFFECT OF PROTEIN CONTENT AND ALPHA-AMYLASE ACTIVITY ON THE BAKING QUALITY OF TRITICALE FLOUR

BY

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A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

ACKNOWLEDGEMENTS

The author wishes to recognize and thank Agriculture Canada and the Manitoba Department of Agriculture for partial financial support of this research through the Agroman project. The assistance of Pioneer Grain Company Ltd. is acknowledged for supplying grain samples.

The technical assistance and guidance of M. Latta, S. Johnson, M. Rourke, R. Zillman, R. Weselake, R. Oree and R. Pena is acknowledged with deep appreciation and gratitude. The general assistance of the staff members of the Department of Foods and Nutrition who served as sensory panel members is also gratefully acknowledged. The guidance of Dr. J.F. Brewster of the Statistics Department in the analysis of data is greatly appreciated.

The support and guidance of my advisor, Dr. B. Watts, in the planning and executing of the study and her assistance in preparing this report is acknowledged. Appreciation is expressed to Dr. W. Bushuk and R. Diamant for their patience and support.

Finally, the author wishes to extend her thanks to Doug and Jenna Fyfe for their patience and consideration.

ABSTRACT

Alpha-amylase activity was determined for 26 grade 1 and 18 grade 2 triticale milling samples, which had been assessed visually for percent sprouted kernels. The linear coefficient of correlation (r) between percent sprouted kernels and alpha-amylase activity for all 44 samples was low (r = 0.39). Mean activities were 2.38±2.60 and 4.34±5.27 IDC units/mg for grades 1 and 2 respectively. Within both grades there was a wide range of alpha-amylase activities, from 0.13 to 9.99 IDC units/mg for grade 1 and from 0.50 to 19.04 IDC units/mg for grade 2 samples.

Whole-grain triticale flours, prepared from a low (11.2%) and a high (14.4%) protein triticale, and each formulated to achieve 4 ranges of alpha-amylase activity, were tested for proximate composition, color, farinograph characteristics, falling numbers, and were baked into yeast breads, muffins and sour cream coffee cakes, using consumer-style recipes. Pup loaves were also baked, but water levels were varied in the formulation. For the consumer yeast breads and muffins, 50% of the flour used was all-purpose, and 50% bread flour was used in pup loaves. A whole-wheat flour served as a control throughout the baking studies.

Low protein flours contained 0.37, 2.94, 4.93 and 6.25 IDC units/mg for alpha-amylase ranges 1 to 4, and the high protein flours contained 1.07, 3.37, 5.26 and 7.05 IDC units/mg. Triticale flours were extremely high in alpha-amylase activity by comparison to the wheat flours

(0.07 to 0.12 IDC units/mg). High protein flours had a mean farinograph absorption of 69.6% while absorption for low protein flours was 64.5%. High protein flour produced slightly longer development times than low protein (3.81 vs. 3.35 minutes), but poorer mixing tolerances (115 vs. 52 B.U.). All triticale flours had shorter development times, shorter stabilities and lower mixing tolerances than wheat flours.

High protein flours produced significantly higher volumes than low protein flours in consumer-style yeast breads (1894 vs. 1776 cc), pup loaves (677 vs. 646 cc) and muffins. Volume was affected by flour alpha-amylase activity, generally decreasing as alpha-amylase increased; however low protein content yeast breads, and low and high protein content pup loaves had higher volumes with alpha-amylase in the 2 middle ranges. Higher levels of alpha-amylase resulted in lower crumb quality and higher moistness scores for all products. Instrumental assessments of crumb texture reflected differences in volume and density of the crumb; coffee cakes and yeast breads became firmer and gummier with lower volumes. Yeast breads, pup loaves and muffins baked from high protein flour were judged to be of better overall quality than the low protein flours at all levels of alpha-amylase activity. The use of higher water levels in pup loaf formulations exaggerated the effects of protein content and alpha-amylase activity on volume and crumb quality characteristics, while lower water levels minimized the effects.

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I. INTRODUCTION

Triticale is a new cereal species synthesized by crossing the genomes of wheat (Triticum) and rye (Secale). Plant breeders developed triticale using synthetic hybridization techniques to introduce advantageous genes into the new cereal. The combination of the winter hardiness and vigor of the rye parent with the recognized agronomic and quality characteristics of wheat make triticale a desirable crop species to supplement food resources in a world where population growth and food shortages are apparent.

The first fertile triticale was described by Rimpau in Germany in 1891, however attempts to intercross some of the naturally occurring triticale were generally unsuccessful prior to the 1930's. During the 30's and 40's, synthesis of fertile intergeneric hybrids could be made because of the discovery of the chromosome doubling ability of colchicine. It was not until 1954 that the first intensive triticale development program was initiated at the University of Manitoba, Winnipeg, Manitoba. This research was launched with the establishment of the Rosner Research Chair in the Department of Plant Science at the University of Manitoba. Many of the best lines produced were intercrossed to overcome some of the deficiencies of early crosses. In 1964, a cooperative program in triticale breeding was established

between the Department of Plant Science at the University of Manitoba and CIMMYT (International Maize and Wheat Improvement Center) in Mexico, which resulted in a continual interchange of triticale breeding material between Canada and Mexico (Bushuk and Larter, 1980; Zillinsky and Borlaug, 1971).

Triticale has some agronomic as well as nutritional advantages over wheat. Triticale has proved itself in areas of the world where adverse soil conditions and plant diseases restrict wheat growth (Bushuk and Larter, 1980). Accurate figures of world production of triticale grain are unavailable, however triticale could well become an important commercial crop for human use. Triticale has been described as having a higher protein content, a slightly better balance of essential amino acids and a somewhat higher lysine content (Villegas et al, 1970) than wheat.

The commercial success of triticale not only depends on its agronomic and nutritional advantages, but also on the post-harvest quality of the grain. Triticale as a flour is generally known to have inferior baking quality relative to wheat (Haber et al, 1976; Lorenz, 1972; Tsen et al, 1973; Unrau and Jenkins, 1964). It has been reported that the poor baking quality of triticale is due to two factors: (1) low gluten protein content and inferior gluten protein quality (Tsen et al, 1973) and (2) high alpha-amylase activity

(Lorenz, 1972; Singh, 1976). Inferior baking quality along with inconsistency in quality characteristics has limited the acceptability of the flour.

Triticale flour became popular in the late 1970's and early 1980's when increasing amounts of whole-grain flour were marketed for home and commercial baking. The flour appealed to consumers because of its good flavor and image as a healthful whole-grain food. Some users however, experienced problems with triticale due to its inconsistent baking performance. Much of the variability can be attributed to differences in alpha-amylase activity and protein content. At the same time, grading standards for triticale were established. Grading standards for grain are based on many characteristics of which percent sprouted kernels is one. The relationship between percent sprout damage, alpha-amylase activity and the baking quality of wheat flour has been investigated, however this relationship has not been studied in triticale grain. Triticale for milling is selected on the basis of grade and percent sprout damage alone, and neither protein content nor actual alpha-amylase activity are indicated in the selection criteria.

Therefore, this study investigated the relationship between alpha-amylase activity and visible sprout damage in triticale grain, and the relationship of alpha-amylase activity and protein content to the baking quality of triticale

flour. The objectives of the present study were as follows:

1. To determine whether alpha-amylase activity correlated with visible sprout damage in triticale grain.
2. To investigate the relationship of alpha-amylase activity to the baking quality of triticale flour using a consumer-style bake test for muffins, sour cream coffee cake and yeast bread and a standard pup loaf bake test.
3. To investigate the relationship of protein content to the baking quality of triticale flour using a consumer-style bake test for muffins, sour cream coffee cake and yeast bread, and a standard pup loaf bake test.
4. To investigate interrelated effects of alpha-amylase activity and protein content on the baking quality of triticale flour using a consumer-style bake test for muffins, sour cream coffee cake and yeast bread, and a standard pup loaf bake test.

II. LITERATURE REVIEW

A. Genetics and Agronomic Background of Triticale

Plant breeders have long been interested in combining the hardiness, vigor and tolerance to poor soils of rye, with the baking quality characteristics of wheat. The result of their efforts has been the development of triticale, a hybrid synthetic species named by combining parts of the generic names of its two parents Triticum (wheat) and Secale (rye). Durum wheat when crossed with rye results in a hexaploid (six sets of chromosomes) triticale, while bread wheat crossed with rye results in an octaploid (eight sets of chromosomes) triticale. Practically all of the advanced lines of triticale are hexaploids, because they are more fertile and productive than the octaploids, however the hexaploids have usually been crossed with an octaploid triticale or a bread wheat at some stage of development to introduce bread wheat characteristics (Bushuk and Larter, 1980). Lorenz (1974a) has written a comprehensive review of the development of triticale.

Triticale has much larger spikes and kernels than wheat, and therefore may have the potential for higher yields. For regions of the world where adverse soil conditions or plant diseases restrict wheat growth, it has been claimed that triticale has proved to be a superior crop for human

use (Bushuk and Larter, 1980). In the United States however, early triticale lines were not competitive with the best wheat varieties even when locations and environmental conditions differed widely (Lebsock, 1974; Welsh and Lorenz, 1974; Rooney et al, 1969; Ruckman et al, 1973). The improved agronomic characteristics of more recently developed triticale lines have resulted in higher yields. In Canada, by 1980, triticale outyielded the highest yielding wheat varieties (Bushuk and Larter, 1980). Even with improved agronomic performance, triticale, to be competitive with wheat for human use, must have comparable milling and baking quality.

B. Composition of Triticale Grain

The proximate composition of triticale is similar to wheat, although the two species differ in some compositional respects. Table 1 presents the proximate composition as given by various authors for triticale and wheat grains. The values presented are for a number of cultivars grown under widely varying conditions. Triticale protein content has been reported to be slightly higher than that of wheat by most researchers. Fat, carbohydrate and ash contents of triticale and wheat grains were reported to be similar.

Table 1. Approximate Gross Composition (14% m.b.) of Triticale and Wheat Grains

	Triticale	Wheat
Moisture		
Bushuk & Larter (1980)	9.5 - 12.9	9.5 - 12.0
Lorenz & Welsh (1977)	9.7 - 12.9	10.0 - 11.9
Protein, total		
Bushuk & Larter (1980)	12.7	11.6
Ruckman et al (1973)	13.2 - 14.7	12.0 - 13.2
Lorenz & Welsh (1977)	9.5 - 17.7	9.1 - 17.8
Anderson et al (1974)	12.0 - 14.7	12.6 - 14.1
Rooney et al (1969)	15.6 - 16.3	14.4 - 18.0
Unrau & Jenkins (1964)	14.0 - 16.6	14.7 - 14.8
Kaltsikes & Larter (1970)	16.1 - 16.7	16.4
Lorenz (1972)	12.7 - 14.6	12.7 - 14.3
Fat, crude		
Bushuk & Larter (1980)	1.3	1.6
Anderson et al (1974)	1.3 - 1.7	1.6 - 1.9
Carbohydrate, total		
Bushuk (1980)	67.1	67.1
Ash		
Bushuk & Larter (1980)	1.7	1.7
Anderson et al (1974)	1.7	1.7
Lorenz & Welsh (1977)	1.7 - 2.1	1.6 - 1.8

C. The Relationship of Protein Content and Composition to Baking Quality of Triticale Flour

Tsen et al (1973) have suggested that the poor baking quality of triticale flour could be due to low gluten protein content and inferior gluten protein quality. In terms of inherent factors in flour, it is well established that the main factor controlling mixing requirements and baking characteristics in wheat flour is the gluten protein. Since triticale also forms gluten, it is likely that these characteristics are also controlled primarily by the gluten component. Generally gluten protein would be expected to increase with increasing total protein content, therefore it is likely that high protein content triticale flour would ensure better baking characteristics. Protein solubility distributions and amino acid compositions (Chen and Bushuk, 1970) of triticale protein are pertinent to the gluten quality and functional baking properties.

1. Total Protein Content and Baking Quality

It is the higher total protein and higher lysine content of most triticale varieties, when compared to wheat, which have caused interest in this cereal (Villegas et al, 1970; Sikka et al, 1978). In addition to the nutritional implications, protein content is a factor which affects the baking quality.

Studies from the early development period (1960's) of triticale report high protein contents. For the 1969-1970 crop year, Zillinsky and Borlaug (1971) have reported protein contents ranging from 11.0 - 15.4% for 191 lines of triticale grown in the CIMMYT program in Mexico. Unrau and Jenkins (1961) found that protein contents of their samples ranged from 14.1 to 15.6% (14% m.b) with an average of 15.1%, which was comparable to the wheat protein contents which they tested. Analysis of 25 varieties or crosses of triticale grown in 1964 by Villegas et al (1970) found an average protein content of 15.0% (14% m.b.)

Studies emerging from the 1970's showed a decline of triticale protein content, which approached that of wheat. Wu et al (1978) reported that high yielding triticales had 10.5 to 13.5% protein compared to 10 to 12% in bread wheats grown in the same fields at CIMMYT in Mexico. Ruckman et al (1973) found triticale had higher whole-grain protein content than wheat (14.0% vs. 12.3%) for 3 triticales and 3 wheats grown in 5 locations in California. Larter et al (1980) reported that although there exists a considerable range in protein among the strains of triticale over the years, the overall average was approximately 3% above the average values for wheat.

Early triticale lines had shrivelled seeds because of poor endosperm development, and it is likely that the

high protein contents reported for this period, were due to the higher ratio of bran to endosperm. With improvements in grain type producing plumper kernels, protein contents have declined somewhat and now approach those of wheat.

Studies have shown that the protein content of triticale is strongly affected by the environment as is the protein content of wheat. Ruckman et al (1973) and Welsh and Lorenz (1974) grew three triticale lines and three wheat varieties in California and Colorado respectively, using various locations in each state. The grain protein contents were quite variable, ranging from 13.2 to 14.7% (14% m.b.) in California and 12.8 to 19.7 (14% m.b.) in Colorado. The protein contents for the hard red spring wheat controls ranged from 12.0 to 13.7% and 9.9 to 17.3% respectively. The triticale protein was slightly higher than the wheat protein at both locations.

For wheat of one variety, protein content is the major factor accounting for variation in loaf volume. The relationship between protein content and volume is linear; the higher the protein content the greater the volume of bread, and generally, the gluten component is expected to increase with increasing protein contents of flours (Finney and Barmore, 1948). Because triticale lacks some of the gluten-forming properties of wheat (Tsen et al, 1973), it would be logical to use triticale flour which has a high

protein content to ensure a better baking quality flour.

Little data can be found to demonstrate the relationship of protein content and gluten protein to loaf volume for triticale flour. Singh (1976) determined the effect of triticale protein content on pup loaf volume, using seven triticale varieties. There was no clear relationship between volume and protein content, possibly because of the confounding effect of variable alpha-amylase levels within flour. Lorenz and Welsh (1977) found that within a triticale strain, as the flour protein increased, there was no corresponding increase in bread loaf volume.

2. Effects of Protein Composition on Baking Quality

Triticale appears to have an inferior baking quality to wheat due to low gluten protein content (Chen and Bushuk, 1970; Ahmed and McDonald, 1974). It is also likely that triticale gluten is inferior to that of bread wheats as a result of the partial or total absence of D-genome chromosomes in the background of hexaploid triticales (Kerber and Tipples, 1969). Proteins coded for by D-genome chromosomes make an important contribution to the baking and mixing properties of wheat flours.

The contribution of flour components to baking quality has been extensively studied in wheat. It is well

accepted that factors associated with mixing requirements are interrelated with factors associated with baking quality (Finney et al, 1982). Booth and Melvin (1979) and MacRitchie (1978) found that differences in baking quality between wheat flours were accounted for by differences in gluten character when fractionation - reconstitution studies were carried out.

When a dough is washed with sodium chloride solutions, the starch and soluble materials are washed out and gluten, a rubbery mass, remains. Gluten comprises 78 - 85% of the total flour protein in bread wheats (Pence et al, 1954). Gliadin, glutenin and residue protein (insoluble glutenin) are the main protein fractions of gluten. In order to produce a dough with appropriate elasticity that is able to tolerate mechanical work and to maintain structure during the stages of breadmaking, and to be sufficiently extensibile to allow for dough expansion, suitable proportions of gliadin and glutenin are required. When added to flour these proteins tend to increase mixing time, mixing tolerance and loaf volume potential of a flour (Harris and Frokjer, 1952; Preston and Tipples, 1980). Residue protein also contributes importantly to the mixing properties of wheat flours (Preston and Tipples, 1980; Shogren et al, 1969).

Chen and Bushuk (1970) examined the protein solubility distributions of triticale flour milled from the line 6A-190, its parent durum (Stewart) and rye (Prolific), and a hard red spring wheat flour (Manitou). Proteins were extracted in a manner similar to the classical fractionation procedure of Osborne (1907) using water, salt, alcohol and acetic acid solutions. The solubility distribution of triticale proteins was intermediate between those of its parents as shown in Table 2. In comparison to hard red spring wheat, triticale had more water soluble protein (albumin), slightly more salt-soluble protein (globulin), slightly less alcohol soluble protein (gliadin), similar acetic acid soluble protein (glutenin) and considerably less residue protein. The same solubility fractionation procedure was used by Ahmed and McDonald (1974) on seven newer varieties of triticale. For all cultivars the amounts of solubility fractions were similar to those reported by Chen and Bushuk (1970). The deficiency in residue protein was reported to be a major factor influencing the inferior quality of triticale flours.

When synthetic flours were reconstituted with residue, and with glutenin and gliadin - like fractions, Pena (1984) found that control of the baking potential of triticale and wheat flours resided in the combined effects of glutenin and gliadin proteins. Synthetic flour reconstituted

Table 2. Proportion (%) of Protein[1] in Fractions Extracted by Various Solvents[2]

Fraction	Triticale	Rye	Durum Wheat	Hard Red Spring Wheat
Water soluble (albumin)	26.4	34.3	12.2	11.9
Salt soluble (globulin)	6.5	10.7	4.7	5.2
Alcohol soluble (gliadin)	24.4	19.0	40.7	28.5
Acetic acid soluble (glutenin)	17.3	9.4	18.3	16.6
Residue (insoluble glutenin)	19.0	20.6	23.2	34.0
Nitrogen recovery (%)	93.6	94.0	99.1	96.2

1 Percent of total protein (14% m.b.).

2 Chen and Bushuk (1970a).

with residue protein actually decreased loaf volume.

Triticale amino acid composition reflects the difference in proportion of fractions between triticale and wheat. When the amino acid composition of triticale (6A-190) was compared to that of its actual parental species durum (Stewart) and rye (Prolific) and a hard red spring wheat (Manitou), most amino acids were found to be at levels between those of durum and rye (Chen and Bushuk, 1970). These data are in agreement with those of Yong and Unrau (1966) who determined the amino acid content of triticale, rye, and durum grown under similar environmental conditions. Compared with hard red spring wheat, triticale had a lower glutamic acid content and higher aspartic acid and lysine contents. These results are compatible with the solubility characteristics of proteins examined by Chen and Bushuk (1970). It is recognized that water soluble wheat flour proteins are higher in aspartic acid and lysine contents and that wheat gluten is higher in glutamic acid content. The lower glutamic acid content of triticale protein may be pertinent to its functional breadmaking properties.

3. Farinograph Characteristics and Baking Quality

The rheological properties of dough are used to predict the bread-making quality of flours. Reported farinograph data indicate that triticale flours have considerably

shorter dough development times and lower mixing tolerances (higher M.T.I. values) than wheat flours. Most researchers report triticale flour absorptions, as indicated by the farinograph, to be lower than those of wheat. Table 3 summarizes farinograph characteristics obtained by several researchers.

Singh (1976), Ahmed and McDonald (1974), Rooney et al (1969), Tsen et al (1973), Haber et al (1976) and Lorenz and Welsh (1977) reported weak mixing curves with lower peak times, shorter stabilities and lower mixing tolerances for triticale flours when compared to wheat flours. The short development and stability times and lower mixing tolerances of triticale flours suggest that they have less gluten for dough development. The weaker dough structure will not form as strong a gluten network to hold and entrap gases during fermentation and baking as will a bread wheat flour (Haber et al, 1976; Tsen et al, 1973). Two of the triticale flours in the study by Tsen et al (1973) contained a higher protein content than the wheat flour, however they still had shorter development times and shorter stability than wheat flours. It was suggested that although triticale was rich in other protein fractions, it had less gluten for dough structure formation.

Rooney et al (1969) found triticale flour absorption to be higher than that of wheat, but most researchers have found higher absorptions for wheat flours.

Table 3. Farinograph Characteristics of Triticale and Wheat Flours

Reference	Type of Flour[1]	Peak Time (min.)		Stability (min.)		M.T.I.[1]		Absorption (%)	
		Triticale	Wheat	Triticale	Wheat	Triticale	Wheat	Triticale	Wheat
Singh (1976)	Wholegrain	4 - 7	-	0.5 - 2	-	55 - 70	-	69	-
Ahmed and McDonald (1974)	Extracted	2 - 3	6	-	-	140 - 240	40	56 - 58	63.5
Rooney et al (1969)	Extracted	1.8 - 2.5	5	-	-	200 - 230	50	-	-
Tsen et al (1973)	Extracted	Faster	Slower	Shorter	Longer	-	-	Lower	Higher
Haber et al (1976)	Extracted Commercial	2.9	4.4	3.7	10.4	105	20	57.6	62.8
Lorenz & Welsh (1977)	Extracted	Faster	Slower	Shorter	Longer	Higher	Lower	-	-

[1] Flours with low M.T.I. have good tolerance to mixing; flours with high M.T.I. are critical to mixing.

These differences could have been due to differences in variety, flour extraction and moisture content of the flours. Lower flour absorption would generally indicate lower gluten content of flours.

4. Milling, Flour Extraction Rates, and Protein Content

Triticale's use as a food grain has been evaluated by standard procedures, one of them being milling. All milling studies reported indicate that triticale generally yields less white flour than does bread wheat. Table 4 summarizes flour extraction rates of wheats and triticales obtained by using several experimental mills as reported by Lorenz (1972), Kaltsikes and Larter (1970), Ahmed and McDonald (1974), Unrau and Jenkins (1964), Rooney et al (1969) and Anderson et al (1974). Invariably, the triticale grains produced lower extraction rates than the wheats.

The protein content of triticale grain used in these comparative milling studies (Table 4) was generally equal to or higher than that of wheats, as indicated by the grain protein values. The protein content of the triticale flours, however, was equal to or less than the comparative wheat flour samples. Therefore, due to the low extraction rates obtainable, the protein advantage of triticale was generally lost when the grain was milled into a low extraction flour that could be used to produce white bread. Anderson et al (1974) demonstrated that a greater percentage

Table 4. Extraction Rates and Protein Content of Triticale and Wheat Grains and Flours[1]

Reference	Number of Cultivars[2]	Type of Mill	Flour Extraction (%)		Grain Protein (%)		Flour Protein (%)	
			Triticale	Wheat	Triticale	Wheat	Triticale	Wheat
Anderson et al (1974)	6T 1W	Buhler Experimental	60.7 - 65.0	-	12.0 - 14.7	14.1 —	8.8 - 10.4	-
Rooney et al (1969)	6T 2W	Quadrumat Sr.	50.5 - 63.1	57.8 - 70.1	15.6 - 16.3	14.4 - 18.0	-	-
Unrau and Jenkins (1964)	13T 2W	Buhler Experimental	60.4 - 68.8	69.6 - 71.9	14.0 - 16.6	14.7 - 14.8	13.0 - 14.7	13.9 - 14.0
Kaltsikes and Larter (1970)	10T 1W	Buhler Experimental	54.0 - 58.0	71.6	16.1 - 16.7	16.4	13.2 - 13.8	15.1
Ahmed and McDonald (1974)	7T	Buhler Experimental	63.2	-	12.9 - 14.1	-	10.8 - 12.5	-
Lorenz (1972)	2T 2W	Quadrumat Jr.	42.1 - 61.9	69.1	12.7 - 14.6	12.7 - 14.3	11.3 - 12.8	12.4 - 14.3

[1] Corrected to 14% m.b.

[2] T = Triticale, W = Wheat.

of protein in triticale grain is removed in the bran and shorts when compared to wheat. Therefore, to take advantage of triticale's higher protein content, whole-grain or blended flours should be used because there is no loss of protein from the milling process.

D. Amylase Activity and Baking Quality of Triticale Flour

Production of bread with good volume and crumb structure depends on a paced and measured evolution of carbon dioxide. The level of fermentable sugars in flours is too low to support optimum yeast growth. Amylase activity in flours produces further fermentable sugars by acting on damaged starch granules during dough fermentation and on gelatinized starch during baking. Although undamaged granular starch is not susceptible to hydrolysis by amylases, all flours contain a certain percentage of starch that has been damaged during milling. While an optimum degree of amylase action is needed to obtain optimum bread volume and crumb quality, there is a deterioration in functional quality when excess alpha-amylase is present. High levels of alpha-amylase such as those found in triticale and rye flours, or in flours from sprouted wheat, may cause excess gassing power, which in turn causes an open crumb structure and an eventual collapse of loaf volume (Schwimmer, 1981).

Alpha-amylase is an endoenzyme that hydrolyzes accessible starch at the alpha-1, 4 glucosidic linkages at random points producing low molecular weight dextrins. Beta-amylase is an exoenzyme which attacks the alpha-1, 4 glucosidic linkages from the non-reducing ends of the chain only, with the liberation of maltose. The action of beta-amylase does not progress beyond the alpha-1, 6 glucosidic linkages (or branching points) present in the amylopectin part of the starch, producing what are referred to as beta-limit dextrins which resist further action of the enzyme. The amylose molecule is a straight-chain and is almost completely broken down by beta-amylase (Schwimmer, 1981).

Ungerminated wheat has an abundance of beta-amylase and low, variable levels of alpha-amylase. Most of the starch hydrolyzing activity during baking is due to alpha-amylase because alpha-amylase has greater thermal stability than beta-amylase, and it can therefore act on gelatinizing starch in the center of a loaf when at 60 - 70° C. It is also more stable at the pH of dough (pH 5-5.6).

When flour has high amylase activity and high starch damage, detrimental effects on baking are likely. An increase in damaged starch gives a direct increase in water absorption at the mixing stage. Then during

fermentation, the dough softens due to amylase action. The water that was held by starch is released and the dough at make-up stages is difficult to handle; the baked bread crumb is gummy and sticky. Generally, hard wheat flours have higher starch damage than soft wheat flours. Starch granules in soft wheat flours are loosely bound and easily released during milling, while starch granules in hard wheats are firmly bound in a protein matrix, therefore they are liable to damage when fragments are reduced during milling. Berry et al (1971) and Haber et al (1976) found a lower percentage of starch damage for rye and triticale flours compared to durum and hard red spring wheats.

The most striking characteristic of triticale is its reported high alpha-amylase activity, in contrast to the levels usually found in sound wheats. Higher alpha-amylase activity is typical of the rye parent. Alpha-amylase activity has been directly correlated with grain density, kernel shrivelling and kernel type (Klassen and Hill, 1971; Kaltsikes and Larter, 1970). Pena and Bates (1982) found that alpha-amylase of eight triticales varied with the extent of grain shrivelling within cultivars. The fact that alpha-amylase content may be higher in the aleurone layer (Dedio et al, 1975) makes alpha-amylase levels for whole-grain triticale flour especially significant. The structure of triticale starch has been studied by Berry et al, 1971 and Klassen and Hill, 1971. No peculiarity of the starch

component was present, although related to the starch component was the high alpha-amylase activity.

Few studies have directly measured alpha-amylase activity in triticale; most have used indirect measures of alpha-amylase activity, such as amylographs and falling numbers. Several investigators, comparing wheat and triticale flours, have reported lower amylograph peak viscosities and lower temperatures of initial gelatinization (Berry et al, 1971; Klassen and Hill, 1971; Lorenz, 1972; Singh, 1976; Haber et al, 1976) for the triticale flours, an indication of high alpha-amylase activity. Berry et al (1971) reported peak height values (B.U.) of 110, 140, 920 and 1,000 and initial pasting temperatures of 58, 58, 79 and 64°C for triticale, rye, durum and hard red spring wheat flours respectively. Klassen and Hill (1971) also reported lower peak amylograph viscosities of 30 and 70 B.U. for triticale and rye when compared to 290 and 390 B.U. for durum and hard red spring wheat flours.

It has been reported that the alpha-amylase activity of triticale is strongly influenced by agronomic and climatic conditions during the final stages of growth and maturation (Lorenz, 1974b; Welsh and Lorenz, 1974). Welsh and Lorenz (1974) reported that for triticales grown at various locations in Colorado in the 1973 crop year, the alpha-amylase activity as measured by amylograph viscosity ranged from

20 - 840 B.U. Spring and winter triticales grown in Colorado during the 1972-72 crop years, (Lorenz 1974b) had alpha-amylase activities that varied drastically from one year to the next. In both studies triticale consistently produced B.U. values below 900 indicating high enzyme activity, whereas the wheat controls produced values of 2000 B.U. or more. Amylograph viscosity values of 2000 B.U. are high and indicate that a modified amylograph procedure was used.

Alpha-amylase measurement methods can be divided into two basic categories; (1) methods using well-defined added substrates; (2) autocatalytic methods that use the substrate that occurs with the enzyme in nature. A brief summary of some of the common methods for measuring alpha-amylase activity in grain and flour are presented in Table 5. The most common method for measuring alpha-amylase in triticale has been the amylograph procedure, which is an indirect measure of amylase activity.

E. Relationship of Sprout Damage to Alpha-Amylase Activity and Baking Quality

The extent of sprouting is an important criterion in the grading of cereal grains because sprouted grain is considered damaged. The detrimental effect of sprouted wheat on baking quality has been attributed to increased alpha-amylase activity (Lorenz, 1981). Lorenz (1974b) stated that triticale and rye have a stronger tendency to

Table 5. Methods for Measuring Alpha-Amylase Activity in Cereals[1]

Action Measured	Substrate	Measurement	Method and/or Units	Amylase Measured
Gas Production	Native Damaged Starch	Gas Pressure	Gassing Power	α and B
Reducing Sugar	Native Starch	Titration	Maltose No.	α and B
Dextrinizing	B-limit Dextrin	Colorimetric With Iodine	°Litner SKB Units Du Farrand Units IDC Units	α
	Dye Labelled Amylose	Colorimetric	Cibracron-blue	α
		Fluorometric	B-limit Dextrin Anthranilate	
Dextrinizing/ Gel Diffusion	Gelatinized Starch	Diameter Size	Agar Plate	
	Dye Labelled Amylose	Diameter	Phadebas	α
Liquefaction	Native Starch	Viscosity	Amylograph	
			Falling Number	
Change in Light Scattering	B-limit Dextrin	Nephelo-metric	Grain Amylase Analyzer	α

1 Adapted from Campbell (1980).

pregerminate in the kernel than wheat. The relationship of sprouting and of alpha-amylase activity to the baking quality of flour has been studied extensively in wheat (Ibrahim and D'Appolonia, 1979; Ranhotra et al, 1977; Finney et al, 1980); however this relationship has not been studied in triticale.

Ibrahim and D'Appolonia (1979) suggested that sprouting, as measured by visual examination, is not necessarily an indication of actual amylase activity present in wheat. Because incipient sprouting cannot be detected visually, an accurate measure of alpha-amylase activity as an index to sprouting and baking quality is important. McCrate et al (1981) determined sprout damage and alpha-amylase activity on hard red winter wheat samples which had been subjected to a sprouting environment. Sprouting and alpha-amylase activity were positively and highly correlated, however, some cultivars deviated from this relationship. Enzyme activity was not always directly related to visible sprouting. Selecting for both sprouting resistance and low alpha-amylase production was recommended because the two traits are not mutually inclusive.

It is commonly assumed that laboratory germinated grain or malt can be used in research, replacing naturally or field sprouted grain, although Meredith and Jenkins (1973) disputed this use by presenting evidence that sprouted

wheat presents an amylolytic component in addition to alpha-amylase. Generally, laboratory sprouting of cereal grains causes increased enzyme activity, a loss in total dry matter, an increase in total protein, a change in amino acid composition, a decrease in starch, increases in sugars, a slight increase in crude fat and crude fiber, slightly higher amounts of vitamins and minerals, as well as many changes in rheological and baking properties of flours (Lorenz, 1981). Field sprouting produces the same changes, however these take place much more slowly since conditions for sprouting are not as ideal as those in the laboratory.

The effects of sprouting on the bread baking characteristics of triticale flours has not been studied. Although research has indicated that there is often high alpha-amylase activity in triticale flours, the relationships between directly determined alpha-amylase activity and breadmaking quality have not been established. Several researchers have studied the effects of sprouting and alpha-amylase on the bread making quality of wheat flour (Lorenz, 1981, Ibrahim and D'Appolonia, 1979, Ranhotra et al, 1977; McCrate et al, 1981; Finney et al, 1980). All studies reported that sprouting beyond minimal levels increased alpha-amylase activity and decreased the functional quality of the wheat flour.

Lorenz (1981) measured the deterioration of the

baking quality of sprouted wheat using the farinograph. Shorter peak times and reduced mixing tolerances were found when 78% sprouted wheat was compared to 0% sprouted wheat. Breads baked from the sprouted wheat had very poor bread baking characteristics. The crumb color of the breads was darker and the grain and texture inferior when compared to bread baked from sound wheat.

Ibrahim and D'Appolonia (1979) obtained hard red spring wheat from the 1977 crop year in which the wheat contained different levels of sprouting (0.4 to 12.3%). With increasing sprout damage there was a progressive decrease in falling number and in amylograph peak height, in addition to decreased farinograph absorption and development time. One particular sample with 23% sprout damage, was expected to have a lower alpha-amylase activity than a sample with 3.9% sprout damage. However the 23% damaged sample had a lower falling number and lower amylograph peak height, which suggested that visual examination to measure alpha-amylase activity was not necessarily an indication an indication of actual alpha-amylase activity.

Ranhotra et al (1977) sprouted hard red winter wheat for 3 to 5 days, then freeze-dried it and hammermilled it into flour. Pound and pup loaves were made using a sponge-dough and no-time process. Sprouted wheat flour was added at levels of 0, 5, 10, 15, 20% to sound wheat flour in

the baking formulations. Improved loaf volume was found when low levels of 5% sprouted flour were incorporated. Apparently the low amylolytic activity provided additional but not excessive fermentable sugars and therefore increased loaf volume. A gradual decrease in bread quality occurred when sprouted wheat was added at levels higher than 5%.

F. Protease Activity and Baking Quality of Triticale Flour

When Madl and Tsen (1973) conducted baking quality studies using triticale flours, their results suggested that the enzymatic activity of precursory dough systems was detrimental and that proteolytic activity of triticale flours was considerably higher than for most wheat flours. In 1974, Madl and Tsen compared the proteolytic activity of whole-grain, bran and flour of mature triticale grain with that of wheat and rye. Proteolytic activity of rye and triticale flours was higher than that of wheat, and bran fractions of all flours possessed much higher activity than the flours. The authors concluded that the proteolytic activity of the milling fractions increased with increased protein content of the fractions.

Bakers employ proteolytic enzymes for bread production to reduce mechanical dough requirements of strong wheat flours. Protease activity lowers dough elasticity by mellowing the gluten. Sprouted grain or grain that is

susceptible to early sprouting, such as triticale or rye might show excessive proteolysis which would be detrimental to the baking quality of the flour.

G. Baking Studies with Triticale Flour

1. Bread-Baking

a) Use of 100% Extracted Triticale Flours; Baking Modifications. Triticale flour is deficient in gluten quantity and quality, and is also apparently high in alpha-amylase activity. Triticale's weak dough structure could be due to the synergistic weakening effects of both factors. Largely because of triticale's weak dough structure, Unrau and Jenkins (1964) and Haber et al (1976) could not prepare acceptable bread from 100% extracted triticale flour using standard bread-making quality tests for wheat. Unrau and Jenkins (1963) prepared standard pup loaves by the remix and straight dough procedures using tetraploid, hexaploid and octaploid triticales. Baking trials using 100% flour gave unsatisfactory results. Haber et al (1976) baked pup loaves with commercial hard red spring wheat, rye and triticale flours using a straight dough process. Triticale and rye flours gave extremely poor volume, and poor internal and external characteristics.

The successful production of 100% triticale flour breads has been reported by Lorenz et al (1972), Lorenz

(1972) and Tsen et al (1973). All doughs were prepared by the straight dough procedure, however mixing and baking modifications were necessary to produce acceptable breads.

Studies by Lorenz et al (1972) and Lorenz and Welsh (1977) showed that the use of a dough hook for mixing triticale flour doughs was completely unsatisfactory. The doughs would not pick up, making scraping during mixing necessary. The use of a cake paddle instead of the dough hook improved the ease of mixing, although the doughs were slightly soft and sticky after mixing. Mixing times and speeds for triticale doughs (Lorenz, 1974b) had to be lowered because triticales lack some of the gluten forming properties of wheat flour and therefore are not as tolerant to over-mixing.

Lorenz et al (1972), Lorenz and Welsh (1977) and Tsen et al (1973) shortened triticale flour dough fermentation times considerably when compared to wheat flour doughs. Lorenz and Welsh (1977) decreased total fermentation time from 90 minutes for wheat to 60 minutes for triticale flour at 30°C, 85% relative humidity. Fermentation times were shortened because over-fermentation presumably led to rupture of dough structure and collapse of the loaf before baking.

Tsen et al (1973) reported the improving effects

of various additives such as ethoxylated monoglycerides, sucrose tallowate, sucrose monopalmitate, sucrose mono- and distearate, and sodium steroyl-2-lactylate in 100% extracted triticale flours. The additives used were at 0.25, 0.50, and 1.0% of the triticale flour in a no-time process. All additives improved the baking quality of triticale flour, and in general ethoxylated monoglycerides gave a slightly larger loaf while stearoyl-2-lactylate produced a slightly better texture.

Lorenz (1974b) reported that even with modifications of the baking process, there was no assurance of a good quality 100% triticale bread, because the variability in quality was considerably greater among triticales than wheats. Environmental conditions have a major effect on the quality of triticale and its bread baking characteristics. Welsh and Lorenz (1974) grew 3 winter triticales and 2 winter wheats at different locations in Colorado. The wheat controls produced higher bread volumes than the triticales at all locations, however among the triticales, the statistical differences between varieties, between locations, and the variety location interaction demonstrated wide variability in quality.

b) Use of Blends of Triticale and Wheat Flours. Improvements in the quality of white bread have been reported when composites of triticale and wheat flours were used in bread

formulations (Unrau and Jenkins, 1964; Rooney et al, 1969; Kaltsikes and Larter, 1970). Unrau and Jenkins (1964) substituted different levels of hexaploid triticale flour for wheat (Pembina) in a standard pup loaf baking method. Substitution of triticale flour for up to 30 to 40% of the wheat flour, did not markedly decrease loaf volume and internal characteristics. Volumes were actually increased, when approximately 20% triticale flour was incorporated. Unrau and Jenkins (1964) postulated that Pembina wheat was overly strong, preventing maximum dough expansion. Adding triticale flour produced a dough in which the gas pressure and gluten strength were optimum. It is also possible that the high alpha-amylase activity in triticale flour compensated for an amylase deficiency in the wheat flour, thereby contributing to gas pressure and volume improvements.

Rooney et al (1969) carried out a similar baking study, using a standard straight dough baking procedure to produce pound and pup loaves. When levels of triticale flour were substituted for wheat flour, substitutions of up to 20 to 30% did not markedly decrease loaf volume and internal characteristics of bread. Detrimental effects were found when levels greater than 30% were used. Ahmed and McDonald (1974) produced pup loaves using a 50/50 triticale wheat blend and compared the bread quality to that of bread baked with Chris wheat flour. Overall, the blends made reasonably good breads, however their texture, color and

loaf symmetry were not quite as good as those of the 100% wheat bread.

c) Use of Whole-Grain Triticale Flour. The major reason for promoting the use of triticale for bakery products has been its generally high protein content and good amino acid balance. However, the flour extraction rates obtainable with triticale produce flour which does not have a protein advantage over wheat. To take full advantage of its higher protein content, Lorenz (1974b) used a whole-grain triticale meal (18.5% protein) in a white bread formulation. The bread baked was of extremely low quality and it was realized that whole-grain triticale could only be used in a blend with strong wheat flour.

Lorenz (1974b) baked breads in which triticale meal replaced 10, 20, 30, 40, 50% of the wheat flour. All external and internal bread characteristics were satisfactory up to a level of 30% triticale flour, considering that these were specialty breads. When more than 30% triticale was used bread volume decreased, crust and crumb color became dark, and the texture was harsh and sticky. High triticale content breads can easily be over-fermented, resulting in bread with a coarse grain structure. This is due to rupture of gluten strands caused by the excess gas pressure produced by alpha-amylase (Schwimmer, 1981).

The importance of alpha-amylase was apparent in a study by Lorenz (1972). The amylograph viscosity of two triticale samples was determined with and without addition of 5mg of alpha-amylase inhibitor per/100g flour. For the alpha-amylase inhibited flours B.U. values increased, indicating a reduction in alpha-amylase activity, and pup loaves had increased volume and higher bread scores. Lorenz and Welsh (1977) baked breads from several semi-dwarf triticale lines, grown at 3 locations in Colorado. Of the 7 lines grown at the Fort Collins site, 5 flours with high amylase activity, as measured by amylograph viscosity, were unsuitable for bread-baking. One variety, Rahum, consistently produced satisfactory bread, even though the amylograph viscosity values varied considerably from one site to another. It would seem desirable to use triticale flours with the lowest alpha-amylase activity possible.

2. Cake and Quick-Bread Baking.

Studies by Thompson and Vaisey (1971) showed that cakes made from chlorinated and unchlorinated triticale flours were inferior to those baked from a soft wheat cake flour. Treatment of triticale flour with increments of chlorine resulted in a decrease in alpha-amylase activity as measured by the amylograph. Cakes made with chlorinated flour had better volume, crumb structure, and evaluations of texture as measured by the texturometer and sensory panels.

Kissell and Lorenz (1976) showed that cake quality of triticale flours was improved by modifying milling conditions or by the addition of emulsifiers. Volumes from as-milled, chlorinated triticale flour were significantly below the level of cake produced from soft red winter patent flour. Performance increased when rebolting and progressive pin-milling were used. By increasing the emulsification of the batter system with commercial mono and diglycerides, additional improvement was attained. Using 3% added emulsifier, 20 to 50% triticale to wheat blends produced cakes equal to or significantly larger than soft red wheat without emulsifiers.

The use of triticale flours in pancakes and waffles was reported by Lorenz (1974b). Triticale pancakes were preferred over wheat pancakes for their flavor, and the products were indistinguishable in appearance.

To summarize, baking studies using triticale flour indicate that baking performance was generally poor when compared to that of wheat flour, probably because triticale flour was deficient in gluten quantity and quality, and had high alpha-amylase activity. Acceptable baked products were produced when mixing and baking modifications were used, and when triticale was blended with wheat flour. Despite the baking problems, triticale flour is valued for

its nutritional composition; as well, consumers enjoy the wholesome, nutty flavor of products baked with triticale flour.

III. MATERIALS AND METHODS

A. Experimental Design

In examining the effect of alpha-amylase activity and protein content of triticale grain on the baking performance of triticale flour, a two phase experiment was carried out. Phase I was designed to meet objective I, and phase II was designed to meet objectives 2, 3 and 4 (page 4).

Phase I. A group of 44 graded milling samples, 26 grade 1 and 18 grade 2, were used in the initial phase of this study. Correlations were calculated between percent sprout damage and alpha-amylase activity for all 44 samples, and for the grades 1 and 2 samples separately. In each case, a 5% level of significance was used to test the null hypothesis that there was no correlation between the sprout damage and alpha-amylase activity.

Phase II. Test flours were prepared from a low protein and a high protein triticale flour; both had relatively low alpha-amylase activity. Both protein content flours were formulated to four ranges of alpha-amylase activity resulting in flours of 8 protein X alpha-amylase combinations (low protein with alpha-amylase ranges 1, 2, 3, and 4 and high protein with alpha-amylase ranges 1, 2, 3, and 4). Three sets of these flours were prepared, one

for each replication of the experiment, making a total of 24 formulated flours (2 protein contents X 4 alpha-amylase levels X 3 replications). Alpha-amylase activity, protease activity, proximate analyses, color, farinograph characteristics and falling numbers were determined for the flours.

Formulated flours were baked into consumer-style recipes of muffins, sour cream coffee cakes and yeast breads. Whole-wheat flour was baked into the same products and served as a control. Volume, sensory analysis of exterior and interior characteristics, instrumental texture measurement, crumb color and percent moisture content and baking loss were determined for the products. Pup loaves were also baked with the formulated flours, but had the additional variable of 3 water levels in the baking formulation. Pup loaves were assessed for volume and crumb quality characteristics.

Factorial analysis of variance was used to determine the main and interactive effects of protein content and alpha-amylase activity (and water level for pup loaves) on triticale flour and baked product quality parameters. Significant differences were accepted at $p=0.05$ or less.

B. Materials

1. Milling Samples

Forty-four triticale milling samples were obtained

from Pioneer Grain Company, Ltd., Winnipeg, after harvest. The triticale samples were from Manitoba, Saskatchewan and Alberta, and the varieties were unknown. Samples were assessed for percent sprouted kernels by a qualified grain inspector, and a grade assigned to the samples on the basis of percent sprouted kernels, according to the official Grain Grading Guide (Canadian Grain Commission, 1984). Standards permit up to 0.5% sprouted kernels for No. 1 and up to 2% sprouted kernels for No. 2 grade triticale. Both No. 1 and No. 2 grades may be used in milled flour for commercial use. Graded samples were stored at 4°C until they were tested for alpha-amylase activity.

2. Grain for Flour Formulation

Two lots of triticale grain [1], line 6TA-419, one with a high protein content, and one with a low protein content, were obtained from the 1981 crop year. To identify the variety of the two lots of triticale grain, three replications of polyacrylamide gel electrophoresis (Bushuk and Zillman, 1978) were carried out.[2] Known standards[3] of grain, including Marquis wheat, and Rosner, Welsh, Carman and 6TA-419 triticales were used for comparison. The electrophoregram (Figure 1) confirmed that the grain lots were both line 6TA-419 triticale.

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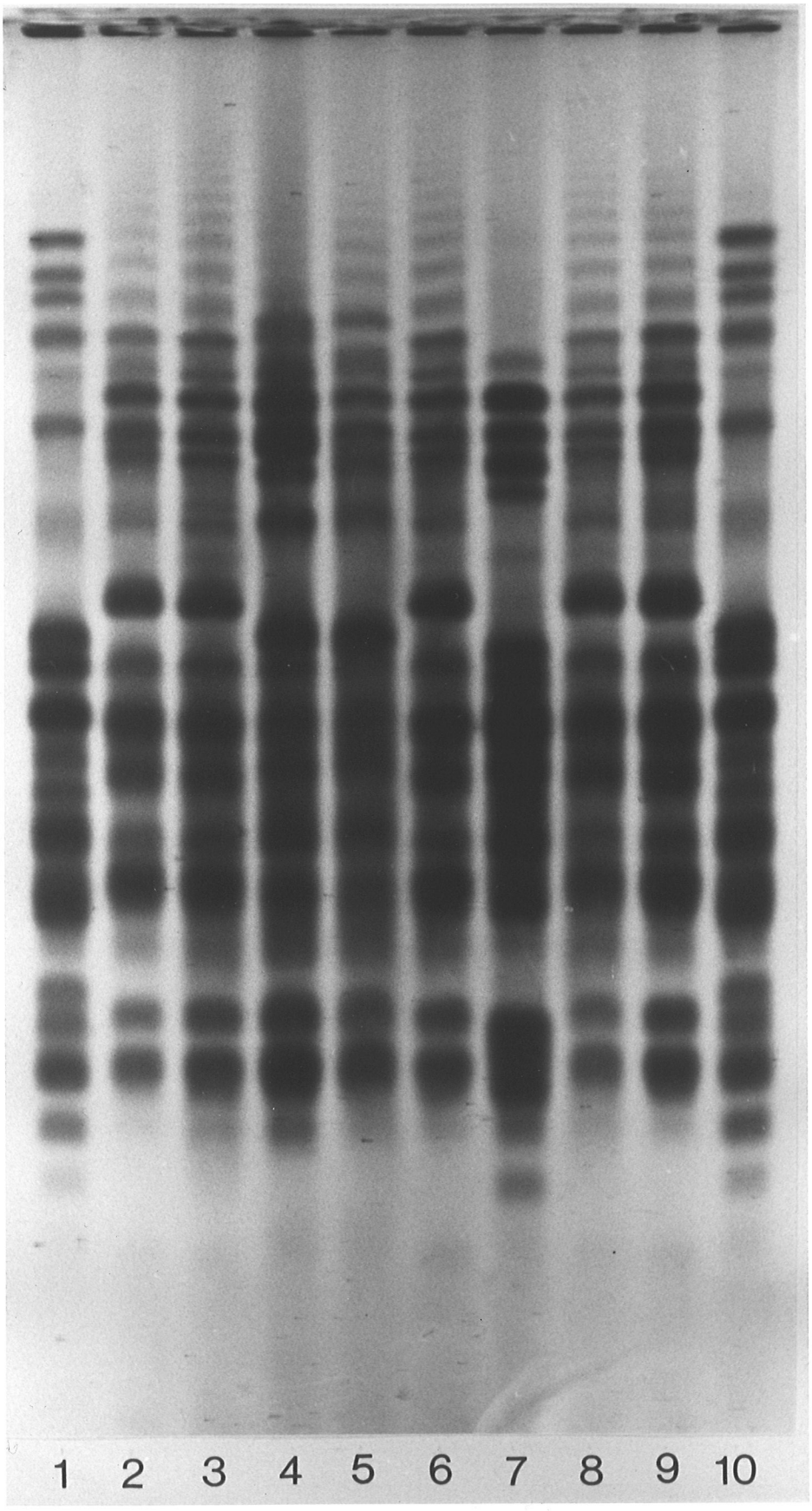
1 Courtesy of Pioneer Grain Company Ltd., Winnipeg, Manitoba.

2 Courtesy of R. Oree, Department of Plant Science, University of Manitoba.

3 Courtesy of Dr. E. Larter, Department of Plant Science, University of Manitoba.

Figure 1. Gliadin electrophoregrams of triticale and wheat cultivars.

1 = Marquis wheat, 2 = unknown triticale, low protein, 3 = unknown triticale, high protein, 4 = Rosner triticale, 5 = Carman triticale, 6 = 6TA-419 triticale, 7 = Welsh triticale, 8 = unknown triticale, 9 = unknown triticale, high protein, 10 = Marquis wheat.


1
2
3
4
5
6
7
8
9
10

C. Enzyme Activity Determination

1. Alpha-Amylase Activity

Alpha-amylase activity of grain or flour was evaluated using the method of Briggs (1961) as modified by MacGregor et al (1971). This method (Figure 2) is based on an arbitrarily chosen set of optical densities, which allow both incubation period and enzyme dilution to be varied so that the optical densities observed will fall within the prescribed limits. A unit of activity is defined as the amount of enzyme required to change the optical density of a beta-limit dextrin solution from 0.6 to 0.4 in 100 minutes. A given extract was usually tested at two different dilutions; and if the alpha-amylase activity was very low, the extract was tested at two incubation times.

2. Protease Activity

Protease activity of the formulated flours was determined by the method of Singh and Katragadda (1980), but with tyrosine used as a standard for the protein determination, and final results were calculated in HUT units as specified in AACC methods 22-62 and 22-63 (AACC 1983).

D. Proximate Analysis

Proximate analyses for moisture, protein and ash were performed in duplicate using AACC method 44-15A (one

Figure 2. Determination of alpha-amylase activity by the iodine dextrin color (IDC) method

Procedure:

Enzyme Extraction

1. If using grain samples, grind using a 30X mesh screen on a Wiley Mill.[1]
2. Combine 3 g ground sample or flour and 10 mL sodium-acetate buffer (Appendix A) in a covered beaker. Stir on a magnetic stirrer at 4°C for 1 hour.
3. Centrifuge[2] at 0-4°C at 14,000 g for 25 minutes. Refrigerate supernatant (4°C).

Enzyme Assay

1. Dilute enzyme extract appropriately up to 20,000 fold for germinated seed to as little as 1/50 for mature grain.
2. Pipette 2 mL aliquots of diluted extract into test tubes. Prepare blank and standards with water as shown in table below.
3. Preincubate prepared tubes, as well as dextrin working solution (Appendix A) to 35°C in a water bath.
4. Add 2 mL dextrin working solution to each of the tubes as required and incubate at 35°C for 15 - 60 minutes.
5. After the time has elapsed, add to each tube 10 mL I-KI working solution (Appendix A). Mix thoroughly.
6. Allow tubes to stand at room temperature for 30 minutes.
7. Read absorbance at 540 nm.[3]

After the I-KI has been added, tubes should contain:

	Enzyme Extract (mL)	H_2O (mL)	Dextrin (mL)	I-KI Solution (mL)
Blank	-	4	-	10
Standard	-	2	2	10
Enzyme	2	-	2	10

[1] Arthur H. Thomas Co.

[2] International Refrigerated Centrifuge, Model B-20.

[3] Bausch and Lomb Spectronic 20.

Figure 2. Continued

Calculations of Alpha-Amylase Activity.

1. Prepare a standard graph. On semi-log paper, plot optical density (O.D.) units on the log scale from 0 to 1.0 and minutes on the horizontal scale, 0 to 100 minutes. Minutes are labelled Relative Time Units. Draw a line from the time point = 0, O.D. = 0.6 to time = 100 minutes, O.D. = 0.4.
2. Correct all O.D. readings by multiplying by a correction factor to obtain the corrected optical density (C.O.D.) as follows:

$$\text{O.D.} \times \frac{0.6}{\text{O.D. Standard}} = \text{C.O.D.}$$

This is carried out because the standard will not always be exactly 0.6 and, it is necessary to correct it and the values obtained after incubation, so that the values obtained on different days are comparable.
3. Using the standard graph, record a relative time value appropriate for each C.O.D.
4. Divide the Relative Time by the time of incubation to give an Activity Unit.
5. Determine the activity per mL of extract by dividing the number of units by 2 and multiplying by the dilution factor. The value obtained is the number of IDC units per mL of extract.
6. Determine the activity per g of sample by multiplying the IDC units/mL by a factor of 3.33. This factor takes into account the ratio of buffer to sample used (10/3 = 3.33); it was assumed that the extract was 100% recovery of buffer.

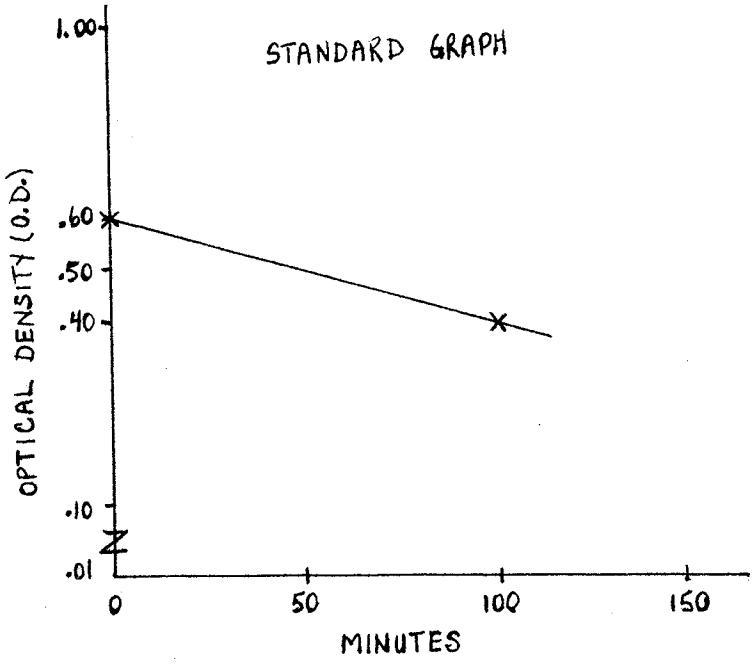


Figure 2. Continued

Sample Calculation

Sample	Dilution	Incubation Time	O.D.	C.O.D.	Relative Time	IDC/ mL	IDC/ g
1	1/100	20	0.506	0.421	87/20	218	725.94
2	1/200	20	0.610	0.510	41/20	205	682.65
Standard	-	20	0.721	0.600	-	-	-

Therefore the average IDC units/g = 704.30

OR IDC units/mg = 0.70

stage), method 46-12 using a titanium catalyst as described by Williams (1973), and method 08-01 respectively (AACC 1983). Protein, calculated as NX5.7, and ash results were expressed on a 14% moisture basis.

E. Flour Color Measurement

Flour color was measured using a Hunter Color Difference Meter, model D25-2. The machine was calibrated using the white standard (L = 92.4, a = -1.2, b = 0.5) and values for lightness (L), red-green (a), blue-yellow (b) were obtained. In addition, the total color change (E) from the white standard was calculated where $\Delta E = \sqrt{L^2 + a^2 + b^2}$. Readings were made on 250 mL flour placed in a 10 x 10 cm plexiglass sample holder. Readings for each sample were taken in duplicate.

F. Farinograph Characteristics

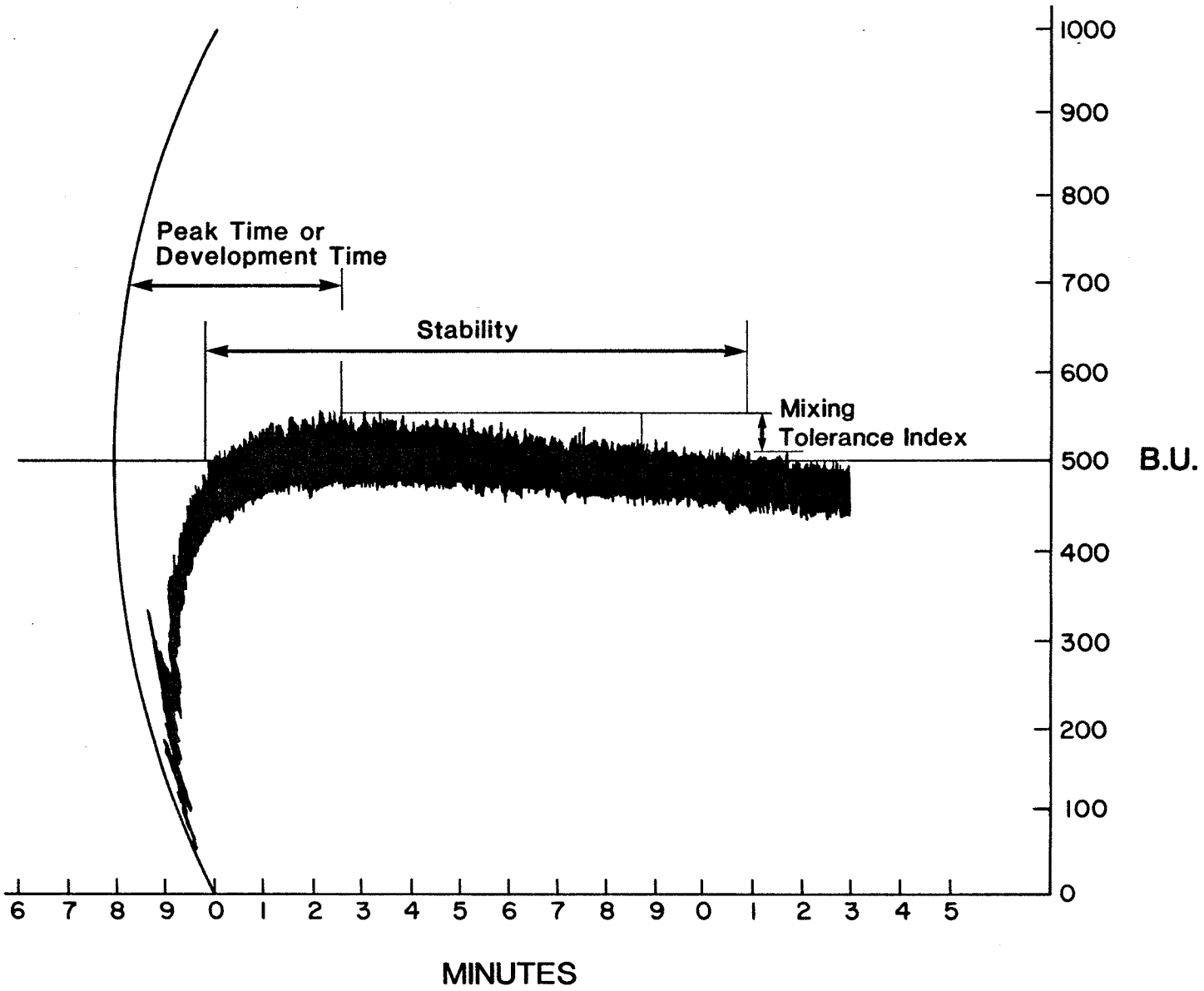
The farinograph was used to evaluate the absorption of the flours and to determine characteristics of doughs during mixing, using AACC method 54-21 (AACC 1983). The small mixing bowl (50 g flour) and the constant flour weight procedures were used. Absorption (%) was calculated and development time, stability and mixing tolerance index (M.T.I.) were determined from the farinograph curves. Peak time or development time is the time from the first addition of the water to the development of the dough's maximum

consistency. Stability is the difference in time between the time when the curve first intercepts the 500 B.U. (Brabender Units) line and the time when the curve leaves the 500 B.U. line. Mixing tolerance index is the difference in B.U. from the top of the curve at the peak to the top of the curve measured 5 minutes after the peak. Absorption is the amount of water required by a given weight of flour to yield a dough with a consistency that corresponds to a curve that centres on the 500 B.U. line. One farinograph curve was obtained for each flour treatment in each replication. A typical farinograph curve is presented in Figure 3.

G. Falling Number Determinations

Falling numbers were determined for the flours using AACC method 56-81B (AACC 1983). An indirect method of measuring the ability of alpha-amylase to liquefy a starch gel, falling numbers are defined as the time in seconds required to stir and allow the stirrer to fall a measured distance through a hot aqueous flour gel undergoing liquefaction. During preliminary investigations, it was found that all triticale flours produced falling numbers of 60, using the standard procedure of 7 g flour and 60 seconds stirring time (60 is the minimum falling number obtainable). Therefore, 9 g flour and 40 seconds mixing time were used

Figure 3. Typical farinograph curve.
(for a strong wheat sample)


Peak Time or
Development Time
Stability
Mixing
Tolerance Index
1000
900
800
700
600
500
400
300
200
100
0
B.U.
6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
MINUTES

for all flours except the untreated bread flour, so that the falling numbers would be elevated and differences among flour treatments could be observed. One falling number was obtained for each treatment flour in each replication.

H. Flour Formulation

Two lots of triticale grain, one with a high protein content (14.4%) and one with a low protein content (11.8%), calculated on a 14% moisture basis, were stored for four months at 4°C and then milled into whole-grain flour using a consumer-type flour mill[4]. The flours were divided into three lots, one for each replication of the experiment.

Based on the alpha-amylase activities determined in Phase I, four ranges of alpha-amylase activity were selected for the flour formulations. Selected ranges for the four levels of alpha-amylase were as follows:

Range	IDC units/mg flour
1	< 1.5
2	2.5 - 3.5
3	4.5 - 5.5
4	6.5 - 7.5

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[4] Magic Mill III, Milltown International, Winnipeg, Manitoba.

Range 1 included the activities of the original flours, range 2 represented the activity present in the grade 1 samples, range 3 represented the activity of the grade 2 samples, and range 4 represented the activity that might occur in the flour if the alpha-amylase content of the samples were in the higher range of activity. Table 6 presents the designated flour treatments. Alpha-amylase ranges are indicated by numbers 1 to 4 and protein content by the lettters "L" and "H" for the low and high respectively.

Sprouted, freeze-dried, ground triticale of the appropriate protein content was added to the initial flours to raise the alpha-amylase activities to the selected ranges. Figure 4 presents the preparation procedure of the sprouted material. Three sproutings were carried out for the three replications of each protein content grain.

In the baking experiments, a commercial whole-wheat (WW) flour served as the control flour. A commercial all-purpose (AP) flour and an untreated bread (B) flour were blended with formulated triticale flours in the baking experiments, and were therefore indicated as blending flours. The bread flour, ordered from a local mill[5] was specified to be a strong bread flour equal in quality to Neepawa wheat, and containing no additives.

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[5] Ogilvie Mills Ltd., Winnipeg, Manitoba.

Table 6. Treatment Designations in the Experimental Replications

Alpha-Amylase Range[1]	Protein Content (%)	
	Low (11.2)	High (14.4)
1	L1	H1
2	L2	H2
3	L3	H3
4	L4	H4

[1] Where 1 is the lowest and 4 is the highest alpha-amylase range.

Figure 4. Procedure for preparation of sprouted material

Procedure:

Sterilizing
Combine 500 mL White Magic bleach and 1 L distilled water. Add 750 mL grain and soak 15 minutes. Drain sample in sieve for 1 minute.

Soaking
Rinse sample in 3 L distilled water; three times. Place in 3 L distilled water, and refrigerate (4°C) for 24 hours. After 12 hours soaking, change water with 3 L fresh distilled water. Drain sample in sieve for 1 minute.

Sprouting
Line three 28 x 38 cm aluminum trays with 6 paper towels; pour 125 mL distilled water over the towels. Divide soaked grain into thirds and spread on trays. Cover each tray with 6 paper towels and pour 125 mL distilled water evenly over each tray.

Place trays in controlled temperature and humidity room (59% r.h., 20°C) for a total 72 hours. At 24, 36, 48, 60 hours of sprouting, pour 125 mL distilled water over top of paper towels on each tray.

Freeze-drying
Remove sprouted grain from trays; place in covered 500 mL plastic containers, and freeze (-24°C). Freeze dry each container for 30 hours. Refrigerate (4°C) freeze-dried samples. Grind samples in Wiley Mill, using a 30 mesh screen.

I. Consumer-Style Baked Products

1. Preparation of Baked Products

Formulated flours were baked into muffins, sour cream coffee cakes and yeast breads using standardized formulations. Baking performance was assessed by means of objective, sensory and instrumental methods.

Whole-wheat flour was baked into the same three products to serve as a control using the same formulation and procedure. Two wheat products, named C1 and C2 were prepared for each replication of baked products, to ensure there was enough sample for testing. Flour moistures and farinograph absorptions were disregarded in the baking formulations, liquid levels used were standardized in the formulations.

Weights of ingredients used in the formulations were standardized by taking the mean of several weighings of the ingredients which had been measured in metric (Appendix B). The average weight of 250 mL triticale flour was determined to be 116 g, however 125 g were used to equal the weight of 250 mL of all-purpose flour, and to ensure exact 50/50 proportions of flour in the baking formulations.

One replication of baking and assessment was carried out before the next replication was begun. Baking of one replication for one product was completed during one

day. Treatments within one product were baked in random order.

a) Muffins. The recipe source, formula and procedure used for muffins are presented in Figure 5. The muffin formulation contained 50% triticale flour and 50% all-purpose flour. Ingredients and equipment used are shown in Appendix C1.

b) Sour Cream Coffee Cakes. The recipe source, formula and procedure used for sour cream coffee cake are presented in Figure 6. The coffee cake formulation contained 100% triticale flour. Ingredients and equipment used are shown in Appendix C2.

c) Yeast Breads. The recipe source, formula and procedure used for yeast breads are presented in Figure 7. The yeast bread formulation contained 50% triticale flour and 50% all-purpose flour. Ingredients and equipment used are shown in Appendix C3.

2. Evaluation of Consumer Baked Products

a) Volume. Volume (cc) of the products was measured by rapeseed displacement in a volumeter.[6] Specific volume (cc/g) was calculated for the muffins, since the batter weight per muffin varied. Four muffins were selected at

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[6] National Manufacturing Co. Ltd., Lincoln, Nebraska.

Figure 5 Recipe source, formula and procedure for muffins

Source: Recipe developed and tested by Fyfe, B. (1982). (Additional Specifications in Appendix C1).

Formula	Metric Measurement		Weight (g)
All-purpose flour (as is moisture basis)	250	mL	125.0
Triticale or whole-wheat flour	250	mL	125.0
Salt	2.5	mL	2.5
Baking Powder	15	mL	12.7
Brown sugar, firmly packed	125	mL	83.3
Milk	250	mL	257.0
Oil	75	mL	58.0
Egg	1		51.0

Procedure:

The day before baking
Weigh out flours into tightly covered, numbered containers. Weigh out salt, baking powder and brown sugar into covered containers.

Morning of baking
Allow egg, milk and oil to come to room temperature (21°C). Turn on oven. Place paper liners into muffin cups, weigh tins with liners. Break 2 eggs into a bowl; mix lightly with a fork. Use this container of egg to add or remove the weight of egg required in the formula.

Baking schedule
Mixes are 20 minutes apart. Begin procedure as soon as one set of muffins goes into the oven. When one set is baked, remove from oven and replace with the next prepared set.

Mixing
Break egg into 750 mL plastic container, beat lightly with a fork. Adjust weight by adding or removing egg with a pipette. Add milk weight to egg weight, then add oil weight to egg and milk weight. Blend liquid ingredients together with a fork.

Combine flours, salt and baking powder in mixing bowl, stir. Stir in brown sugar a small amount at a time. Use a creaming motion against the side of the bowl so that no lumps remain. Make a well in the center of the dry ingredients.

Figure 5. Continued.

Pour liquid ingredients into dry ingredients. Moisten the ingredients using a wooden spoon to fold ingredients together 10 times (15 seconds). Scrape bowl with rubber scraper. Stir mixture 10 times (25 seconds) so that ingredients are just blended.

Baking

Spoon batter into muffin cups. Fill cups as evenly as possible, using all the batter in the bowl. Weigh filled muffin tins.

Place tins on centre rack of oven. Bake 20 minutes.

Cooling

Remove muffins from tins and place on cooling racks. Allow to cool 1 hour. Place muffins back into tins and weigh. Remove muffins and lay in a single layer in polyetheylene freezer bags. Freeze (-24°C) until further testing.

Figure 6 Recipe source, formula and procedure for sour cream coffee cakes.

Source: Formula adapted from recipe found in Triticale, New Harvest Recipes (1981), Tritirich Products Ltd. Cinnamon topping was omitted. (Additional Specifications in Appendix C2).

Formula	Metric Measurement		Weight (g)
Margarine	125	mL	111.0
Sugar	250	mL	207.0
Eggs	2		102.0
Vanilla	5	mL	3.0
Triticale or whole-wheat flour	425	mL	219.0
Baking powder	7	mL	6.2
Salt	1	mL	1.3
Baking soda	5	mL	4.0
Sour cream	250	mL	256.0

Procedure:

The day before baking

Weigh out flours into tightly covered, numbered containers. Weigh out sugar, vanilla, baking powder, salt, baking soda and sour cream into covered containers. Refrigerate sour cream (4°C).

Morning of baking

Allow margarine, eggs and sour cream to come to room temperature (21°C). Turn on oven. Line cake pans with waxed paper cut to fit the bottom. Lightly grease bottom and sides of pans with shortening. Weigh cake pans. Break 2 eggs into a bowl (250 mL), mix lightly with a fork. Use this container to add or remove weight of egg in the formula.

Baking Schedule

Begin the preparation of each cake 25 minutes after the previous cake has been in the oven. When one cake is baked, remove from oven and replace with the next prepared cake.

Mixing

Break eggs into a 250 mL plastic container, beat lightly with a fork. Adjust weight by adding or removing egg with a pipette. Combine flour, baking powder, salt and baking soda in a 1.5 L bowl, stir.

Figure 6. Continued.

Place margarine in a 2 L bowl. Cream margarine until soft, about 20 strokes (30 seconds). Add sugar, cream until light and fluffy, 50 strokes (45 seconds). Add 1/2 of the egg mixture at a time, beating well after each addition (50 times, 20 seconds each). Stir in vanilla.

Stir in flour and sour cream alternately into creamed mixture, starting and ending with flour. This requires 3 additions of flour and 2 additions of sour cream. Beat well after each addition, 25 strokes for flour and 10 strokes for sour cream. Scrape bowl periodically with rubber scraper.

Baking

Spread batter in prepared baking pan. Scale batter to a constant weight of 875 g.

Place baking pan on center rack of oven. Bake for 45 minutes.

Cooling

Remove baking pan from oven and place on cooling rack. Allow to cool for 2 hours and weigh cake in pan. Remove cake from pan with metal spatula, peel off waxed paper. Wrap cake in polyethylene film. Freeze (-24°C) until further testing.

Figure 7 Recipe source, formula and procedure used for yeast bread. (Additional Specifications in Appendix C3).

Formula	Metric Measurement	Weight (g)
Sugar	5 mL	3.4
Warm water (30°C)	125 mL	125.0
Active dry yeast	15 mL	11.8
All-purpose flour	655 mL	328.3
Triticale or whole wheat flour	655 mL	328.3
Milk	250 mL	257.0
Sugar	50 mL	44.8
Salt	10 mL	10.0
Shortening	30 mL	24.0
Cold water	125 mL	125.0

Procedure:

The day before baking

Weigh flours into tightly covered, numbered containers. Weigh out sugars, yeast and salt into covered containers. Weigh shortening onto small pieces of waxed paper. Place a jug, filled with distilled water (1.5 L) in refrigerator (4°C). Fill enough Erlenmeyer flasks to hold 1.5 L water, attach them to a water bath (35°C).

Morning of baking

Turn on oven, fermentation cabinet and water bath. Lightly grease 4 L mixing bowls with shortening. Weigh loaf pans.

Baking schedule

Mix first 3 treatments 30 minutes apart; wait 1 hour, then mix 3 more treatments 30 minutes apart. Proceed until baking schedule is complete. The extra time between mixes is necessary to handle and form loaves.

Mixing

Weigh warm water into 250 mL pyrex measuring cup. Stir in 5 mL sugar. Sprinkle yeast over top. Wrap cup with dry towel and let stand 10 minutes; stir.

During the 10 minute fermentation period, weigh milk into plastic mixer bowl[1]. Heat milk in microwave oven on full power for 3 minutes. Stir in 50 mL sugar, salt and shortening. Stir to melt shortening. At 6 minutes of yeast fermentation, add cold water and stir. Stir in yeast mixture after the 10 minute period.

[1] Braun Kitchen Machine

Figure 7. Continued.

Add all-purpose flour. Mix in electric mixer for 1 minute on speed I. Add treatment flour and mix 1 minute on speed I. Mix dough for 2 minutes on speed II. Turn dough onto lightly floured board and knead for 5 minutes. Knead dough by pushing away with palms of hands, then turn dough 1/4 of a turn, repeating every 3 seconds.

Fermentation
Round up dough and place in greased 4L bowl. Turn dough to greased side. Place in fermentation cabinet (85% rh, 35°C) and let rise 1 hour.

Forming loaves
Punch dough down with 5 blows of the fist. Turn onto lightly greased surface. Divide dough into 2 portions each weighing 600 g. With a rolling pin, roll out dough to a uniform thickness, stretching by hand to form a rectangle, 23 X 30 cm. From short edge, roll dough up, sealing with heal of hands after each roll of dough. Seal ends of loaf by using the side of hand to get a thin sealed strip. Fold sealed ends of loaf under, using fingers. Place shaped loaves, seam-side down in loaf pans.

Proofing
Place loaves in fermentation cabinet (85% rh, 35°C) and proof 45 minutes.

Baking
Transfer proofed doughs to oven. Bake 35 minutes.

Cooling
Remove loaves from pans and place on cooling racks. Allow to cool 2 hours, then weigh loaves. Place loaves in polyethylene freezer bags. Freeze at -24°C until further testing.

Time Schedule for Consumer Yeast Bread Method.

Loaf No.	Mixing	Ferment	Punch & Form	Proof	Oven In	Oven Out
1	800	830	930	940	1025	1100
2	830	900	1000	1010	1055	1130
3	900	930	1030	1040	1125	1200
4	1000	1030	1130	1140	1225	100
5	1030	1100	1200	1210	1255	130
6	1100	1130	1230	1240	125	200

random from the twelve muffins available, for volume determinations. Volume determinations were carried out on products after they had been frozen and thawed for 12 hours at room temperature.

Sour cream coffee cakes and yeast breads were cut in half and volume determined for both halves, because the volume of the whole products exceeded the capacity of the volumeter. Volumes of the halves were combined to give the total volume of the products. All volumes were determined in duplicate.

b) Sensory Evaluation. The sensory characteristics of each product were evaluated by a seven-member trained panel using a semi-structured line scale (Stone et al, 1974) for scoring the products. The ballots used for muffins, sour cream coffee cakes and yeast breads are presented in Appendices D1, D2, D3, respectively. Descriptions of an "ideal" product were given where applicable. Line scales were anchored with appropriate verbal descriptors and judges indicated the appropriate value for each characteristic in relation to a whole-wheat reference. The control scores were permanently positioned on the line scale, having been predetermined during panel training by taking the mean of panelists scores for two training sessions. In order to obtain numerical values, a grid was superimposed over the scale and a number from 0 to 60 was assigned to the scores.

The ballots were constructed and tested during three formal training sessions which occurred just prior to the baking trials. Training was based on the evaluation of a whole-wheat control, and products baked from formulated flours containing the lowest and highest range of alpha-amylase activity. Judges discussed particular quality characteristics, and diagrams of crumb quality characteristics, (cell size, cell distribution, cell wall thickness) were used as aids. Definitions of "ideal" characteristics that were used on the ballots were decided upon during training. The handling technique used by panelists was also discussed.

It was established during training that nine treatments for one product (control plus eight treatment products) were too many to evaluate in one session. Therefore the triticale flour treatments were evaluated in two sessions on one particular day (morning and afternoon sessions). For each session, panelists received a control (reference) and four randomly selected triticale treatments. All panelists received the same four treatments at any one session, however the random selection of session treatments differed for each product and replication. Reference samples were taken from C1 and C2 of each product for the morning and afternoon sessions respectively.

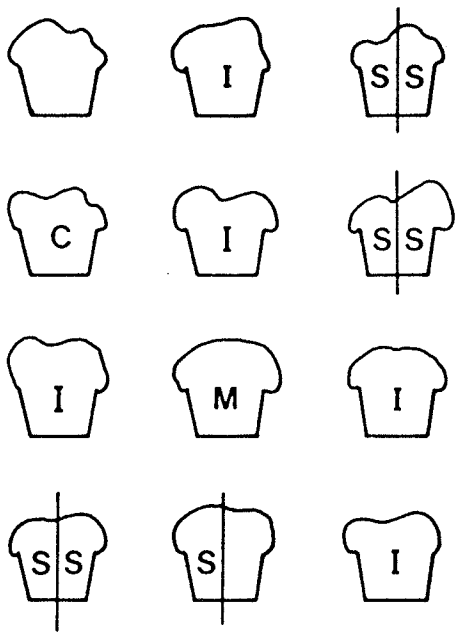
Sampling procedures for the sensory evaluation of each product are shown in Figures 8a, 9a and 10a. Each

Figure 8(a-c) Sampling procedures used for muffins.

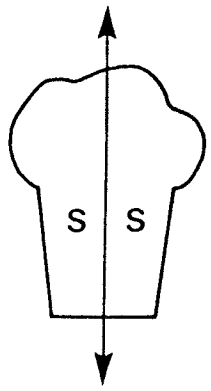
(a) sampling from one dozen muffins (selected at random)
(b) sample for sensory evaluation (one half)
(c) sample for instrumental texture evaluation (bottom portion).

S = sensory evaluation, I = instrumental texture measurement, C = sensory evaluation of color, IC = instrumental color measurement, M = percent moisture content determination.

(a)



(b)



(c)

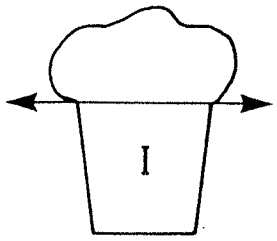
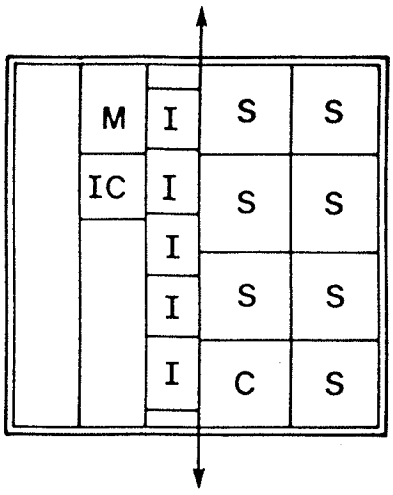


Figure 9(a-c). Sampling procedures used for sour cream coffee cake.

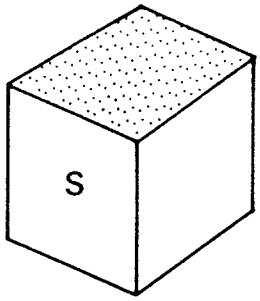
(a) sampling from whole cake
(b) sample for sensory evaluation (a piece)
(c) sample for instrumental texture evaluation (a piece)

S = sensory evaluation, I = instrumental texture measurement, C = sensory evaluation of color, IC = instrumental color measurement, M = percent moisture content determination.

(a)



(b)



(c)

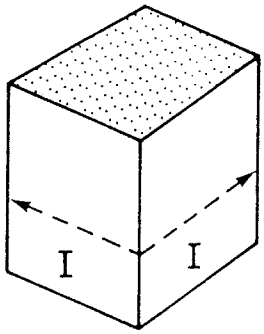
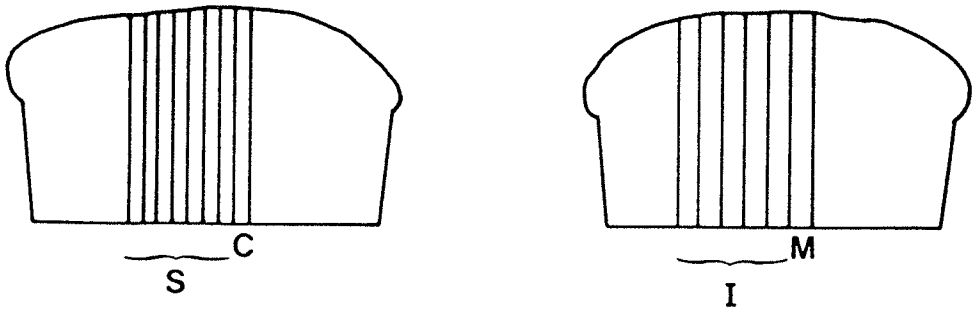


Figure 10(a-c). Sampling procedures used for yeast breads.

(a) sampling from whole loaves
(b) sample for sensory evaluation (a slice)
(c) sample for instrumental texture measurement (a slice)

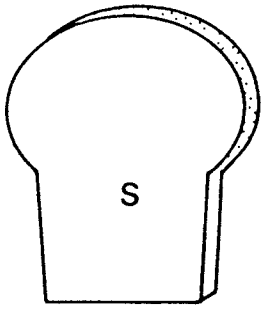
S = sensory evaluation, I = instrumental texture measurement, C = sensory evaluation of color, IC = instrumental color measurement, M = percent moisture content determination.

(a)

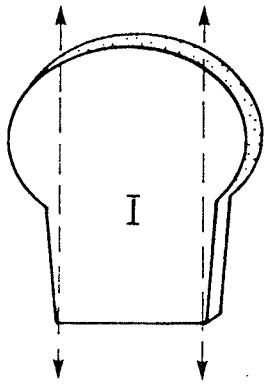


Loaf 1 Loaf 2

(b)



(c)



panelists received sample from the same position in the baked product throughout each session. Sample sizes were one half (cut vertically) of a muffin, a 5 x 5 cm piece of cake, and a 1.5 cm slice of bread (Figures 8b, 9b, 10b). To ensure adequate testing material for all sensory sessions, two whole-wheat controls were baked. Reference samples were taken from C1 and C2 following the sampling procedures shown in figures 8a, 9a, 10a. Baked products had been frozen prior to sampling.

Samples were served wrapped in polyethylene film, and placed on a tray with a utensil (fork for cake, knife for muffins and bread). Samples were coded with 3-digit random numbers and served in a random order. Distilled water and unsalted crackers were provided for rinsing and clearing the mouth between samples. Evaluation took place in a sensory analysis unit with partitioned booths; fluorescent lighting was used.

For the interior and exterior color evaluations, samples were placed in a MacBeth controlled light cabinet under examolite daylight. Panelists evaluated these two characteristics before going into the sensory analysis unit to complete the ballot. All panelists evaluated the same sample.

c) Instrumental Texture Measurement. A physical evaluation of the crumb characteristics was made using the General

Foods Texturometer. The testing was carried out on the products which had been frozen, then thawed for 18 hours. Testing was carried out on the same day as sensory analysis. Measurements were taken on five samples, which were taken from each product as shown in Figures 8a, 9a, 10a. Sample sizes were 2.5 cm height (top removed) for muffins, 4 X 4 X 1.5 cm (top removed) for cake, and 2 cm thick slice (side crusts removed) for bread (Figures 8c, 9c, 10c). Test conditions for each product are presented in Table 7.

The parameters of hardness, cohesiveness, and gumminess were determined for each sample as outlined in Figure 11. The areas, A1 and A2 were estimated by tracing the area with a compensating polar planimeter.

d) Color Measurement of Crumb. The color of the crumb of the baked products was assessed using the Hunter Color Difference Meter, model D25-2. The machine was calibrated using the white standard (L = 92.4, a = -1.2, b = 0.5) and values for lightness (L), red=green (a), blue-yellow (b) were obtained. The total color change (ΔE) from the white standard was calculated where $\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$.

Muffins and bread samples which were used for instrumental texture measurement served as samples for the crumb color evaluation. Samples were taken from the cake as shown in Figure 9a. All samples were trimmed of upper

Table 7. Test Conditions for the General Foods Texturometer

	Baked Product		
	Muffin	Sour Cream Cake	Yeast Bread
Volts	2	3	2
Chart Speed	750 mm/min	750 mm/min.	750 mm/min
Plunger	22 mm leucite	22 mm leucite	50 mm nickel
Sample Cup	Aluminum plate	Aluminum plate	Aluminum plate
Washers	-	3 mm	-
Chewing speed	Low	Low	Low

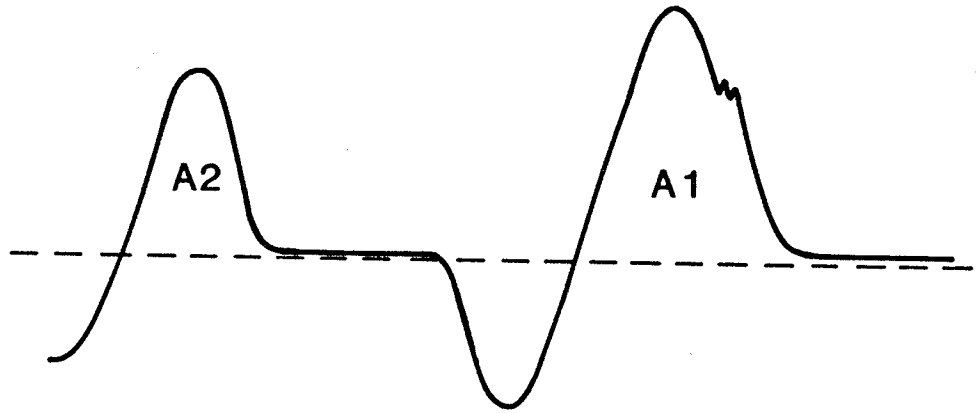


Figure 11. Classical texturometer curve (hardness = height of first peak/volts input, cohesiveness = area 2/area 1, gumminess = hardness x cohesiveness).

and lower crusts, then processed in a food processor[7] fitted with a steel knife, until fine crumbs were formed. One 250 mL measure of crumbs was placed in a 10 X 10 cm plexiglass sample holder for the color readings. Duplicate readings were taken on each sample.

e) Percent Moisture Content and Percent Baking Loss. Percent moisture content was determined by freeze-drying weighed samples of baked products. Samples were taken from standardized positions of the muffins, cakes and yeast breads (Figures 8a, 9a, 10a). Samples were placed in covered 250 mL plastic containers and frozen (-24°C) for at least 24 hours. Containers with samples were uncovered and placed in a freeze dryer[8], then freeze-dried for 24 hours. The moisture content of the freeze-dried material was assumed to be 0%. Percent moisture content was calculated as the percent difference between the weight of the baked sample and the dried product weight.

Percent baking loss was calculated as the percent difference between raw batter weight and the cooked weight. Baking loss for cakes and muffins was considered as the loss during baking and cooling, while in the case of yeast breads the loss was calculated from the beginning of proofing to cooling.

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7 Cuisinart model DLC-10E.

8 Virtis Gardiner Model # 10-145 MR-BA.

J. Standardized Pup Loaf Baking Trials

1. Preparation of Pup Loaves

Formulated flours (Table 6, p. 53) were baked into pup loaves using three water levels for each treatment flour. Water levels selected were 58, 63 and 68%. The pup loaves were prepared using 50% formulated triticale flour and 50% bread flour. A 50/50 whole-wheat and bread flour combination served as a control. All loaves were prepared in duplicate and three replications of the experiment were carried out.

Preliminary experiments showed that 63% absorption was optimum for dough handling ability. Arbitrary levels of 58 and 68% were selected to represent doughs that would be too dry or wet respectively. The 63% whole wheat control was considered to be optimum and was used as the standard, against which all other treatments, including the 58 and 68% controls were compared.

Yeast was purchased in three lots; each lot of yeast was used for all three water levels within one replication. In one day, breads from one water level for one replication were baked (8 formulated flours plus a control X duplicates = 18 loaves). Total baking time required nine days. Baking performance was assessed by subjective scoring and volume measurements.

A no-time sheeting method was used to prepare the pup loves (Figure 12). This method has a short mixing time, dough is developed by sheeting rolls and a no-time baking formula, and the bulk fermentation step is eliminated. This method proved to be an effective tool in investigating the baking potential of triticale and wheat flours (Pena, 1984). Ingredients and equipment used for each product are shown in Appendix E1. Solution preparation for the bake test are presented in Appendix E2.

2. Evaluation of Pup Loaves

a) Volume. Volume (cc) of the loaves was measured by rapeseed displacement in a volumeter. Volume determinations were carried out on fresh loaves after they had cooled. Volume determinations were carried out in duplicate.

b) Subjective Product Scoring. A subjective quality evaluation of the loaves was carried out by four experienced judges using the score card developed for the product (Figure 13).

The score card (Figure 13) was developed to include the three characteristics which were considered to be most important to product quality. A scale of 1 to 10 was used, where 10 represented the ideal or maximum score for the characteristics. Descriptions accompanied the scale and

Figure 12. Formula, and procedure used for pup loaves

Method: No time/sheeting method
(Adapted from Pena, 1984)

Formula	Amount
Flour (14.0% moisture basis)	100g
Yeast	4.0%
Salt	1.0%
Sucrose	2.5%
Potassium bromate	60 ppm
Ammonium phosphate	0.1%
Ascorbic acid	70 ppm
Skim milk powder	4 g
Shortening	3 g
Dough water	variable

Procedure:

The day before baking:
Prepare salt-sugar and bromate-phosphate solution (Appendix E2). Weigh flour (calculated on a 14% moisture basis), skim milk powder and shortening into tightly covered, numbered containers. Determine baking absorption and dough water.

Calculation of Dough Water
The calculation of dough water takes into account the flour moisture and the displacement of ingredients added in the form of solutions. Example of dough water calculation:

Given flour moisture = 13.5%
Then flour weight = 99.4 g
If absorption = 63.0%
Then gross dough water = 100 + 63 - 99.4 = 63.4 mL
Water contained in solutions = 44 mL
Net dough water = 63.4 - 44 = 19.4, where
1 mL = bromate-phosphate solution
1 mL = ascorbic acid
$\therefore$ use 17 mL

Morning of test baking
Turn on oven (220°C) proofer (35°C, 85% rh), solution bath (30°C) and water jacketed mixing bowl (30°C). Check temperatures and humidities. Make up ascorbic acid and yeast suspensions (Appendix E2). Grease pans and fermentation bowls with shortening.

Baking schedule
Set the baking schedule. Mixes are 10 minutes apart, therefore subsequent operations such as sheeting, molding and transfer of loaves to and from the oven are also 10 minutes apart.

Figure 12. Continued.

Mixing and sheeting
Add flour, skim milk powder and shortening to mixer bowl about 3 minutes before scheduled mix time. Pipette all liquid suspensions into bowl. Start the mixer immediately and continue mixing for 1 minute. Remove dough immediately after mixing and pass it 15 times through sheeting rolls set 1/8 inch apart. Round the dough up and place it in fermentation bowl. Continue mixing, maintaining time schedule for remaining samples.

Rest time
Allow the dough to rest for 20 minutes in the proofer.

Sheeting and Molding
Remove dough from fermentation bowl and wipe it lightly with flour. Pass it through sheeting rolls three times, once each at 7/32 inch, 5/32 inch, then 1/8 inch. Place the leading edge of the sheeted dough on the rollers. Lower the top roller and run the molder for 30 seconds. Remove dough and pinch together ends and seam. Place dough back in rollers and run molder a few seconds to smooth the seam. Place dough in a baking pan containing a numbered slip of paper to identify the sample. The seam is placed on the bottom of the pan and ends are pushed downwards with fingertips. Place pan in fermentation cabinet.

Proofing
Proof for 1 hour.

Baking
Transfer proofed doughs from fermentation cabinet to the oven at scheduled times. Bake 25 minutes.

Cooling
Remove loaves from pans and place on cooling racks. Determine the volume of the loaves, then place in polyethylene bags and freeze at -24°C until further testing.

Time Schedule for No-time Sheeting Method

Loaf No.	Mix & Sheet	Sheet & Mold	Oven In	Oven Out
1	800	820	920	945
2	10	30	30	955
3	20	40	40	1005
4	30	50	50	1015
5	900	920	1020	1045
6	10	30	30	1055
7	20	40	40	1105
8	30	50	50	1115
9	1000	1020	1120	1145

Figure 13. Pup loaf evaluation score card

Relative crumb quality score

(a) Moistness - use fingertips to touch the crumb.

9 - 10	ideal, moist but not wet or dry
7 - 8	slightly wet or dry
5 - 6	moderately wet or dry
3 - 4	very wet or dry
1 - 2	extremely wet or dry

(b) Cell size

9 - 10	ideal, large percentage of medium sized cells
7 - 8	large percentage of slightly larger or smaller cells
5 - 6	large percentage of moderately larger or smaller cells
3 - 4	large percentage of very large or small cells
1 - 2	large percentage of extremely large or small cells.

(c) Cell distribution

9 - 10	ideal, relatively even, uniform cell distribution
7 - 8	slightly even or uneven
5 - 6	moderately even or uneven
1 - 2	extremely even or uneven

the appropriate word(s) were verified during scoring. A total score for the characteristics was calculated.

The loaves were thawed at room temperature (21°C) for 12 hours. Each product was cut in half lengthwise and placed in order, on a table for observation. All loaves including the 58% and 68% controls were compared to the 63% control. The 63% control was considered ideal and was assigned a score of 10 (Figure 13) and all other treatments were given a relative score, keeping in mind the scales and their descriptors.

Moistness was evaluated by separating the halves of the loaves and touching the crumb to feel the moistness. One loaf was opened at a time, so that the crumb did not dry out. After moistness was evaluated, all loaves were opened, crumb-faced up. Cell size and cell distribution were evaluated. Because there were duplicate loaves for each treatment, judges subjectively averaged their scores to produce one score. The three replications of loaf evaluation were carried out consecutively in one day.

K. Statistical Analyses

Alpha-amylase activities found in Canada No. 1 and No. 2 grades of triticale grain were compared with percent

sprouted kernels and linear regression and correlation coefficients were calculated using the GLM procedures of SAS (1983).

Mean square values for one way and factorial analysis of variance for farinograph characteristics and falling numbers, muffin characteristics, sour cream coffee cake characteristics, yeast bread characteristics, and pup loaf characteristics are given in Appendices G (1,2), H (1,2,3), I (1,2,3), J (1,2,3) and K (1,2) respectively.

Data for farinograph characteristics, falling numbers, volume, sensory analyses and instrumental measurements were analyzed by both one-way and factorial analysis of variance using the GLM and ANOVA procedures of SAS (1983). Significant differences were accepted at $p=0.05$ or less, and differences among treatment means were determined by Duncan's Multiple Range Test ($p<0.05$). For the factorial analysis of variance, the main effects examined were protein content, alpha-amylase range, replication, judge (for sensory analyses) and water level (for pup loaf bake test). The error source of variation consisted of all three, four or five way interactions, as well as the two-way interactions including a judge effect.

IV RESULTS AND DISCUSSION

A. Relationship of Alpha-Amylase Activity to Sprout Damage in Triticale Milling Samples.

In order to satisfy the first objective of this study, which was to determine the relationship between sprout damage and alpha-amylase activity in triticale grain, and in order to determine the levels of alpha-amylase activity that would be characteristic of grades 1 and 2 triticale, alpha-amylase activity was determined for 26 samples of grade 1 and 18 samples of grade 2 triticale which had previously been assessed visually for percent sprout damage (Appendix F). As shown in Figure 14, the linear coefficient of correlation (r) betwen percent sprouted kernels and alpha-amylase activity for all 44 samples was low, $r = 0.39$. When grade 1 samples were considered separately, the correlation coefficient was even lower, ($r = 0.29$) while for the grade 2 samples the correlation coefficient was the same as that for the total group (Table 8). Within both grades there was a wide range of alpha-amylase activities, from 0.13 to 9.99 IDC units/mg for grade 1 and from 0.50 to 19.04 IDC units/mg for grade 2 samples. Mean activities were 2.38 ± 2.60 and 4.37 ± 5.27 IDC units/mg for grades 1 and 2 respectively. Standard deviations were greater than the means in both cases, an indication of the extent of variation present in the graded samples.

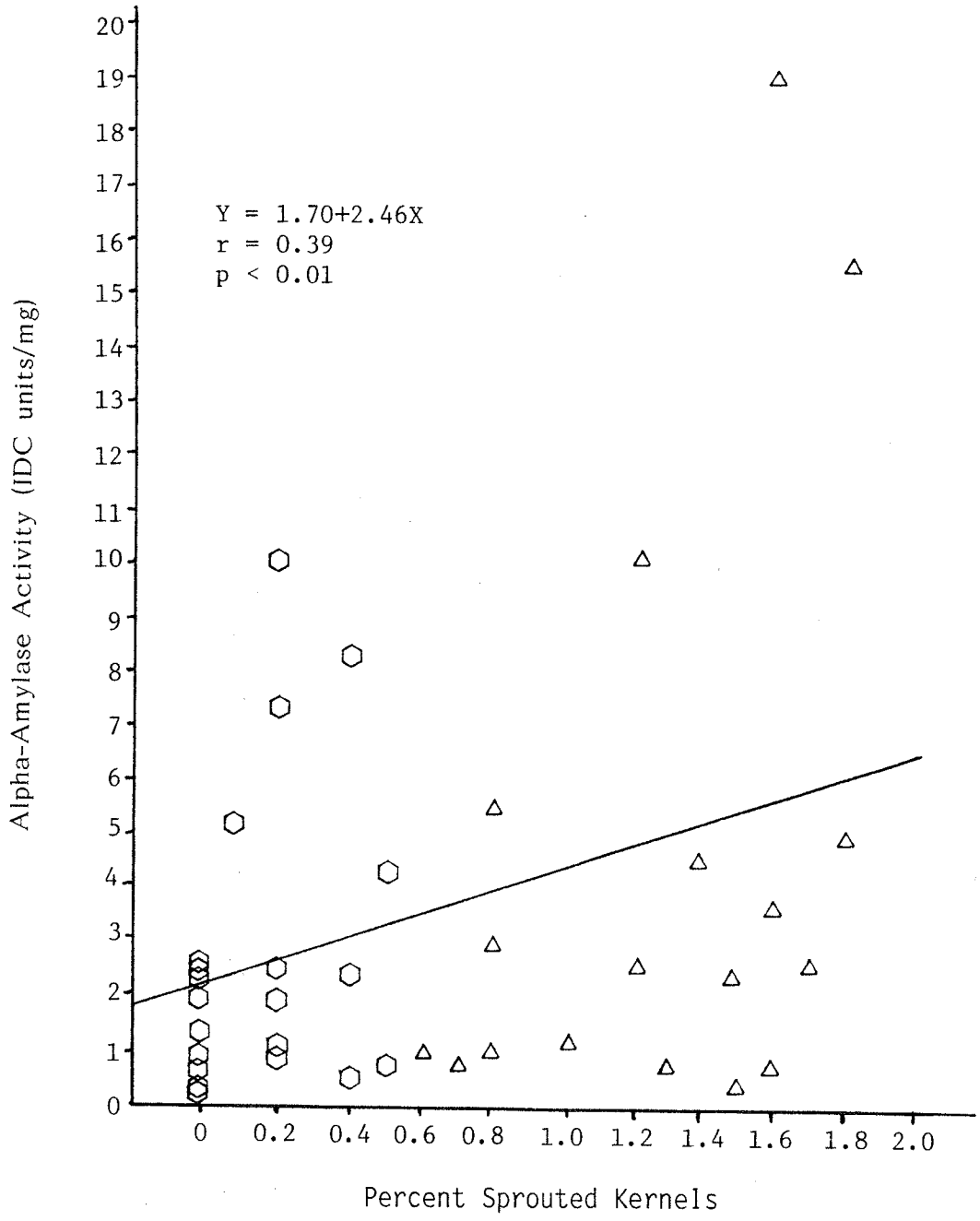


Figure 14. Relationship between percent sprouted kernels and alpha-amylase activity (⬡ grade 1, △ grade 2).

Table 8. Relationships Between Percent Sprouted Kernels and Alpha-Amylase Activity for Grades of Triticale Milling Samples

	Grade 1	Grade 2	Grades 1 & 2
Linear Relationship[1]	Y = 1.75 + 4.23 X	Y = -0.77 + 4.19 X	Y = 1.70 + 2.46 X
Correlation Coefficient (r)	0.29	0.39	0.39
Mean Activity (IDC units/mg)	2.38	4.37	3.20
Variance	6.48	26.21	15.49
Standard Deviation	2.60	5.27	3.98
Mean Sprout (%)	0.15	1.23	0.60
Variance	0.03	0.23	0.38
Standard Deviation	0.18	0.49	0.63

[1] Where Y = Alpha-amylase activity and X = percent sprout damage.

The poor correlation between visible sprout damage and level of alpha-amylase activity in triticale was expected, since similar results have been reported for both wheat and rye. Ibrahim and D'Appolonia (1979) and McCrate et al (1981) concluded that the extent of sprouting in wheat as measured by visual examination was not necessarily an indication of alpha-amylase activity levels. Kruger and Tipples (1982) found it difficult to assess the extent of sprout damage present in 82 rye samples, and they reported a correlation coefficient of 0.49 between percent sprouted kernels and alpha-amylase activity; a value very close to that determined for the triticale samples in this study. Because the samples used in this study may not have been a single variety, this may have partially contributed to the lack of correlation between sprout damage and alpha-amylase activity. Results of this initial study therefore confirmed that for triticale as for wheat and rye, percent sprout damage does not provide an accurate measure of alpha-amylase activity.

B. Measurement of Flour Quality

1. Alpha-Amylase and Protease Activity

Table 9 presents the alpha-amylase activities of the formulated triticale and of the wheat flours. The four ranges of alpha-amylase activity selected for the formulated flours were based on the activities determined for the milling samples. Initially (range 1), both lots of triticale grain were relatively low in alpha-amylase activity. The

Table 9. Alpha-Amylase Activities of Formulated Flours

Protein Level	Alpha-Amylase Activity Range	Alpha-Amylase Activity[1] (IDC Units/mg) Rep 1	Rep 2	Rep 3	Mean
Low	1	0.39 ± 0.02	0.36 ± 0.05	0.35 ± 0.05	0.37
	2	3.00 ± 0.00	3.00 ± 0.00	2.82 ± 0.62	2.94
	3	5.03 ± 0.26	5.03 ± 0.26	4.73 ± 0.25	4.93
	4	6.51 ± 0.35	6.10 ± 0.01	6.11 ± 0.00	6.25
High	1	1.13 ± 0.12	1.07 ± 0.23	1.04 ± 0.06	1.07
	2	3.32 ± 0.33	3.22 ± 0.38	3.55 - 0.51	3.37
	3	4.82 ± 0.46	5.47 ± 0.51	5.48 ± 0.25	5.26
	4	6.92 ± 0.93	7.13 ± 0.93	7.13 ± 0.35	7.05
All-purpose		0.07 ± 0.01	0.07 ± 0.01	0.07 ± 0.01	0.07
Whole-wheat		0.12 ± 0.01	0.12 ± 0.01	0.12 ± 0.01	0.12
Bread		0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.03

[1] Mean of triplicate determinations.

high protein content grain was somewhat higher in alpha-amylase activity (1.07 IDC units/mg) than the low protein content grain (0.37 IDC units/mg); but both had much lower levels of alpha-amylase activity than the mean of the grade 1 milling samples (2.38 IDC units/mg).

Alpha-amylase activities in the formulated triticale flours were adjusted by adding sprouted material to achieve the selected alpha-amylase activity ranges. Range 1 (<1.5 IDC units/mg) was the activity of the original flours, range 2 (2.5 - 3.5 IDC units/mg) represented the activity present in grade 1 milling samples, range 3 (4.5 - 5.5 IDC units/mg) represented the activity present in grade 2 milling samples and range 4 (6.5 - 7.5 IDC units/mg) represented an extremely high alphaamylase activity (Table 9).

The three wheat flours were extremely low in alpha-amylase activity by comparison with the triticale flours. The whole-wheat flour had slightly higher activity (0.12 IDC units/mg) than the all-purpose and bread flours (0.07 and 0.03 IDC units/mg respectively), because of the inclusion of the bran in which alpha-amylase enzyme is abundantly found (Dedio et al, 1975). All-purpose flour had malted barley flour added to it and therefore was slightly higher in activity than the untreated bread flour (Table 9). The fact that the initial triticale flours were much higher in alpha-amylase activity than the wheat flours is consistent

with the work of several researchers (Berry et al, 1971; Klassen and Hill, 1971) who found lower amylograph peak viscosities for triticale flours. Measured alpha-amylase activity values fell within the selected alpha-amylase activity ranges, except for the low protein content flour with the highest alpha-amylase range which fell slightly below the desired range. As well, alpha-amylase activity was consistent across replications.

Data for protease activity of formulated flours were variable and no consistent increase in proteolytic activity could be seen as the level of sprouted material in the formulated flour increased. Protease levels were approximately 58.8 to 64.6 HUT/g while activity of wheat flour averaged 10.2 HUT/g.

2. Proximate Data and Color Measurements

Table 10 presents the proximate data for the formulated triticale and wheat flours. The mean protein contents of the low protein and high protein flours were 11.2% and 14.4% respectively. Protein determinations for the high protein triticale and the bread flours were similar (>14.0%). The protein content of the whole-wheat and all-purpose flours ranged from 12 to 14%, values typical of wheat flours. In triticale flours protein content did not change over increasing levels of alpha-amylase activity, and protein determinations were consistent across the replications.

Table 10. Proximate Data[1] for Formulated Flours

Protein Level	Alpha-Amylase Range	Protein (14% m.b.)				Ash (14% m.b.)				Moisture (as is)			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
Low	1	11.45±0.12	11.05±0.08	11.18±0.19	11.22	1.65±0.01	1.63±0.02	1.65±0.00	1.64	8.86±0.06	8.97±0.00	9.19±0.01	9.00
	2	11.76±0.60	11.00±0.04	11.09±0.02	11.28	1.65±0.01	1.62±0.01	1.62±0.00	1.63	8.88±0.01	8.85±0.11	8.91±0.02	8.88
	3	11.20±0.16	10.96+0.08	11.35±0.11	11.11	1.62±0.00	1.63±0.01	1.64±0.01	1.63	8.89±0.00	8.92±0.01	8.75±0.00	8.85
	4	11.14±0.00	11.11±0.06	11.09±0.22	11.10	1.61±0.00	1.66±0.00	1.65±0.00	1.64	8.78±0.00	8.66±0.01	8.48±0.03	8.61
Mean Low Protein					11.19				1.63				8.84
High	1	14.55±0.15	14.15±0.03	14.64±0.12	14.44	1.58±0.04	1.62±0.00	1.63±0.01	1.61	8.69±0.04	9.24±0.06	9.38±0.00	9.10
	2	14.04±0.06	14.31±0.03	14.42±0.10	14.26	1.63±0.01	1.62±0.01	1.64±0.00	1.63	8.85±0.08	8.84±0.01	9.22±0.02	8.97
	3	14.51±0.13	14.63±0.04	14.44±0.06	14.52	1.66±0.06	1.62±0.02	1.65±0.01	1.64	8.89±0.02	9.08±0.04	8.80±0.03	8.92
	4	14.38±0.01	14.41±0.19	14.45±0.21	14.41	1.61±0.00	1.64±0.01	1.62±0.02	1.62	8.97±0.04	9.24±0.00	8.52±0.04	8.91
Mean High Protein					14.41				1.62				8.98
All-Purpose		11.80±0.03	11.88±0.08	11.93±0.01	11.87	0.40±0.00	0.41±0.01	0.39±0.00	0.40	12.21±0.06	11.63±0.01	12.55±0.03	12.13
Whole Wheat		14.56±0.01	13.74±0.14	13.64±0.06	13.98	1.24±0.03	1.29±0.01	1.30±0.00	1.28	8.45±0.00	12.06±0.07	11.88±0.08	10.80
Bread		13.97±0.07	14.15±0.12	14.08±0.13	14.06	0.56±0.00	0.57±0.01	0.56±0.00	0.56	13.75±0.01	14.23±0.00	14.14±0.01	14.04

[1] Mean of duplicate samples.

Ash contents (Table 10) of the formulated triticale flours were similar, but were greater than those found for the wheat flours. The higher ash content of the triticale flours (1.63%) as compared to the ash content of the whole-wheat flour (1.28%) was probably indicative of the greater degree of kernel shrivelling in triticale grain as compared to wheat (Klassen and Hill, 1971; Kaltsikes and Larter, 1970). Whole-wheat flour had a higher ash content than the all-purpose and bread flours because the bran was present in this flour. Ash content determinations were consistent across replications.

Moisture contents (Table 10) of the formulated triticale flours were similar, but the triticale flours were drier than the wheat flours. Because triticale flours were milled in a consumer-type flour mill, this may have caused some moisture loss from the flours. Wheat flours were milled at a commercial mill.

Table 11 presents the color values for the formulated and wheat flours as determined by the Hunter Color Difference Meter. Values for lightness (L), red-green (a), blue-yellow (b) and total change in color from the white standard (ΔE) were quite similar for the formulated flours, although the high protein flours had slightly lower L values, indicating darker flour; lower b values, indicating less yellowness; and higher ΔE values, indicating a greater

Table 11. Hunter Color Difference Meter Values[1] for Formulated Flours

Protein Level	Alpha-Amylase Activity Range	L Value				a Value				b Value				ΔE			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
Low	1	80.3±0.28	80.3±0.01	80.6±0.21	80.4	1.7±0.14	1.7±0.00	1.5±0.07	1.6	9.5±0.14	9.7±0.00	9.8±0.00	9.7	15.6±0.07	15.5±0.00	15.3±0.14	15.5
	2	80.4±0.00	80.7±0.07	80.8±0.21	80.6	1.5±0.00	1.4±0.07	1.3±0.07	1.4	9.9±0.00	9.8±0.00	9.7±0.00	9.8	15.5±0.00	15.2±0.07	15.1±0.21	15.3
	3	80.1±0.14	80.7±0.07	80.4±0.14	80.4	1.6±0.07	1.4±0.07	1.5±0.07	1.5	9.6±0.00	9.7±0.01	9.6±0.00	9.6	15.5±0.14	15.1±0.14	15.8±0.14	15.5
	4	80.4±0.07	79.7±0.78	80.1±0.07	80.1	1.5±0.07	1.6±0.14	1.5±0.07	1.5	9.7±0.00	9.6±0.14	9.8±0.00	9.6	15.4±0.07	15.5±0.07	15.7±0.07	15.5
Mean Low Protein					80.3				1.5				9.7				15.5
High	1	80.4±0.07	79.8±0.07	80.1±0.00	80.1	1.5±0.07	1.5±0.07	1.4±0.00	1.5	9.4±0.00	9.4±0.00	9.4±0.14	9.4	15.2±0.07	15.7±0.07	15.4±0.07	15.4
	2	80.4±0.00	79.9±0.07	79.5±0.07	79.9	1.3±0.07	1.4±0.07	1.6±0.07	1.4	9.4±0.00	9.5±0.00	9.4±0.00	9.4	15.1±0.00	15.7±0.07	16.0±0.07	15.6
	3	80.2±0.00	79.2±0.14	79.7±0.14	79.7	1.4±0.00	1.7±0.07	1.6±0.07	1.6	9.3±0.07	9.5±0.14	9.4±0.00	9.4	15.8±0.00	16.2±0.07	15.4±0.14	15.8
	4	79.9±0.07	79.1±0.07	79.8±0.00	79.6	1.5±0.07	1.7±0.00	1.5±0.07	1.6	9.2±0.14	9.5±0.00	9.4±0.07	9.3	15.8±0.35	16.4±0.07	15.6±0.00	15.6
Mean High Protein					79.8				1.5				9.4				15.6
All-Purpose		89.6±0.14	89.4±0.21	89.4±0.07	89.4	0.03±0.07	0.3±0.14	0.2±0.00	0.3	6.7±0.14	6.6±0.07	6.5±0.00	6.6	7.1±0.07	7.00±0.07	6.9±0.07	7.0
Whole-Wheat Bread		81.8±0.35	81.0±0.28	81.1±0.28	81.3	1.0±0.14	0.2±0.14	0.9±0.14	0.7	8.3±0.07	9.1±0.00	8.8±0.00	8.7	13.5±0.57	14.4±0.28	14.2±0.21	14.0
		87.7±0.07	87.6±0.14	86.4±0.14	87.2	-0.4±0.28	-0.3±0.00	-0.3±0.07	0.3	10.3±0.42	10.4±0.00	10.5±0.07	10.4	10.9±0.00	10.8±0.14	10.9±0.21	10.9

[1] Mean of duplicate samples
L = lightness value where 0 = black, 100 = white
a = red-green value, where - indicates green, + indicates red
b = blue-yellow value, where - indicates blue, + indicates yellow
ΔE = calculated as $\sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$ where standard white tile L = 92.4 a = -1.2 b = 0.5

change in color when compared to the white standard. As expected, extracted wheat flours were much lighter in color than the whole-grain flours. The bread flour was a yellow color (higher b value) when compared to the all-purpose flour, because it was unbleached and had a slightly higher ash content (Table 10). Whole-wheat flour was lighter than the triticale flours, most likely due to the greater amount of white endosperm present in milled wheat flour.

3. Farinograph Characteristics and Falling Numbers

Most researchers have reported lower absorptions for triticale flours than for their respective wheat controls (Table 3). Table 12 and Figure 17a demonstrate that absorption for the high protein triticale flour was similar to that of the whole-wheat flour, both were approximately 69.5%. Low protein triticale, all-purpose and bread flours all had absorptions close to 64.2% (Table 12). Farinograph absorption was significantly greater for the high protein flours (Table 13) at all alpha-amylase ranges, than for the low protein flours. The mean absorptions were 69.6% for the high protein triticales and 64.5% for the low protein flours. Alpha-amylase activity significantly reduced farinograph absorption, with the change especially evident from levels 1 to 2, however this effect was largely due to the low protein flours (Figure 17a).

Formulated triticale flours had weak farinograph mixing curves with shorter development times, shorter

Table 12. Mean Values[1] For Effect of Flour on Farinograph Characteristics and Falling Numbers

Protein Level	Alpha-Amylase Activity Range	Absorption (14% m.b.)		Peak Time (Minutes)		Stability (Minutes)		Mixing Tolerance Index (M.T.I.)		Falling Number*	
Low	1	65.23^{b}	±0.14	3.33^{ef}	±0.14	1.83^{cd}	±0.14	50^{cd}	±17.32	218^{c}	±13.45
	2	64.33^{cd}	±0.12	3.42^{def}	±0.29	2.17^{cd}	±0.29	45^{de}	± 5.00	108^{e}	± 2.89
	3	64.23^{cde}	±0.06	3.25^{f}	±0.25	2.08^{cd}	±0.14	55^{cd}	± 0.00	93^{e}	± 1.53
	4	64.03^{de}	±0.21	3.42^{def}	±0.14	2.33^{c}	±0.29	58^{c}	± 2.89	87^{e}	± 0.58
Mean Low Protein		64.46		3.35		2.10		52		127	
High	1	69.77^{a}	±0.25	3.75^{cde}	±0.25	1.75^{cd}	±0.00	107^{b}	± 7.64	166^{d}	±10.12
	2	69.50^{a}	±0.15	3.83^{cd}	±0.29	1.67^{d}	±0.14	112^{b}	± 2.89	112^{e}	± 4.02
	3	69.47^{a}	±0.21	3.75^{cde}	±0.25	1.75^{cd}	±0.00	117^{ab}	± 2.89	96^{e}	± 1.73
	4	69.47^{a}	±0.06	3.92^{c}	±0.14	1.75^{cd}	±0.00	127^{a}	± 2.89	88^{e}	± 2.52
Mean High Protein		69.56		3.81		1.73		115		116	
All-Purpose		64.46^{c}	±0.12	3.00^{f}	±0.00	7.75^{b}	±0.66	33^{f}	± 2.89	503^{b}	±43.66
Whole-Wheat		69.60^{a}	±0.36	5.67^{a}	±0.58	7.83^{b}	±0.58	35^{ef}	± 0.00	742^{a}	±68.53
Bread		64.00^{e}	±0.00	5.00^{b}	±0.00	8.67^{a}	±0.29	37^{ef}	± 2.89	363	±10.07

abcdef Values in the same column bearing the same superscript are not significantly different ($p<0.05$).

1 Mean of 3 replications.

* Statistical analysis did not include bread flour because it was tested under different conditions.

Figure 15. Farinograph curves for formulated triticale flours.

L = low protein, H = high protein.

1-4 represents lowest to highest alpha-amylase ranges.

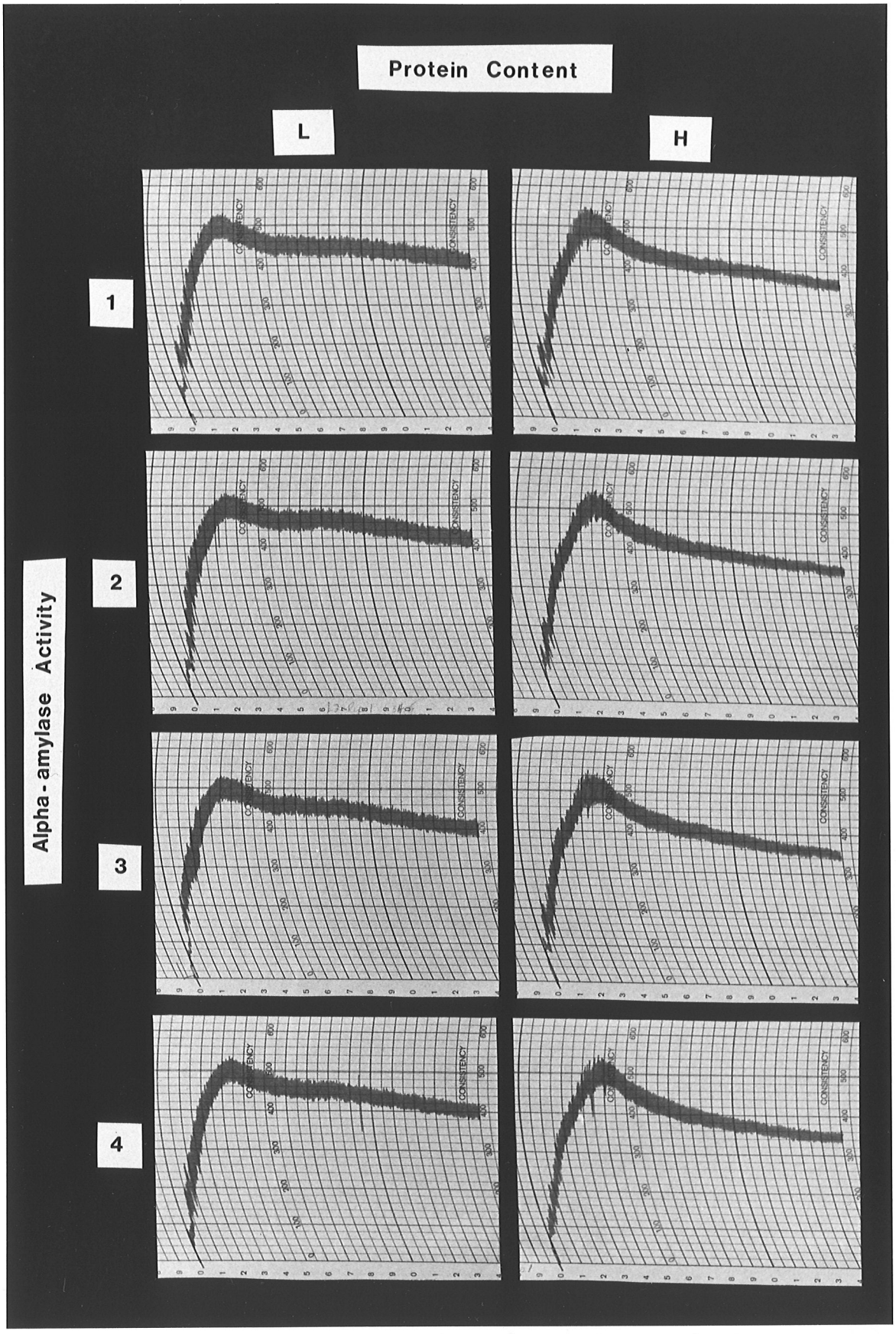
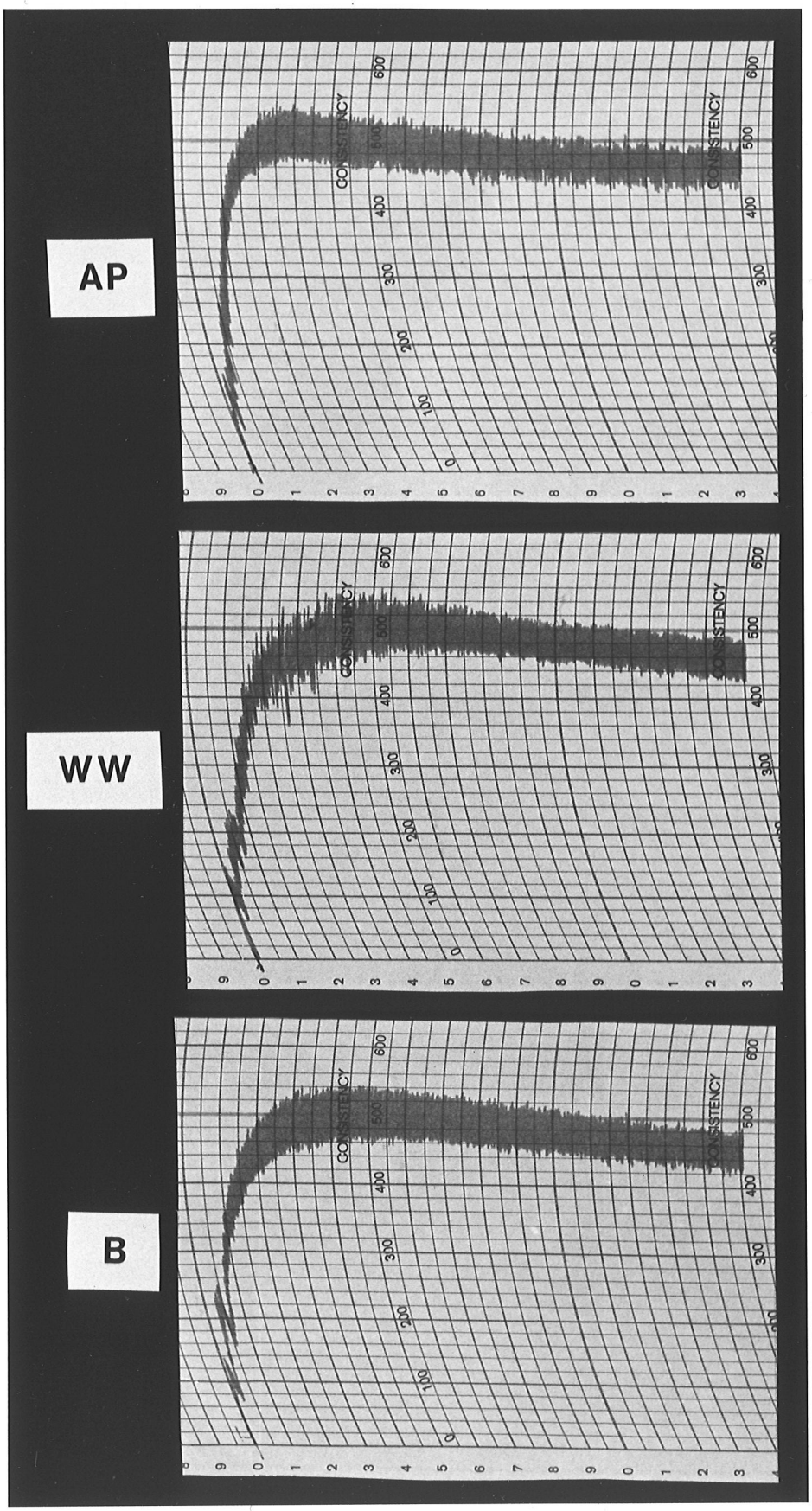

Protein Content
L
H
Alpha-amylase Activity
1
2
3
4
CONSISTENCY

Figure 16. Farinograph curves for wheat flours. AP = all-purpose, WW = whole-wheat, B = bread flours.


AP
WW
B
CONSISTENCY
100
200
300
400
500
600
0
1
2
3
4
5
6
7
8
9

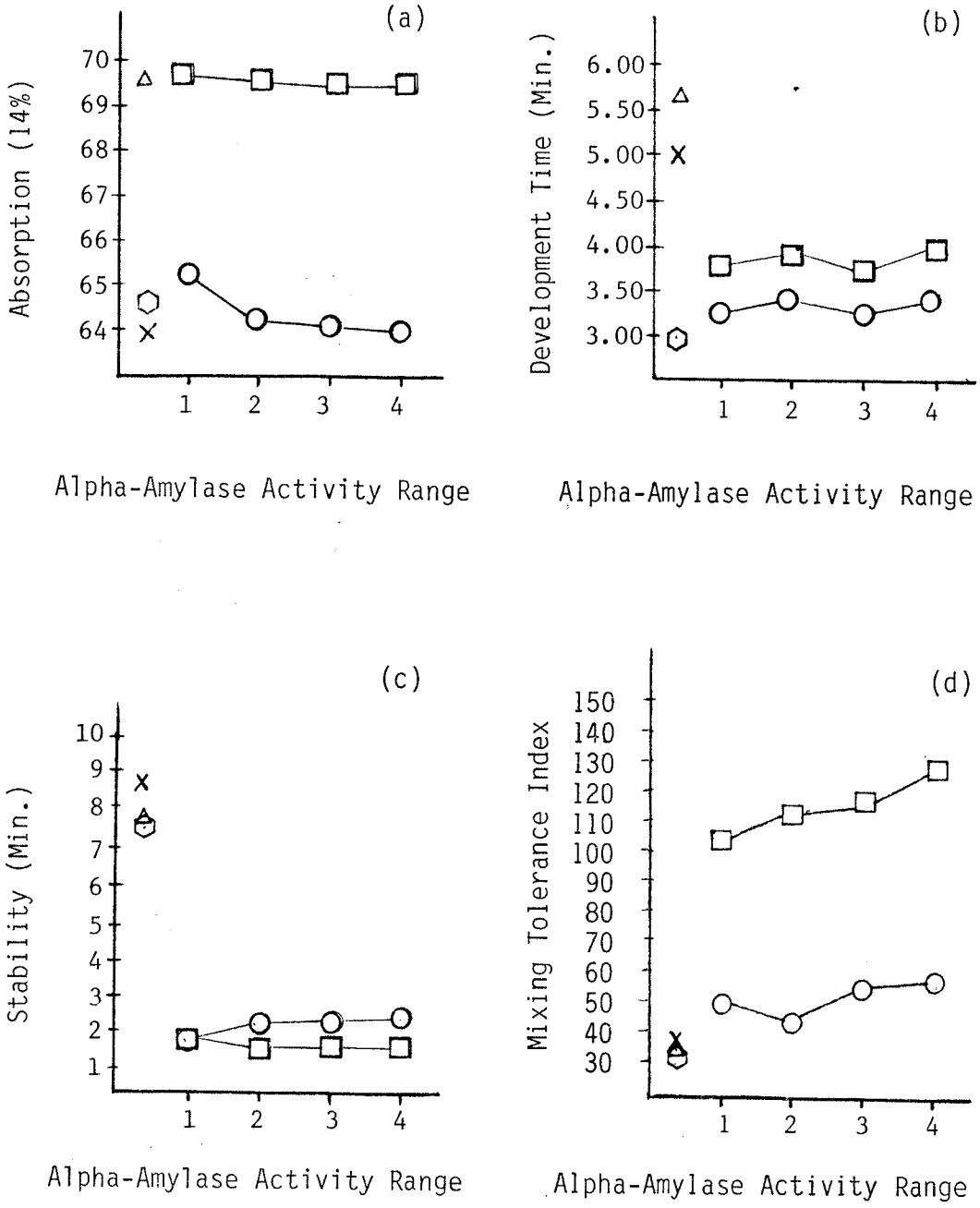


Figure 17 (a-d). Farinograph absorption (a), development time (b), stability (c) and mixing tolerance index (d) for flours (O low protein, □ high protein, ⬡ all-purpose flour, △ whole-wheat flour, X bread flour).

stabilities and lower mixing tolerances (represented by a higher mixing tolerance index value) than the wheat flours (Table 12, Figures 15, 16). These results agree with those of Singh (1976), Ahmed and McDonald (1974), Rooney et al (1969), Tsen et al (1973), Haber et al (1976) and Lorenz and Welsh (1977) who compared farinographs of triticale flour with those for wheat flour. High protein triticale flours had significantly longer development times, but significantly shorter stabilities and lower mixing tolerances than the low protein flours (Table 13, Figures 17b, 17c, 17d). For stability, the differences were small and trends were not consistent across protein levels, therefore it is questionable whether protein content had a real effect on stability. Formulated triticale flours were affected by alpha-amylase activity in that stabilities increased slightly from range 3 to 4 and mixing tolerances decreased from ranges 2 to 3 (Table 14, Figures 17c, 17d). Lorenz (1981) also found shorter peak times and reduced mixing tolerances when sprouted wheat, which has high alpha-amylase activity, was compared to sound wheat.

Farinograph peak time, stability and mixing tolerance are associated with mixing requirements, and are interrelated with factors associated with baking quality. For any flour, higher farinograph absorption, longer peak time, longer stability and greater mixing tolerance generally indicate greater mixing time and/or tolerance to mixing. These factors reflect the flour strength and the gluten

Table 13. Mean Values[1] for Main Effect of Protein Content on Farinograph Characteristics and Falling Numbers

Farinograph Characteristic	Protein Content	
	Low	High
Absorption	64.46[b]	69.55[a]
Peak Time	3.35[b]	3.81[a]
Stability	2.10[a]	1.73[b]
Mixing Tolerance Index	52[b]	115[a]
Falling Number	127[a]	115[b]

[ab] Values in the same row bearing the same superscript are not significantly different ($p<0.05$).

[1] Mean of 4 alpha-amylase ranges X 3 replications.

Table 14. Mean Values[1] for Main Effect of Alpha-Amylase Range on Farinograph Characteristics and Falling Numbers.

Farinograph Characteristic	Alpha-Amylase Range			
	1	2	3	4
Absorption	67.50[a]	66.92[b]	66.85[b]	66.75[b]
Peak Time	3.54[a]	3.62[a]	3.50[a]	3.67[a]
Stability	1.79[b]	1.92[b]	1.92[b]	2.04[a]
Mixing Tolerance Index	78.33[b]	78.33[b]	85.83[a]	92.50[a]
Falling Number	191.83[a]	110.00[b]	94.33[c]	87.83[d]

abcd Values in the same row bearing the same superscript are not significantly different ($p<0.05$).

1 Mean of 2 protein contents X 3 replications.

protein content and quality of a flour. High gluten protein content is beneficial to the bread-making quality of a flour (Haber et al, 1976; Tsen et al, 1973). In this study, high protein triticale flours had absorptions similar to those of whole-wheat flours, but had shorter peak times, stabilities and mixing tolerances. This would indicate that triticale flours probably had less gluten protein for dough development than wheat flours. The fact that high protein triticale flours had higher absorptions, but lower mixing tolerances than the low protein flours, may indicate a difference in gluten quality between the two protein flours.

Falling numbers, which are an indirect measure of alpha-amylase activity, indicated that there was much higher alpha-amylase activity in triticale flours as compared to the wheat flours (Table 12, Figure 18). Falling numbers ranged from values of 100 to 200 for triticale flours as compared to 500 to 700 for all-purpose and whole-wheat flours. The low protein content flours had slightly lower falling numbers than the high protein flours (Table 13), which is in agreement with the values found for measured alpha-amylase activity (Table 3). Falling numbers decreased linearly with increasing alpha-amylase range (Table 14, Figure 18).

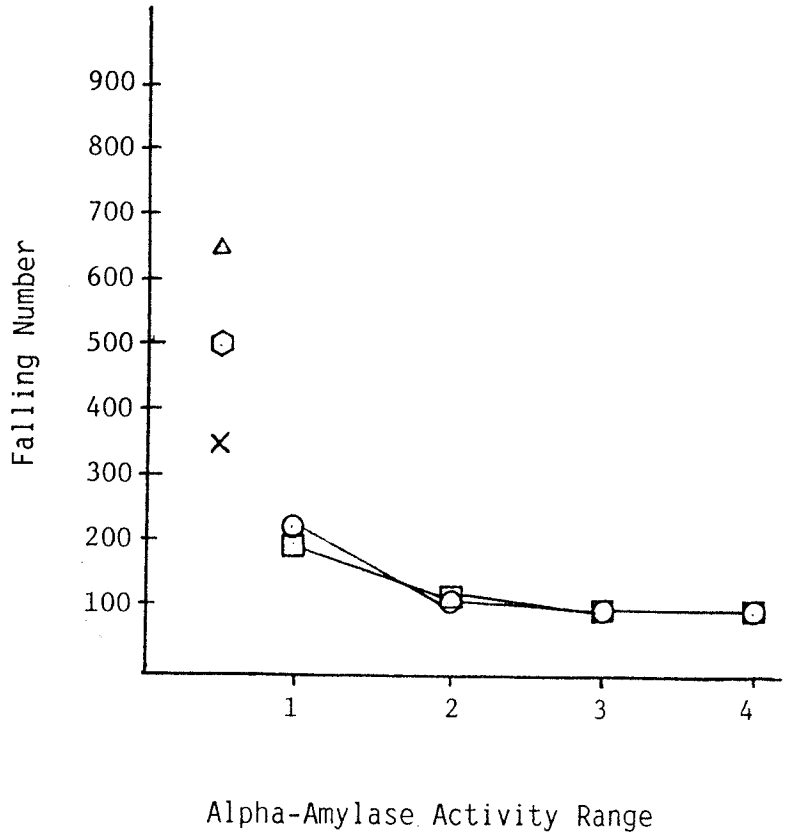


Figure 18. Falling Numbers for flours (○ low protein, □ high protein, ⬡ all-purpose flour, △ whole-wheat flour, X bread flour).

C. Effects of Protein Content and Alpha-Amylase Activity on Consumer Style Baked Products

Consumer products tested to examine the effects of protein content and alpha-amylase activity ranges on the baking quality of triticale flours included muffins, sour cream coffee cakes and yeast breads. In the following discussion the results of the sensory and physical testing will be presented for one product at a time in the following order: volume, crumb quality, tenderness, moistness, color, flavor and overall quality.

1. Muffins

Data for volume, sensory and instrumental texture analyses, moisture content and moisture loss have been tabulated in Table 15. Main effects of protein content and alpha-amylase activity of flour on muffin quality are presented in Tables 16 and 17 respectively. Table 18 presents the Hunter Color Difference meter values for the color of muffin crumb. Illustrations of the effects of protein content and alpha-amylase activity on muffin quality are shown in Figures 19, 20 and 21, and a photograph of the internal structure of the baked muffins is presented in Figure 22.

A comparison of the specific volumes of muffins indicated that whole-wheat flours produced greater specific

Table 15. Mean Values For Effect of Flour on Muffin Quality

Protein Level	Alpha Amylase Activity Range	Volume[1] (cc/g)	Sensory Score[2]								Instrumental Reading[3]				
			Exterior Color	Interior Color	Crumb Quality	Moistness	Tenderness	Flavor Intensity	Flavor Acceptability	Overall Quality	Firmness (cm/volt)	Cohesive-ness	Gumminess	Moisture[4] Content	Moisture[4] Loss
Low	1	2.06^{abc}	34.3^{ab}	35.2^{a}	38.1^{b}	34.3^{a}	31.5^{a}	31.5^{a}	45.2^{ab}	41.7^{a}	2.65^{a}	0.53^{a}	1.42^{a}	33.45^{a}	11.42^{a}
	2	2.00^{bcd}	33.7^{ab}	35.7^{a}	37.7^{b}	32.9^{a}	31.6^{a}	32.0^{a}	44.7^{ab}	40.4^{a}	2.81^{a}	0.55^{a}	1.56^{a}	33.06^{a}	11.44^{a}
	3	1.99^{cd}	33.2^{ab}	35.9^{a}	35.8^{b}	33.6^{a}	31.9^{a}	31.8^{a}	45.5^{a}	41.2^{a}	2.74^{a}	0.52^{a}	1.39^{a}	33.09^{a}	11.56^{a}
	4	1.97^{d}	32.2^{b}	36.6^{a}	35.4^{b}	28.0^{b}	31.7^{a}	32.3^{a}	45.8^{a}	41.1^{a}	2.81^{a}	0.52^{a}	1.43^{a}	32.81^{a}	11.50^{a}
High	1	2.04^{abcd}	32.4^{ab}	36.6^{a}	39.6^{b}	33.6^{a}	31.8^{a}	31.8^{a}	45.6^{a}	43.6^{a}	2.63^{a}	0.52^{a}	1.37^{a}	33.41^{a}	11.21^{a}
	2	2.07^{a}	34.8^{a}	36.7^{a}	39.2^{b}	32.4^{a}	32.1^{a}	31.4^{a}	45.6^{a}	43.1^{a}	2.74^{a}	0.52^{a}	1.42^{a}	32.80^{a}	11.55^{a}
	3	2.04^{abc}	33.9^{ab}	36.7^{a}	38.7^{b}	32.4^{a}	31.4^{a}	31.4^{a}	44.9^{b}	43.4^{a}	2.73^{a}	0.53^{a}	1.45^{a}	32.91^{a}	11.55^{a}
	4	2.00^{bcd}	33.1^{ab}	37.3^{a}	35.7^{b}	31.1^{ab}	32.0^{a}	32.2^{a}	46.0^{a}	42.9^{a}	2.80^{a}	0.53^{a}	1.48^{a}	33.26^{a}	11.34^{a}
Control		2.07^{ab}	28.0^{c}	30.0^{b}	44.0^{a}	34.00^{a}	34.0^{a}	28.0^{b}	43.0^{b}	43.0^{a}	2.47^{a}	0.56^{a}	1.39^{a}	33.62^{a}	11.47^{a}

abcd Values in the same column bearing the same superscript are not significantly different ($p<0.05$).

1 Mean of 4 muffins X 3 replications.

2 Mean of 7 panelists X 3 replications; where a higher value represents darker color, better crumb quality, drier crumb, more tender crumb, more intense and acceptable flavor and better overall quality.

3 Mean of 5 readings X 3 replications.

4 Mean of 3 replications.

Table 16. Mean Values for Main Effect of Protein Content on Muffin Quality.

	Protein Content	
	Low	High
Specific Volume (cc/g)[1]	2.00[b]	2.04[a]
Sensory Scores[2]		
Exterior Color	33.35[a]	33.57[a]
Interior Color	35.85[b]	36.82[a]
Crumb Quality	36.75[b]	38.31[a]
Moistness	32.19[a]	32.36[a]
Tenderness	31.62[a]	31.81[a]
Flavor Intensity	31.89[a]	31.70[a]
Flavor Acceptability	45.29[a]	45.52[a]
Overall Quality	41.10[b]	43.23[a]
Instrumental Readings[3]		
Firmness (cm/volt)	2.75[a]	2.72[a]
Cohesiveness	0.53[a]	0.52[a]
Gumminess	1.45[a]	1.43[a]
Moisture Content[1]	33.10[a]	33.10[a]
Moisture Loss[1]	11.48[a]	11.41[a]

[ab] Values in the same row bearing the same superscript are not significantly different ($p<0.05$).

[1] Mean of 4 alpha-amylase ranges X 3 replications.

[2] Mean of 7 panelists X 4 alpha-amylase ranges X 3 replications.

[3] Mean of 5 readings X 4 alpha-amylase ranges X 3 replications.

Table 17. Mean Values for Main Effect of Alpha-Amylase Range on Muffin Quality

	Alpha-Amylase Range			
	1	2	3	4
Specific Volume (cc/g)[1]	2.05[a]	2.04[a]	2.02[ab]	1.99[b]
Sensory Scores[2]				
Exterior Color	33.36[a]	34.24[a]	33.57[a]	32.67[a]
Interior Color	35.88[a]	36.19[a]	36.28[a]	36.95[a]
Crumb Quality	38.83[a]	38.45[a]	37.26[ab]	35.57[b]
Moistness	33.93[a]	32.64[a]	33.00[a]	29.52[b]
Tenderness	31.64[a]	31.83[a]	31.57[a]	31.81[a]
Flavor Intensity	31.64[a]	31.69[a]	31.60[a]	32.26[a]
Flavor Acceptability	45.41[a]	45.14[a]	45.17[a]	45.91[a]
Overall Quality	42.64[a]	41.71[a]	42.29[a]	42.00[a]
Instrumental Readings[3]				
Firmness (cm/volt)	2.64[a]	2.77[a]	2.73[a]	2.80[a]
Cohesiveness	0.53[a]	0.53[a]	0.52[a]	0.52[a]
Gumminess	1.40[a]	1.49[a]	1.42[a]	1.45[a]
Moisture Content[4]	33.43[a]	32.93[a]	33.00[a]	33.04[a]
Moisture Loss	11.32[b]	11.50[ab]	11.55[a]	11.42[ab]

[ab] Values in the same row bearing the same superscript are not significantly different ($p<0.05$).

[1] Mean of 4 muffins X 2 protein contents X 3 replications.

[2] Mean of 7 panelists X 2 protein contents X 3 replications.

[3] Mean of 5 readings X 2 protein contents X 3 replications.

Table 18. Hunter Color Difference Meter Values[1] for Muffin Crumb

Protein Level	Alpha-Amylase Activity Range	L Value				a Value				b Value				ΔE			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
Low	1	54.0±0.07	54.0±0.21	54.1±0.07	54.0	5.7±0.07	5.5±0.14	5.5±0.07	5.5	19.2±0.07	19.1±0.00	19.1±0.00	19.1	43.3±0.07	43.3±0.21	43.2±0.07	43.3
	2	54.4±0.21	54.3±0.21	54.3±0.07	54.3	5.6±0.07	5.5±0.07	5.5±0.07	5.5	19.1±0.14	19.3±0.07	19.2±0.00	19.2	43.0±0.00	43.0±0.14	43.0±0.07	43.0
	3	54.5±0.28	54.3±0.07	54.3±0.00	54.3	5.4±0.00	5.5±0.07	5.5±0.07	5.5	18.8±0.14	19.1±0.14	19.0±0.14	19.0	43.0±0.07	43.0±0.21	42.9±0.07	43.0
	4	54.9±0.14	53.5±0.21	53.7±0.07	54.0	5.1±0.07	5.6±0.00	5.4±0.07	5.4	19.0±0.07	19.0±0.00	19.0±0.00	19.0	43.3±0.07	43.7±0.21	43.5±0.07	43.5
Mean Low Protein					54.2				5.5			19.1					43.2
High	1	54.2±0.00	53.8±0.14	53.8±0.07	53.9	5.5±0.07	5.5±0.07	5.4±0.00	5.5	18.9±0.00	19.1±0.07	19.1±0.07	19.0	42.8±0.00	43.3±0.14	43.3±0.14	43.2
	2	54.4±0.21	53.8±0.14	53.7±0.14	54.0	5.5±0.07	5.5±0.07	5.5±0.07	5.5	18.9±0.00	19.0±0.07	19.0±0.07	19.0	42.8±0.21	43.3±0.14	43.4±0.07	43.2
	3	54.1±0.07	53.7±0.00	53.7±0.00	53.8	5.5±0.07	5.4±0.00	5.4±0.00	5.4	18.7±0.14	18.9±0.07	19.0±0.07	18.9	43.0±0.07	43.3±0.00	43.4±0.07	43.2
	4	54.1±0.00	53.7±0.21	53.6±0.07	53.8	5.4±0.07	5.5±0.00	5.5±0.07	5.5	18.7±0.07	19.0±0.00	19.0±0.07	18.9	42.9±0.00	43.3±0.00	43.5±0.00	43.2
Mean High Protein					53.9				5.5				19.0				43.2
Control		58.4±0.07	57.4±0.00	58.4±0.07	58.1	4.2±0.00	4.3±0.00	4.3±0.07		18.1±0.00	18.8±0.07	18.1±0.00	18.3	38.3±0.49	39.9±0.07	38.7±0.00	39.0

[1] Mean of duplicate samples.
L = lightness value where 0 = black, 100 = white.
a = red-green value, where - indicates green, + indicates red.
b = blue-yellow value, where - indicates blue, + indicates yellow.
ΔE = calculated as $\sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$ where the standard white tile L = 92.4, a = -1.2, b = 0.05.

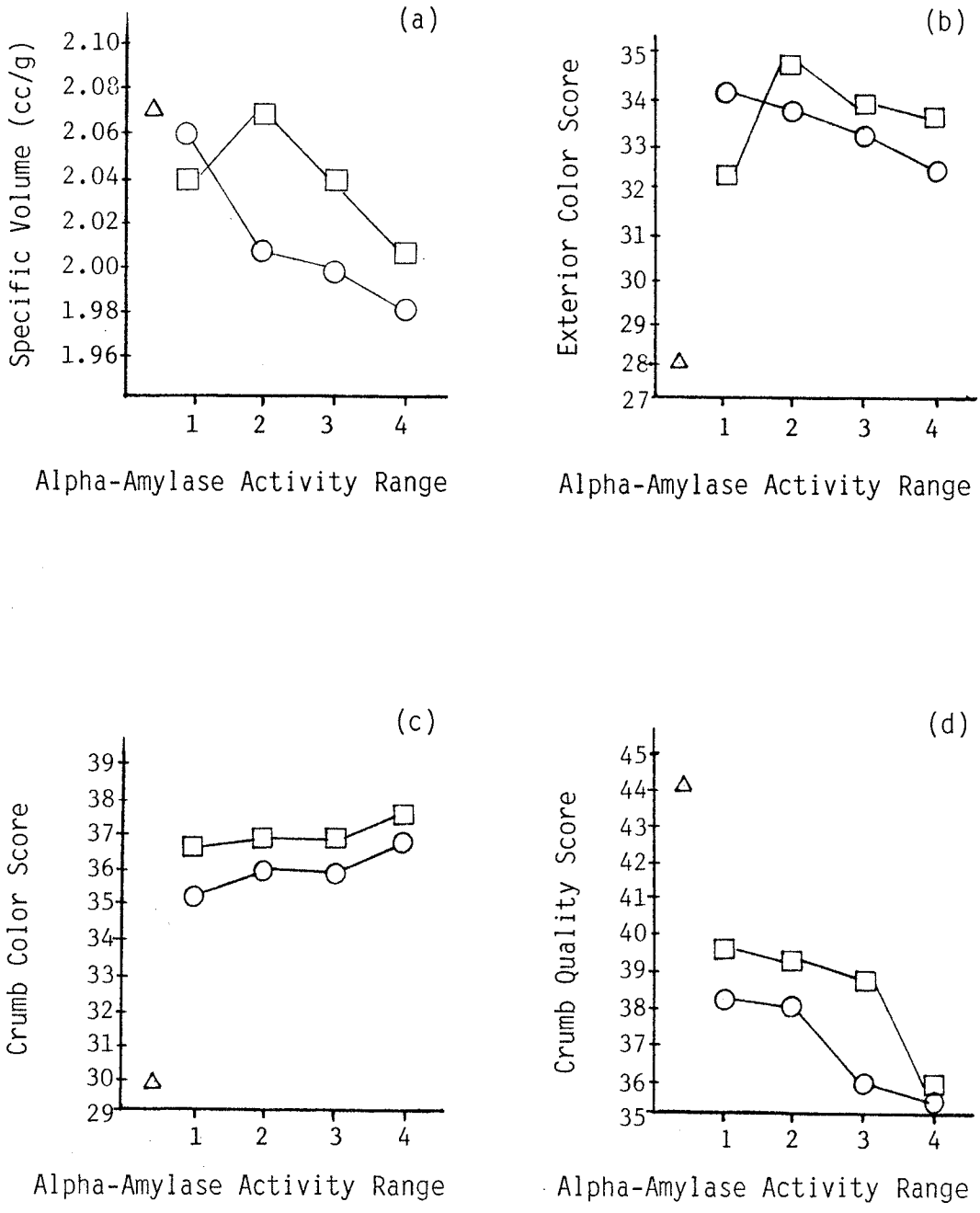


Figure 19 (a-d). Volume (a) and sensory exterior color (b), crumb color (c), and crumb quality (d) for muffins (○ low protein, □ high protein, △ control).

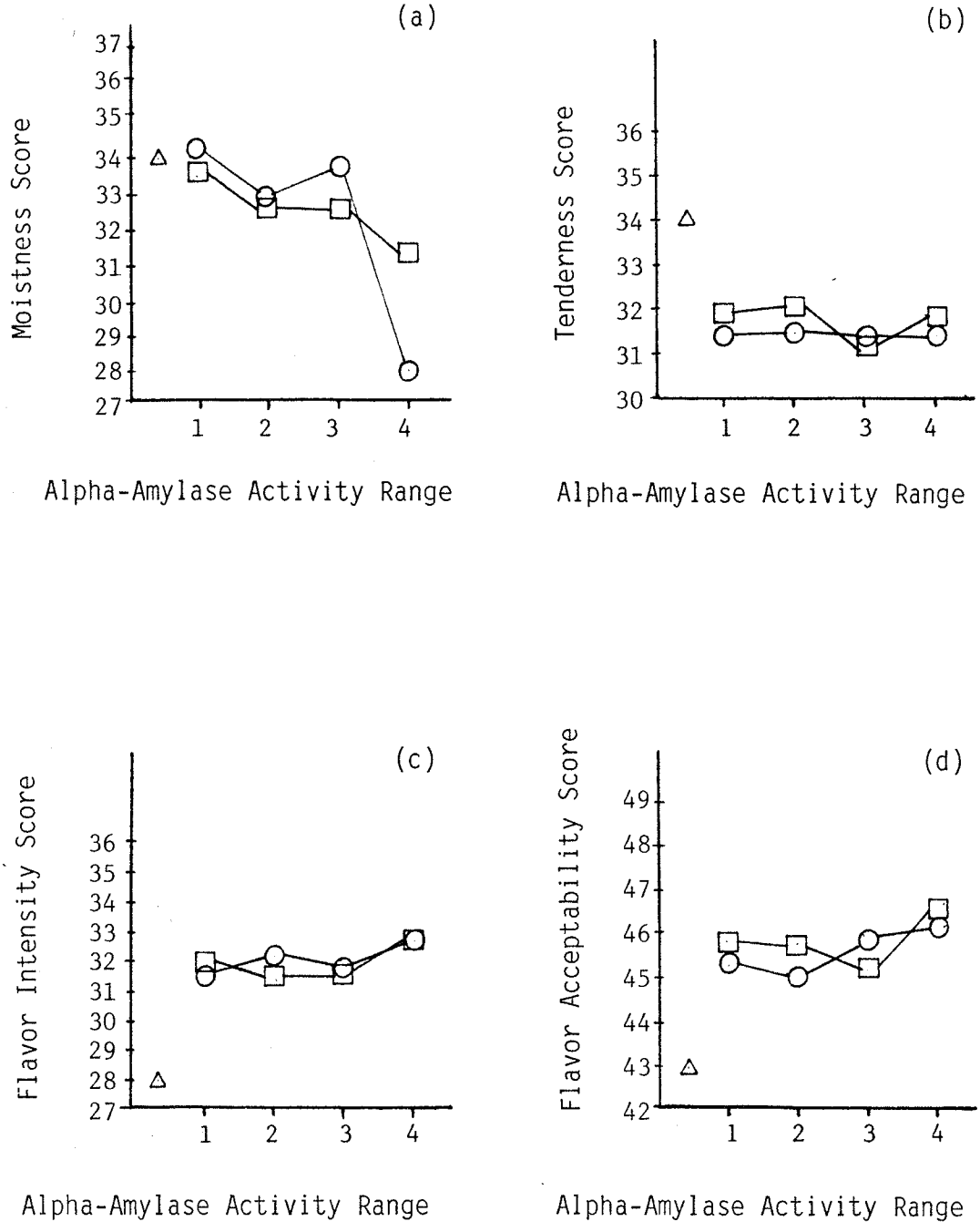


Figure 20 (a-d). Sensory moistness (a), tenderness (b), flavor intensity (c) and flavor acceptability (d) for muffins (○ low protein, □ high protein, △ control).

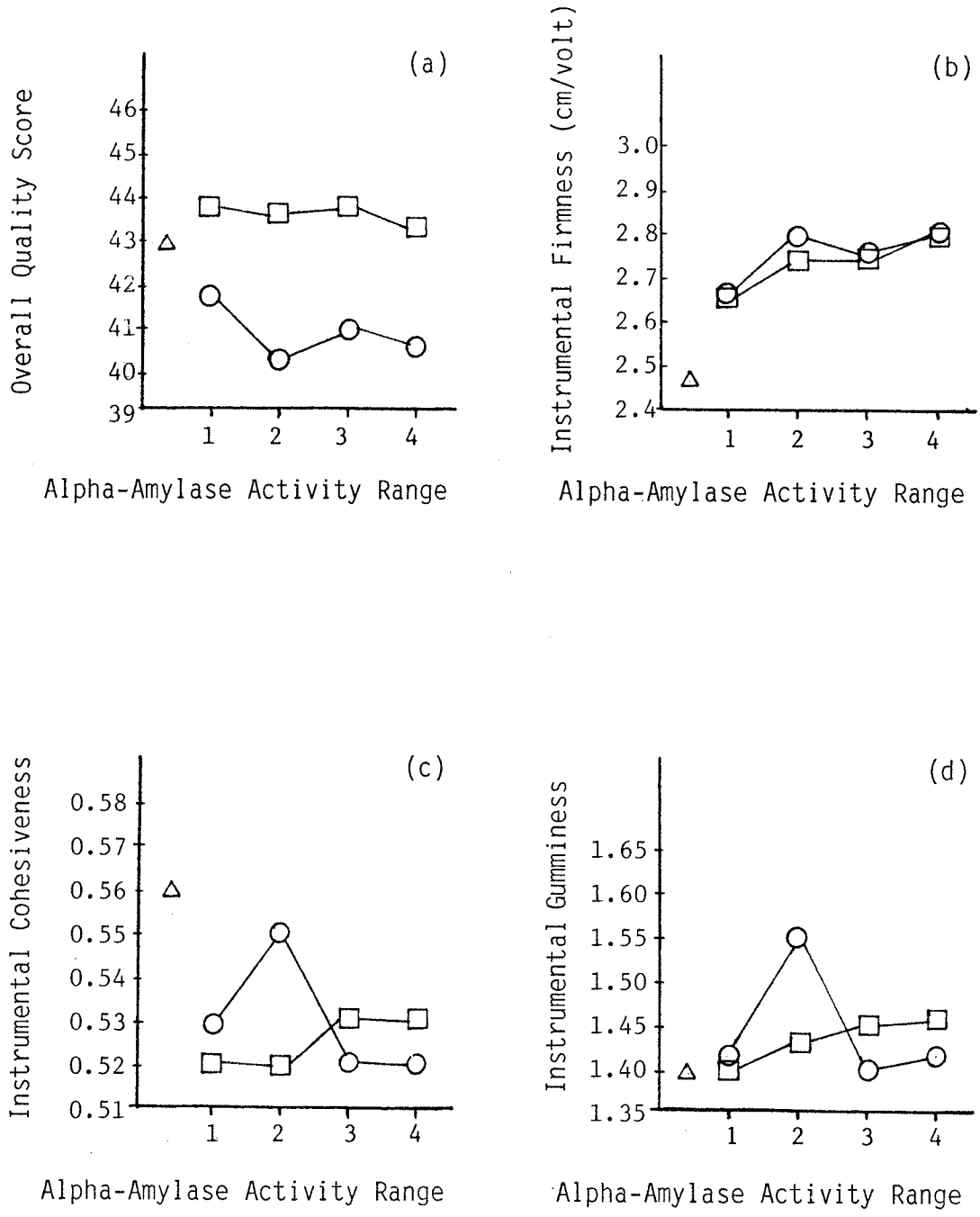
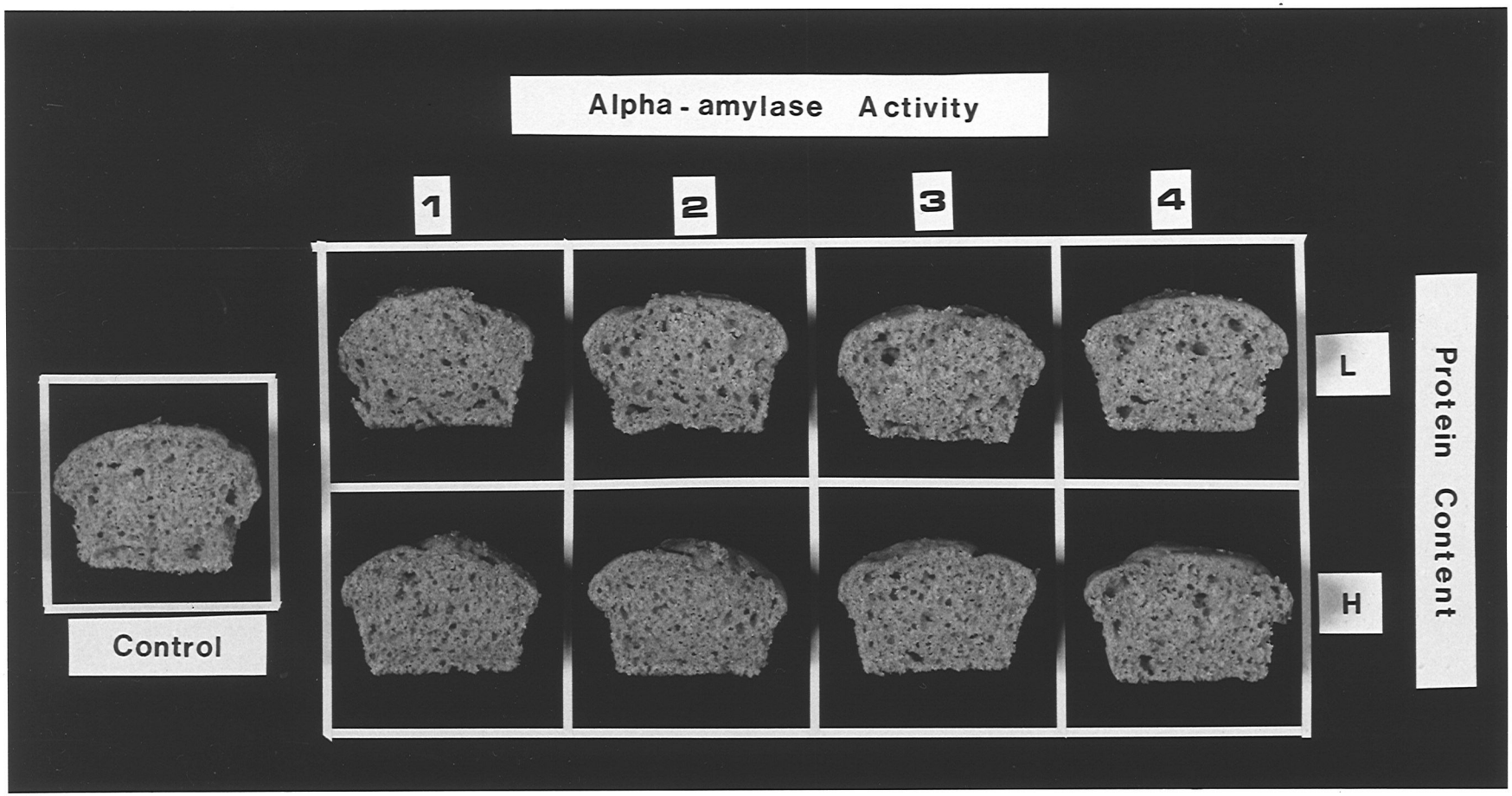


Figure 21 (a-d). Sensory overall quality (a), and instrumental firmness (b), cohesiveness (c) and gumminess (d) for muffins (○ low protein, □ high protein, △ control).

Figure 22. Cross-sections of muffins baked from triticale and whole-wheat flours.
L = low protein, H = high protein.
1-4 represent lowest to highest alpha-amylase ranges.
Control = whole-wheat.


Alpha - amylase Activity
1
2
3
4
L
H
Protein Content
Control

volumes than most triticale muffins (Table 16, Figure 19a). Specific volume for the whole-wheat control was 2.07 cc/g, while the low protein, low alpha-amylase triticale flour and the high protein at the second alpha-amylase range produced specific volumes of 2.06 and 2.07 cc/g respectively. High protein triticale flours produced significantly higher specific volumes than the low protein flours (Table 16, Figure 19a). Increases in alpha-amylase range significantly reduced specific volumes, especially from range 3 to 4 (Table 17, Figure 19a), although there was a slight increase in volume for the high protein flour at alpha-amylase level 2.

Mean values for sensory crumb quality evaluations indicated that the crumb quality of the whole-wheat control was significantly better than the crumb quality of all triticale muffins (Table 15, Figure 19d). For the triticale muffins, the high protein flours produced significantly better crumb quality than the low protein flours (Table 16, Figure 19d). For both protein contents, deterioration of crumb quality occurred with increasing alpha-amylase activity (Table 17, Figure 19d). Sensory crumb quality scores reflected volume changes, since low protein flours and higher alpha-amylase activities caused decreased volumes and poorer crumb structure. The deterioration of crumb structure can be seen in the photographs of the internal

sections of muffins (Figure 22), where the crumb became coarse with open cells, with low protein and high alpha-amylase flours.

Panelists could not detect tenderness differences among the triticale muffins, due to protein content nor alpha-amylase activity (Tables 16, 17). Although there was no significant difference in tenderness between triticale and wheat muffins, there was a trend for the wheat muffins to be more tender than the triticale muffins (Table 15). Instrumentally determined firmness and cohesiveness measurements were also not affected by protein content and alpha-amylase activity (Tables 16, 17; Figures 2b, 2c). There was a trend however, for the triticale muffins to become firmer with increasing alpha-amylase level, and the wheat muffins to be more tender than the triticale muffins.

Sensory moistness scores indicated that the moistness of the wheat control was similar to the low alpha-amylase triticale muffins. Protein content of the flour did not affect the sensory moistness of the triticale muffins (Table 16). Higher alpha-amylase activity resulted in triticale muffins that were significantly gummier; the deterioration occurred largely from alpha-amylase range 3 to 4. Sensory moistness scores (Figure 20a) were not confirmed by instrumental gumminess measurements, as there were no differences among triticale muffins due to protein

content (Table 16) nor alpha-amylase activity (Table 17). Although there were no differences among the triticale muffins for instrumental gumminess (Figure 21d), the muffins baked from the low protein flours at the second alpha-amylase range appeared to be gummier. This may be explained as variability among the samples. Although higher alpha-amylase activity produced actual sensory moistness effects, they were not due to change in moisture content and moisture loss of the muffins, since there were no significant differences found for these parameters.

Exterior color and interior color (Figures 19b, 19c), as determined by sensory analysis (Table 15) of all triticale muffins were significantly darker than the whole-wheat muffins. High protein flours produced a significantly darker crumb (Table 16, Figure 19c), and alpha-amylase activity had no effect on exterior or interior color as evaluated by the sensory panel. When crumb color of the muffins was determined instrumentally (Table 18), the high protein muffins had slightly lower L values, signifying the higher protein muffin crumb was detectably darker.

For flavor intensity (Figure 20c) and flavor acceptability (Figure 20d), the whole-wheat control had less intense flavor which was less acceptable than the flavor of triticale muffins (Table 15). Flavor intensity and flavor acceptability values indicated that there were

no significant differences due to either protein content (Table 16) or alpha-amylase activity (Table 17) among triticale muffins.

Scores for sensory overall quality (Table 15, Figure 21a) indicated that the triticale muffins were equally as acceptable as the wheat control muffins, and all muffins could be considered to be of good quality as they all had scores of approximately 40. High protein flours produced significantly better products than did the low protein flours. Alpha-amylase activity did not affect the sensory overall quality of the muffins (Table 17, Figure 21a). Panelists may have used volume and crumb quality evaluations in their determination of overall quality of muffins, because these scores reflected overall quality, especially for the high protein muffins.

To summarize, protein content had a definite effect on the specific volume, and crumb quality of muffins at all ranges of alpha-amylase activity, but alpha-amylase activity was of more importance in determining internal crumb quality characteristics than the protein content. These findings reflect effects of alpha-amylase on starch granule integrity and starch gelatinization, even in a product which has a relatively short preparation and baking time. Alpha-amylase affected the crumb structure and volume of this product, and while higher protein content did to

some extent, mitigate the effects of high alpha-amylase, as alpha-amylase activity increased, quality decreased. Flavor and overall quality ratings were not affected however, even in muffins containing the highest range of alpha-amylase.

2. Sour Cream Coffee Cakes

Data for volume, sensory and instrumental texture analyses, moisture content and moisture loss have been tabulated in Table 19. Main effects of protein content and alpha-amylase activity of flour on cake quality are presented in Tables 20 and 21 respectively. Table 22 presents the Hunter Color Difference meter values for the color of cake crumb. Illustrations of the effects of protein content and alpha-amylase on cake quality are shown in Figures 23, 24 and 25 and a photograph of the internal structure of the baked cakes is presented in Figure 26.

All sour cream coffee cakes were made with 100% triticale flour and all had volumes significantly lower than the volume of the whole-wheat control cakes (Table 19, Figure 23a). For the cakes made with triticale, mean volumes for the low and high protein cakes were almost the same, 1879.8 cc and 1875.2 cc respectively. While cake volumes were not affected by the protein content of the flours, the alpha-amylase content had a marked effect, with increases in alpha-amylase producing a consistent decrease

Table 19. Mean Values for Effect of Flour on Sour Cream Coffee Cake Quality

Protein Level	Alpha-Amylase Activity Range	Volume[1] (cc)	Sensory Score[2]								Instrumental Reading[3]			Moisture[1] Content	Moisture[1] loss
			Surface Color	Crumb Color	Crumb Quality	Moist-ness	Tender-ness	Flavor Intensity	Flavor Acceptability	Overall Quality	Firmness	Cohesiveness	Gumminess		
Low	1	1906.7^{b}	31.3^{e}	36.2^{a}	39.1^{ab}	28.9^{a}	38.3^{a}	33.9^{a}	46.1^{a}	43.6^{a}	2.12^{bc}	0.64^{bc}	1.35^{d}	26.82^{a}	7.86^{a}
	2	1885.3^{bc}	34.0^{bcd}	36.7^{a}	37.2^{abc}	28.8^{a}	37.2^{ab}	34.2^{a}	45.9^{a}	43.7^{a}	2.30^{ab}	0.63^{c}	1.45^{bcd}	25.90^{a}	7.92^{a}
	3	1865.0^{c}	32.3^{de}	36.9^{a}	35.7^{bc}	27.5^{a}	36.7^{ab}	34.2^{a}	46.2^{a}	41.3^{a}	2.35^{ab}	0.66^{bc}	1.54^{ab}	26.18^{a}	7.83^{a}
	4	1862.5^{c}	35.2^{b}	37.1^{a}	35.2^{c}	27.1^{a}	36.9^{ab}	33.9^{a}	46.1^{a}	42.5^{a}	2.35^{ab}	0.65^{bc}	1.53^{abc}	26.26^{a}	7.67^{a}
High	1	1899.2^{b}	34.2^{bc}	36.8^{a}	39.9^{a}	28.3^{a}	36.1^{ab}	33.8^{a}	46.1^{a}	43.1^{a}	2.27^{ab}	0.67^{bc}	1.53^{abc}	26.33^{a}	7.69^{a}
	2	1881.7^{bc}	35.2^{b}	37.1^{a}	36.7^{abc}	28.4^{a}	36.1^{ab}	33.7^{a}	46.5^{a}	43.7^{a}	2.32^{ab}	0.68^{b}	1.59^{abc}	26.13^{a}	7.83^{a}
	3	1860.8^{c}	34.4^{bc}	37.1^{a}	35.7^{bc}	27.6^{a}	35.3^{b}	34.8^{a}	46.8^{a}	42.3^{a}	2.31^{ab}	0.68^{b}	1.57^{ab}	26.52^{a}	7.59^{a}
	4	1859.2^{c}	38.3^{a}	37.4^{a}	36.1^{bc}	27.2^{a}	36.5^{ab}	34.5^{a}	46.6^{a}	43.0^{a}	2.41^{a}	0.68^{b}	1.63^{a}	26.53^{a}	7.64^{a}
Control		1950.4^{a}	33.0^{cde}	29.0^{b}	39.0^{ab}	29.0^{a}	37.0^{ab}	30.0^{b}	42.0^{b}	41.0^{a}	1.90^{c}	0.73^{c}	1.39^{cd}	27.07^{a}	7.58^{a}

abcd Values in the same column bearing the same superscript are not significantly different ($p<0.05$).

1 Mean of 3 replications.

2 Mean of 7 panelists X 3 replications; where a higher value represents darker color, better crumb quality, drier crumb, more tender crumb, more intense and acceptable flavor and better overall quality.

3 Mean of 5 readings X 3 replications.

Table 20. Mean Values for Main Effect of Protein Content on Sour Cream Coffee Cake Quality

	Protein Content	
	Low	High
Volume (cc)[1]	1879.8[a]	1875.2[a]
Sensory Scores[2]		
Surface color	33.20[b]	35.55[a]
Crumb color	36.71[a]	37.11[a]
Crumb quality	36.79[a]	37.07[a]
Moistness	28.08[a]	27.87[a]
Tenderness	37.27[a]	36.02[b]
Flavor Intensity	34.05[a]	34.20[a]
Flavor Acceptability	46.05[a]	46.46[a]
Overall Quality	42.76[a]	43.01[a]
Instrumental Readings[3]		
Firmness (cm/volt)	2.28[a]	2.33[a]
Cohesiveness	0.65[b]	0.68[a]
Gumminess	1.47[b]	1.58[a]
Moisture Content[1]	26.29[a]	26.38[a]
Moisture Loss[1]	7.82[a]	7.69[a]

[ab] Values in the same row bearing the same superscript are not significantly different ($p<0.05$).

[1] Mean of 4 alpha-amylase ranges X 3 replications.

[2] Mean of 7 panelists X 4 alpha-amylase ranges X 3 replications.

[3] Mean of 5 readings X 4 alpha-amylase ranges X 3 replications.

Table 21. Mean Values for Main Effect of Alpha-Amylase Range on Sour Cream Coffee Cake Quality

	Alpha-Amylase Range			
	1	2	3	4
Volume (cc)[1]	1902.9^{a}	1883.3^{b}	1862.9^{c}	1860.8^{c}
Sensory scores[2]				
Surface color	32.79^{c}	34.57^{b}	33.36^{c}	36.79^{a}
Crumb color	36.50^{a}	36.91^{a}	37.00^{a}	37.24^{a}
Crumb quality	39.48^{a}	36.93^{b}	35.67^{b}	35.64^{b}
Moistness	28.57^{a}	28.62^{a}	27.55^{a}	27.17^{a}
Tenderness	37.24^{a}	36.64^{a}	36.00^{a}	36.71^{a}
Flavor intensity	33.83^{a}	33.98^{a}	34.50^{a}	34.19^{a}
Flavor acceptability	46.07^{a}	46.16^{a}	46.50^{a}	46.31^{a}
Overall quality	43.31^{a}	43.71^{a}	41.79^{a}	42.74^{a}
Instrumental readings[3]				
Firmness (cm/volt)	2.19^{b}	2.31^{ab}	2.33^{ab}	2.38^{a}
Cohesiveness	0.66^{a}	0.66^{a}	0.67^{a}	0.67^{a}
Gumminess	1.44^{b}	1.52^{ab}	1.56^{a}	1.58^{a}
Moisture Content[1]	26.57^{a}	26.02^{a}	26.35^{a}	26.40^{a}
Moisture Loss[1]	7.78^{a}	7.88^{a}	7.71^{a}	7.66^{a}

abc Values in the same row bearing the same superscript are not significantly different ($p<0.05$).

1 Mean of 2 protein contents X 3 replications.

2 Mean of 7 panelists X 2 protein contents X 3 replications.

3 Mean of 5 readings X 2 protein contents X 3 replications.

Table 22. Hunter Color Difference Meter Values[1] for Sour Cream Coffee Cake Crumb

Protein Level	Alpha-Amylase Activity Range	L Value				a Value				b Value				ΔE			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
Low	1	45.7±0.07	45.3±0.00	45.6±0.00	45.5	5.6±0.00	5.7±0.00	5.7±0.07	5.7	17.0±0.00	17.0±0.07	17.0±0.00	17.0	50.1±0.07	50.4±0.07	50.1±0.00	50.2
	2	45.3±0.07	44.6±0.07	45.4±0.07	45.1	5.7±0.07	5.7±0.00	5.7±0.00	5.7	16.9±0.07	16.7±0.07	16.9±0.07	16.8	50.4±0.07	51.0±0.07	50.3±0.07	50.6
	3	45.2±0.14	44.7±0.07	45.3±0.00	45.1	5.9±0.00	5.8±0.07	5.8±0.00	5.8	17.0±0.14	16.9±0.21	17.0±0.07	17.0	50.5±0.07	50.9±0.14	50.4±0.07	50.6
	4	44.6±0.00	44.5±0.14	44.6±0.07	44.6	5.7±0.00	5.7±0.21	5.7±0.00	5.7	16.8±0.07	16.7±0.07	16.8±0.07	16.8	50.9±0.	50.0±0.14	51.0±0.07	50.6
Mean Low Protein					45.1				5.7				16.9				50.5
High	1	45.2±0.07	45.0±0.07	45.2±0.07	45.1	5.5±0.07	5.7±0.00	5.5±0.07	5.6	16.7±0.00	16.6±0.00	16.7±0.00	16.7	50.4±0.07	50.6±0.07	50.4±0.07	50.5
	2	45.3±0.00	44.2±0.07	45.3±0.07	45.3	5.6±0.07	5.7±0.07	5.6±0.07	5.6	16.7±0.00	16.4±0.00	16.7±0.00	16.6	50.2±0.00	51.3±0.07	50.3±0.07	50.6
	3	44.7±0.07	44.7±0.07	44.7±0.07	44.7	5.4±0.28	5.6±0.07	5.5±0.07	5.5	16.7±0.07	16.7±0.07	16.7±0.07	16.7	50.8±0.00	50.9±0.07	50.8±0.00	50.8
	4	44.6±0.00	44.7±0.07	44.6±0.00	44.6	5.7±0.14	5.6±0.00	5.7±0.07	5.7	16.7±0.07	16.8±0.00	16.7±0.00	16.7	50.9±0.00	50.9±0.07	50.9±0.00	50.9
Mean High Protein					44.9				5.6				16.7				50.7
Control		49.4±0.07	50.1±0.21	49.9±0.14	49.8	4.0±0.00	3.9±0.07	3.8±0.00	3.9	16.8±0.00	16.9±0.07	16.9±0.07	16.9	46.3±0.00	45.7±0.21	45.8±0.21	45.9

[1] Mean of duplicate samples.
L = lightness value where 0 = black, 100 = white.
a = red-green value, where - indicates green, + indicates red.
b = blue-yellow value, where - indicates blue, + indicates yellow.
ΔE = calculated as $\sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$ where white standard tile L = 92.4, a = -1.2, b = 0.5.

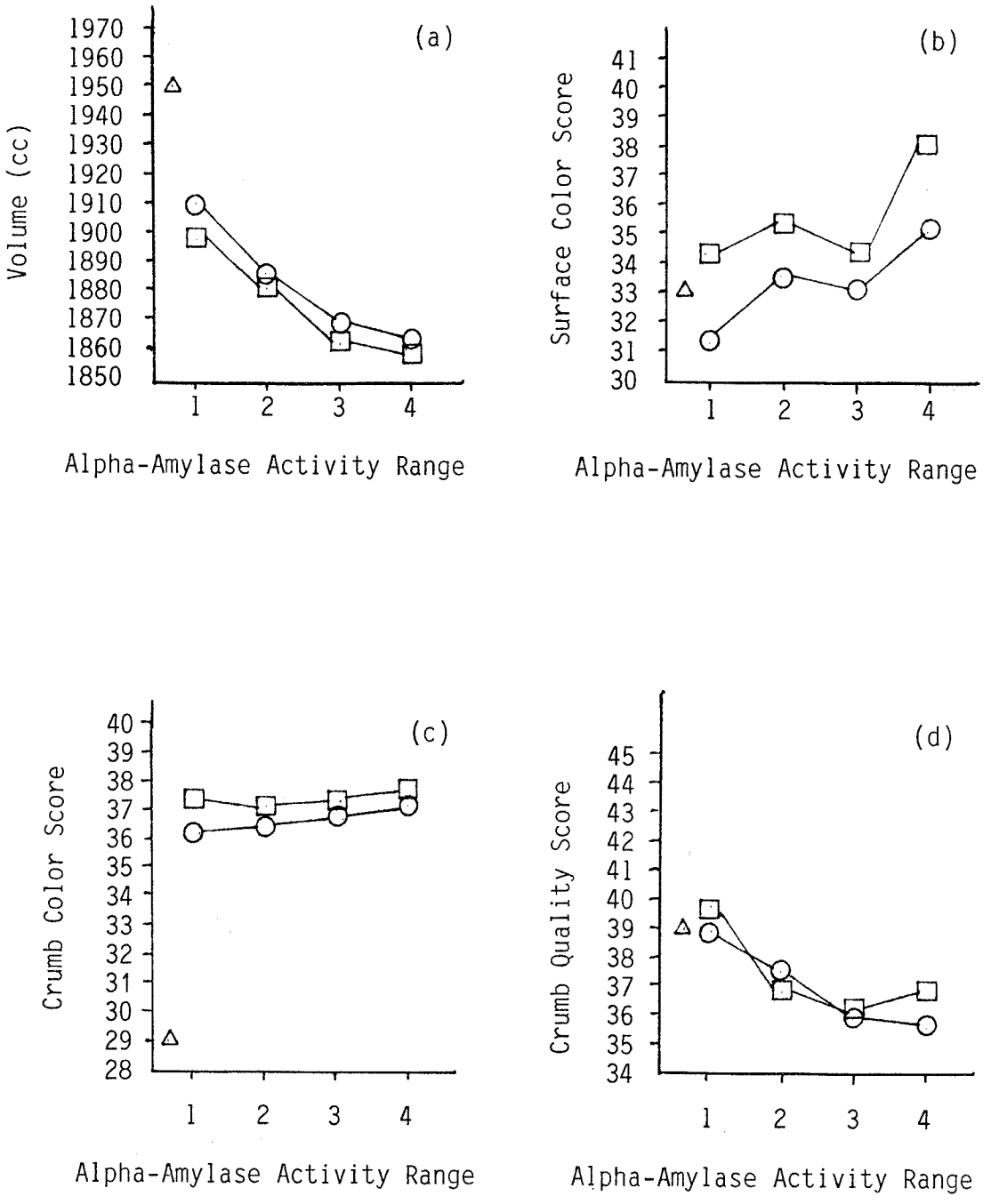


Figure 23(a-d). Volume (a), and sensory surface color (b), crumb color (c) and crumb quality (d) for sour cream cake (○ low protein, □ high protein, △ control).

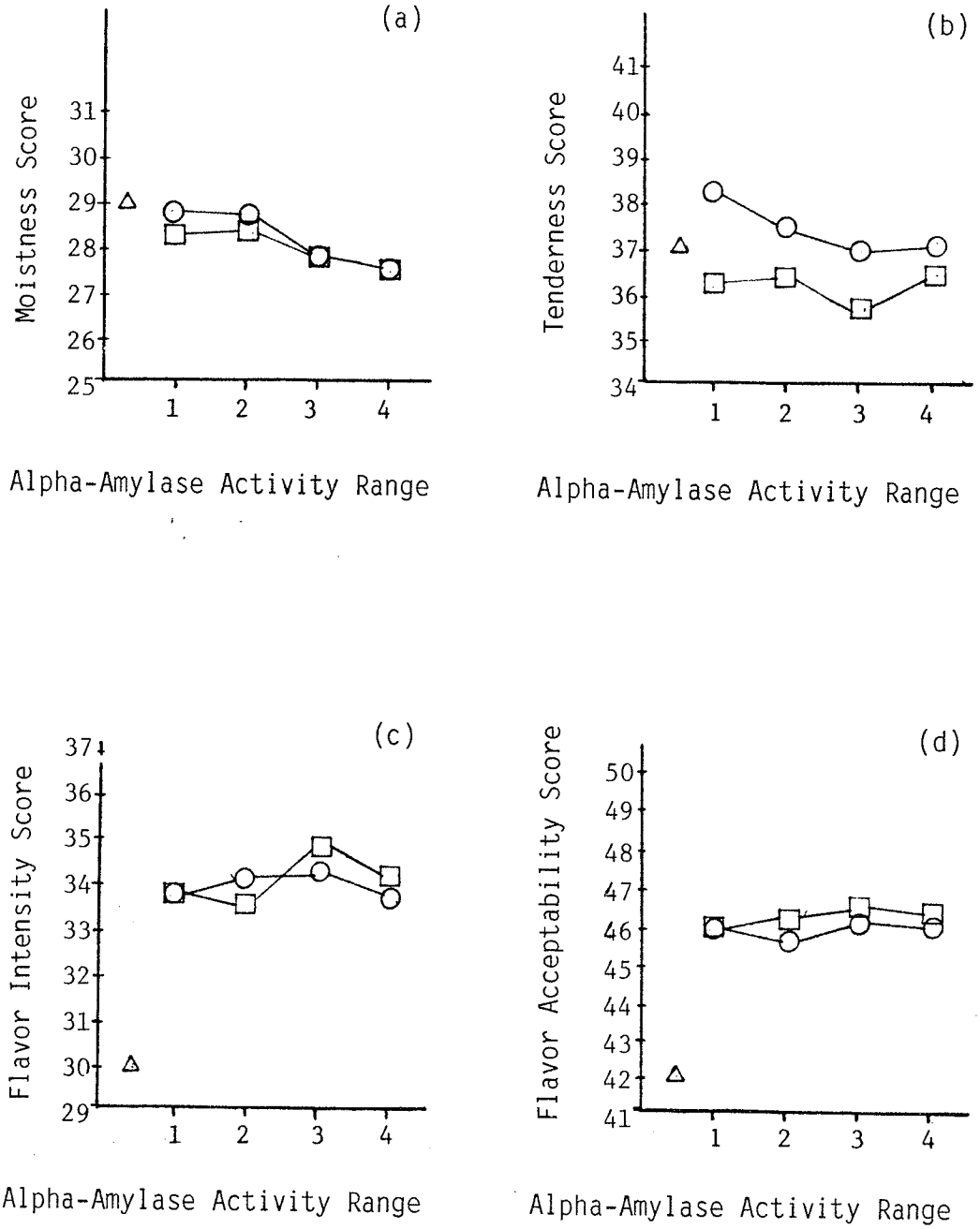


Figure 24 (a-d). Sensory moistness (a), tenderness (b), flavor intensity (c) and flavor acceptability (d) for sour cream coffee cake (○ low protein, □ high protein, △ control).

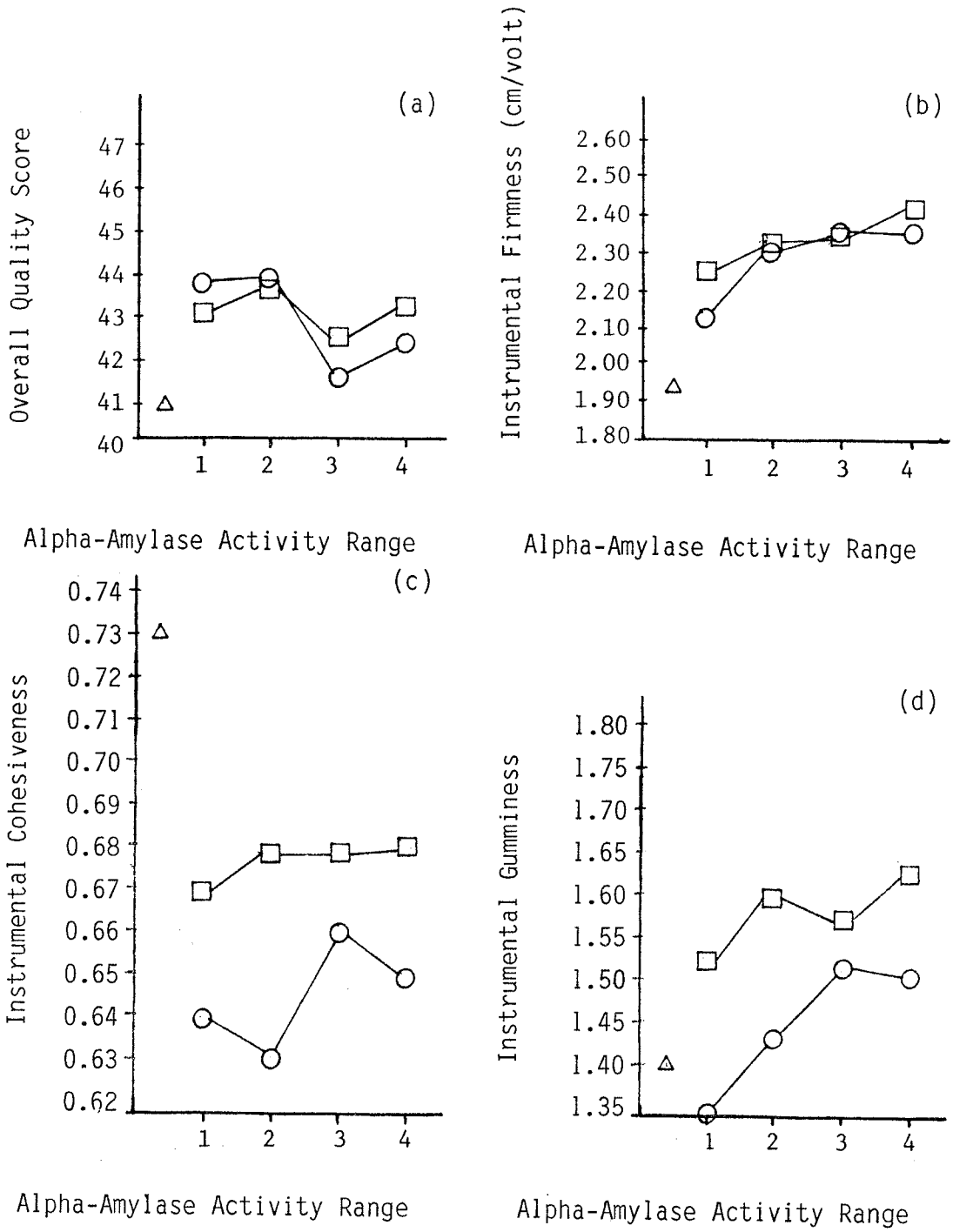
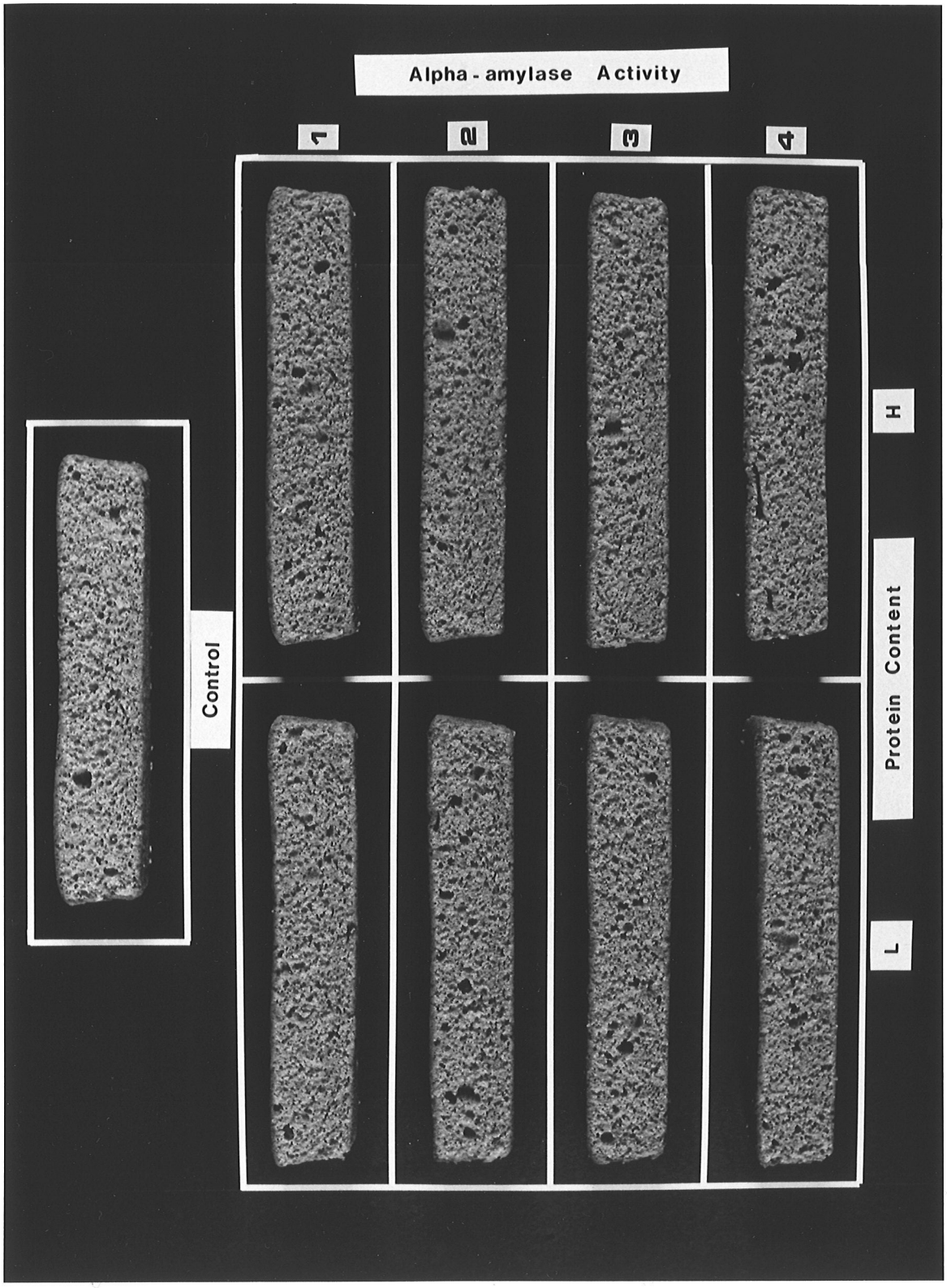


Figure 25 (a-d). Sensory overall quality (a) and instrumental firmness (b), cohesiveness (c) and gumminess (d) for sour cream coffee cake (O low protein, □ high protein, Δ control).

Figure 26. Cross-sections of sour cream coffee cakes baked from triticale and whole-wheat flours.
L = low protein, H = high protein.
1-4 represent lowest to highest alpha-amylase ranges.
Control = whole-wheat.


Alpha - amylase Activity
1
2
3
4
Control
H
Protein Content
L

in cake volumes for both protein categories (Tables 20 and 21). Cakes with the highest levels of alpha-amylase averaged approximately 50 cc lower in volume than cakes in the lowest range of alpha-amylase activity.

Sensory scores for crumb quality of the triticale cakes followed patterns similar to those shown by the cake volumes (Figure 23d). Protein content of the flours had no effect on crumb quality scores (Table 20), but scores decreased as levels of alpha-amylase increased. The mean crumb quality score for the cakes with the lowest level of alpha-amylase was significantly higher than the scores for cakes with the three higher levels of alpha-amylase (Table 21). The more uneven cell size, and cell distribution that characterize poor crumb quality were evident in the cakes made from the higher amylase flours, as shown in the photograph of cake cross-sections (Figure 26).

Low protein cakes scored slightly higher for tenderness than high protein cakes, and the control cakes received an intermediate tenderness score (Table 19, Figure 24d). Instrumental readings also indicated that low protein cakes were less firm than high protein cakes, although differences were too small to be significant (Figure 25b). None of the triticale cakes was as soft in texture as the control cakes, which had a significantly

lower mean firmness readings. Firmness readings were generally higher for cakes of lower volume, probably reflecting the greater density of crumb structure.

Sensory panel scores for moistness varied by less than 2 points for all of the cakes tested, and there were no significant effects of either protein or alpha-amylase on these characteristics, although cakes higher in alpha-amylase were consistently scored as being slightly moister than the low alpha-amylase cakes (Tables 19, 20, 21 and Figure 24a). Instrumentally determined values for gumminess (Figure 25d) were also higher with higher levels of alpha-amylase, which confirmed the sensory moistness results. Differences in actual moisture contents of the cakes (Table 19) were minimal and the cakes with the lowest, and highest gumminess readings made with the low protein, alpha-amylase range 1 flour and the high protein with alpha-amylase in range 4, had almost identical moisture contents.

The exterior or surface color of the high protein cakes was significantly darker than that of the low protein cakes (Tables 19 and 20, Figure 23b). Cakes with alpha-amylase in the highest activity range also appeared to have darker exterior surfaces than cakes with alpha-amylase activities in the lowest range. Surface color of the control cakes was similar to that of the lighter triticale

cakes. There were no significant differences among interior crumb color scores for the triticale cakes, but the control cake crumb appeared much lighter (Figure 2c). When crumb color values, Hunter L, a and b, were determined instrumentally (Table 22) high protein cakes had slightly lower L values than the low protein cakes, signifying that the higher protein cake crumb was detectably darker. High protein cakes also had slightly lower b values, indicating less yellowness in the crumb color. Hunter L and ΔE values confirmed that higher levels of alpha-amylase tended to darken the crumb color.

Flavor intensity (Figure 24c) and flavor acceptability (Figure 24d) scores indicated that there were no differences in flavor, due to protein content (Table 20) nor alpha-amylase activity (Table 21) among the triticale cakes. The control cakes however, had significantly less intense flavor which was less acceptable than the flavor of the triticale cakes (Table 19, Figure 24c, 24d).

Triticale coffee cakes were of overall quality equal to or better than the wheat control (Table 19). Neither protein content (Table 20), nor alpha-amylase range (Table 21) significantly affected the overall quality of the cakes. Factors that determined triticale flour quality, such as volume, crumb quality apparently did not affect the cakes enough to cause a decline in overall quality.

To summarize the results of the evaluation of coffee cakes made with 100% triticale flour, alpha-amylase activity was definitely a more important factor in determining the crumb quality or visible structure of the cakes, than was the protein content of the flours. Because alpha-amylase affects starch granule structure and gelatinization behavior, as alpha-amylase activity increased, less of the free liquid was absorbed by the starch, producing cakes with lower volumes and firmer, moister and a more dense crumb. Because higher protein flour probably contains a larger proportion of gluten forming proteins, this had a toughening effect on the cakes. Thus, cakes baked from low protein flours were judged more tender, less cohesive and less gummy than those baked from high protein flours. Flavor of the triticale cakes however, remained good and overall quality was not lowered significantly, even for cakes containing the highest level of alpha-amylase.

Results of this study showing the similar effects of alpha-amylase activity on cake quality were reported by Thompson and Vaisey (1971). Triticale flours, which had been subjected to chlorination treatments resulting in lowered pH and alpha-amylase activity of the flours, produced cakes baked from these flours that had better volume, better crumb structure, and were softer and less gummy when measured instrumentally by the Texturometer, than had cakes made with unchlorinated flour. Although there was no chlorination

involved in this study, increasing increments of alpha-amylase produced cakes with lower volumes, they had worse crumb quality, and were firmer and gummier than unsupplemented flours.

In the present study, it was expected that the effects of alpha-amylase levels on cake quality would be more apparent than the effects on muffin quality, because flour used was 100% whole-grain, while flour used for muffins was a blend of triticale and all-purpose flour. The amount of actual alpha-amylase present was double that found in equal amounts of flour used for muffins and yeast bread. The total effects of alpha-amylase though, were intermediate between muffins and yeast bread. It is possible that the sour cream in the cake recipe, lowered the pH and negated some of the effects of the alpha-amylase activity. On the other hand, because 100% whole-grain flour was used, the levels of alpha-amylase may have been so high that the effects of alpha-amylase were difficult to define as differences.

3. Yeast Breads

Data for volume, sensory and instrumental texture analysis, moisture content and moisture loss have been tabulated in Table 23. Main effects of protein content and alpha-amylase activity of flour on yeast bread quality are presented in Tables 24 and 25 respectively. Table 26

Table 23. Mean Values for Effect of Flour on Yeast Bread Quality

Protein Level	Alpha-Amylase Activity Level	Volume[1] (cc)	Sensory Score[2]							Instrumental Reading[3]			Moisture[1] Content	Moisture[1] Loss
			Crust Color	Crumb Color	Crumb Quality	Moistness	Flavor Intensity	Flavor Acceptability	Overall Quality	Firmness	Cohesiveness	Gumminess		
Low	1	1732.5^{e}	37.6^{d}	38.2^{a}	34.2^{bc}	28.2^{a}	34.7^{a}	40.2^{a}	35.9^{b}	5.11^{a}	0.58^{bc}	2.97^{a}	37.27^{b}	11.90^{ab}
	2	1816.7^{c}	41.7^{bc}	38.3^{a}	33.0^{bc}	30.0^{a}	33.1^{a}	42.2^{a}	38.2^{b}	3.22^{de}	0.56^{cd}	1.80^{c}	37.04^{b}	12.04^{ab}
	3	1799.0^{cd}	41.8^{bc}	37.5^{a}	33.0^{bc}	27.8^{a}	32.5^{a}	43.5^{a}	38.2^{b}	3.43^{bcd}	0.54^{cd}	1.87^{bc}	37.28^{b}	11.61^{ab}
	4	1756.7^{de}	41.0^{c}	37.7^{a}	30.6^{c}	27.4^{a}	32.9^{a}	40.9^{a}	35.1^{b}	37.2^{b}	0.52^{d}	1.95^{bc}	37.03^{b}	11.52^{ab}
High	1	1900.0^{b}	41.8^{bc}	38.3^{a}	35.2^{b}	30.8^{a}	31.7^{a}	42.3^{a}	37.7^{b}	3.68^{bc}	0.58^{bc}	2.14^{bc}	37.20^{b}	12.32^{a}
	2	1893.3^{b}	44.3^{ab}	39.1^{a}	33.1^{bc}	29.7^{a}	32.5^{a}	43.2^{a}	39.1^{b}	3.42^{bcd}	0.55^{cd}	1.89^{bc}	37.09^{b}	12.28^{ab}
	3	1894.2^{b}	45.5^{a}	38.7^{a}	31.9^{c}	29.1^{a}	33.5^{a}	43.7^{a}	39.3^{b}	3.12^{e}	0.58^{bc}	1.85^{bc}	37.12^{b}	11.48^{b}
	4	1889.2^{b}	46.3^{a}	39.1^{a}	32.1^{bc}	29.0^{a}	33.2^{a}	42.4^{a}	38.5^{b}	3.42^{cd}	0.61^{b}	2.13^{bc}	37.38^{b}	11.60^{ab}
Control		2336.0^{a}	45.0^{a}	28.0^{b}	44.0^{a}	30.0^{a}	22.0^{b}	42.9^{a}	45.0^{a}	3.16^{de}	0.71^{a}	2.25^{b}	38.60^{b}	11.90^{ab}

abcde Values in the same column bearing the same superscript are not significantly different ($p<0.05$)

1 Mean of 3 replications.

2 Mean of 7 panelists X 3 replications; where higher value represents a darker color, better crumb quality, drier crumb, more intense and acceptable flavor and better overall quality.

3 Mean of 5 readings X 3 replications.

Table 24. Mean Values for Main Effect of Protein Content on Yeast Bread Quality

	Protein Content	
	Low	High
Volume (cc)[1]	1776.2[b]	1894.2[a]
Sensory Scores[2]		
Crust Color	40.52[b]	44.45[a]
Crumb Color	37.92[b]	38.79[a]
Crumb Quality	32.70[a]	33.08[a]
Moistness	28.33[b]	29.61[a]
Flavor Intensity	33.29[a]	32.74[a]
Flavor Acceptability	41.69[a]	42.90[a]
Overall Quality	37.83[a]	38.63[a]
Instrumental Readings[3]		
Firmness (cm/volt)	3.87[a]	3.41[b]
Cohesiveness	0.55[b]	0.58[a]
Gumminess	2.15[a]	2.00[a]
Moisture Content[1]	37.16[a]	37.20[a]
Moisture Loss[1]	11.77[a]	11.92[a]

[ab] Values in the same row bearing the same superscript are not significantly different ($p<0.05$).

[1] Mean of 4 alpha-amylase ranges X 3 replications.

[2] Mean of 7 panelists X 4 alpha-amylase ranges X 3 replications.

[3] Mean of 5 readings X 4 alpha-amylase ranges X 3 replications.

Table 25. Mean Values for Main Effect of Alpha-Amylase Range on Yeast Bread Quality

	Alpha-Amylase Range			
	1	2	3	4
Volume (cc)[1]	1816.3[b]	1855.0[a]	1846.6[ab]	1822.9[b]
Sensory Scores[2]				
Crust Color	39.69[b]	43.00[a]	43.64[a]	43.62[a]
Crumb Color	38.24[a]	38.69[a]	38.10[a]	38.38[a]
Crumb Quality	34.71[a]	33.07[ab]	32.45[b]	31.33[b]
Moistness	29.48[a]	29.81[a]	28.41[a]	28.19[a]
Flavor Intensity	33.21[a]	32.79[a]	33.00[a]	33.05[a]
Flavor Acceptability	41.26[a]	42.71[a]	43.60[a]	41.62[a]
Overall Quality	36.76[a]	38.67[a]	38.74[a]	36.76[a]
Instrumental Readings[3]				
Firmness (cm/volt)	4.40[a]	3.32[c]	3.28[c]	3.58[b]
Cohesiveness	0.58[a]	0.55[a]	0.56[a]	0.57[a]
Gumminess	2.56[a]	1.85[b]	1.86[b]	2.04[b]
Moisture Content[1]	37.23[a]	37.07[a]	37.20[a]	37.21[a]
Moisture Loss[1]	12.11[ab]	12.16[a]	11.54[b]	11.56[ab]

abc Values in the same row bearing the same superscript are not significantly different ($p<0.05$).

1 Mean of 2 protein contents X 3 replications.

2 Mean of 7 panelists X 2 protein contents X 3 replications.

3 Mean of 5 panelists X 2 protein contents X 3 replications.

Table 26. Hunter Color Difference Meter Values[1] for Yeast Bread Crumb

Protein Level	Alpha-Amylase Activity Range	L Value				a Value				b Value				ΔE			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
Low	1	57.9±0.07	57.8±0.35	58.5±0.49	58.1	4.2±0.07	4.2±0.07	4.2±0.07	4.2	16.9±0.07	16.8±0.14	17.0±0.00	16.9	38.6±0.07	38.7±0.35	38.1±0.42	38.5
	2	57.4±0.07	57.3±0.21	57.7±0.42	57.5	4.3±0.07	4.2±0.14	4.1±0.14	4.2	16.9±0.14	17.0±0.07	17.0±0.00	17.0	39.1±0.14	39.2±0.14	38.8±0.35	39.0
	3	57.2±0.07	57.1±0.00	57.4±0.07	57.2	4.2±0.00	4.2±0.00	4.3±0.00	4.2	17.0±0.07	17.0±0.00	16.9±0.07	17.0	39.2±0.00	39.1±0.00	39.1±0.07	39.1
	4	56.3±0.21	56.2±0.28	56.6±0.21	56.4	4.2±0.07	4.3±0.21	4.4±0.14	4.3	16.8±0.00	16.8±0.14	17.0±0.00	16.9	39.9±0.14	40.1±0.28	39.8±0.14	39.9
Mean Low Protein					57.3				4.2				17.0				39.1
High	1	57.5±0.07	56.9±0.28	57.6±0.00	57.3	4.3±0.07	4.3±0.00	4.3±0.14	4.3	16.7±0.00	16.6±0.14	16.7±0.00	16.7	38.9±0.07	39.4±0.21	38.9±0.21	39.1
	2	57.2±0.14	56.2±0.14	57.2±0.14	56.9	4.4±0.07	4.4±0.14	4.4±0.07	4.4	16.7±0.14	16.6±0.07	16.7±0.14	16.7	39.2±0.07	39.9±0.14	39.1±0.14	39.4
	3	57.4±0.07	56.4±0.14	57.4±0.28	57.1	4.3±0.07	4.4±0.00	4.3±0.07	4.3	16.9±0.07	16.6±0.07	16.9±0.07	16.8	39.1±0.07	39.8±0.14	39.0±0.28	39.3
	4	56.7±0.07	55.6±0.14	56.7±0.00	56.3	4.4±0.07	4.4±0.14	4.4±0.00	4.4	16.7±0.00	16.7±0.00	16.7±0.00	16.7	39.7±0.07	40.6±0.14	39.6±0.00	40.0
Mean High Protein					56.9				4.4				16.7				39.5
Control		63.4±0.07	63.3±0.00	64.4±0.21	63.7	2.7±0.07	2.7±0.28	2.5±0.14	2.6	15.3±0.07	15.2±0.14	15.3±0.07	15.3	32.8±0.14	32.8±0.00	31.9±0.28	32.5

[1] Mean of duplicate samples.
L = lightness value where 0 = black, 100 = white.
a = red-green value, where - indicates green, + indicates red.
b = blue-yellow value, where - indicates blue, + indicates yellow.
ΔE = calculated as $\sqrt{\Delta L^2 + \Delta a2 + \Delta b2}$ where standard white tile L = 92.4, a = -1.2, b = 0.5.

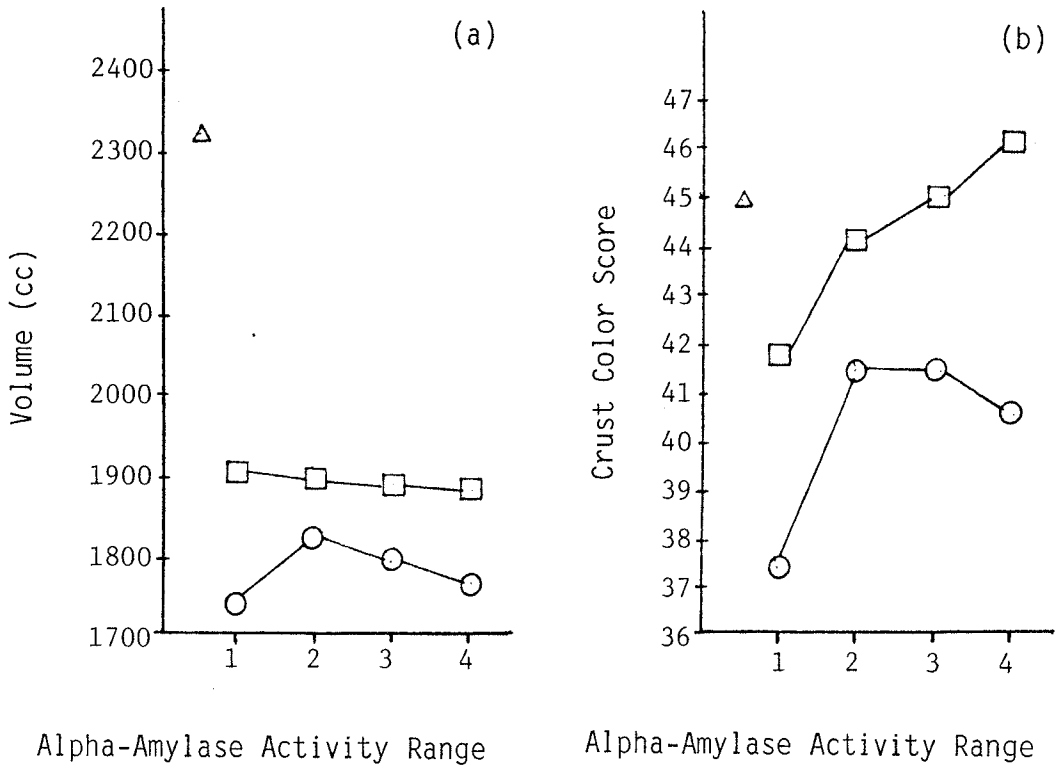


Figure 27 (a,b). Volume (a) and sensory crust color (b) for yeast bread (○ low protein, □ high protein, △ control).

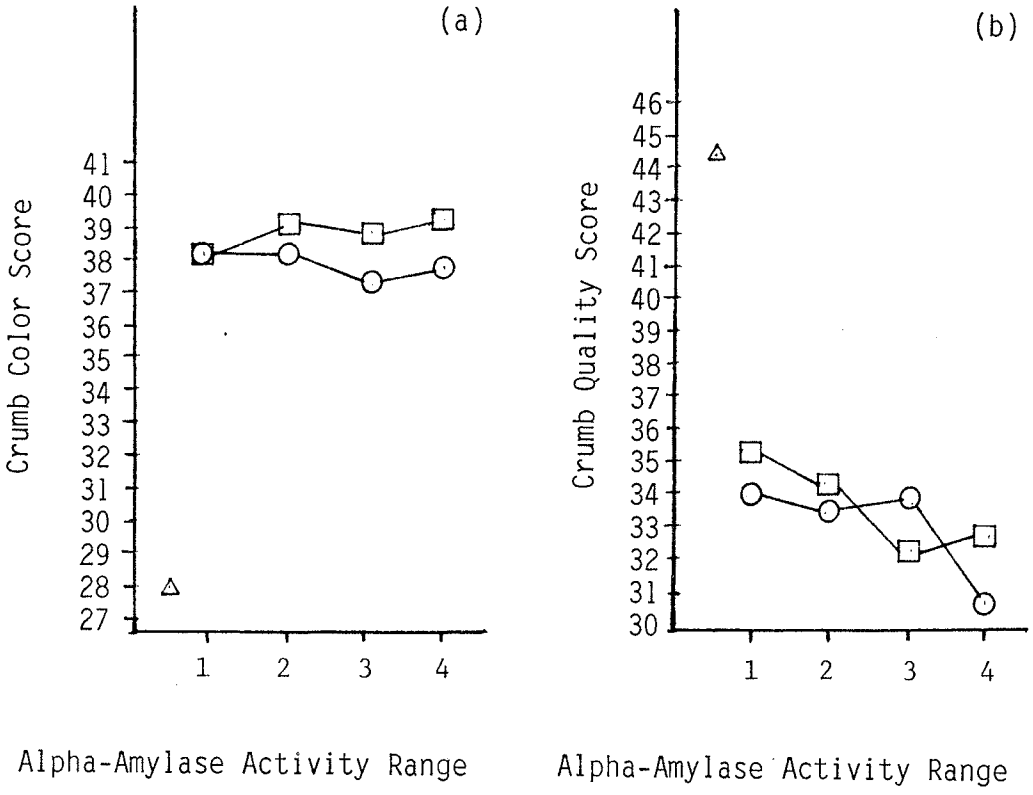


Figure 28 (a,b). Sensory crumb color (a) and crumb quality (b) for yeast bread (○ low protein, □ high protein, △ control).

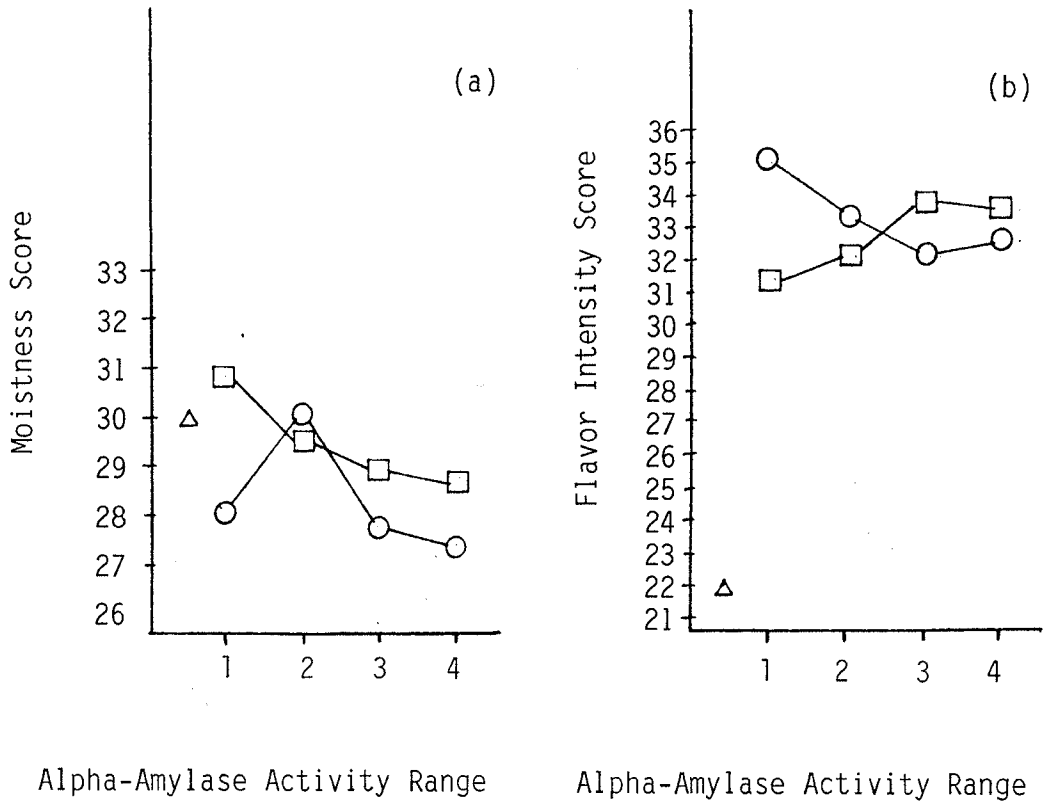


Figure 29 (a,b). Sensory moistness (a) and flavor intensity (b) for yeast bread (O low protein, □ high protein, △ control).

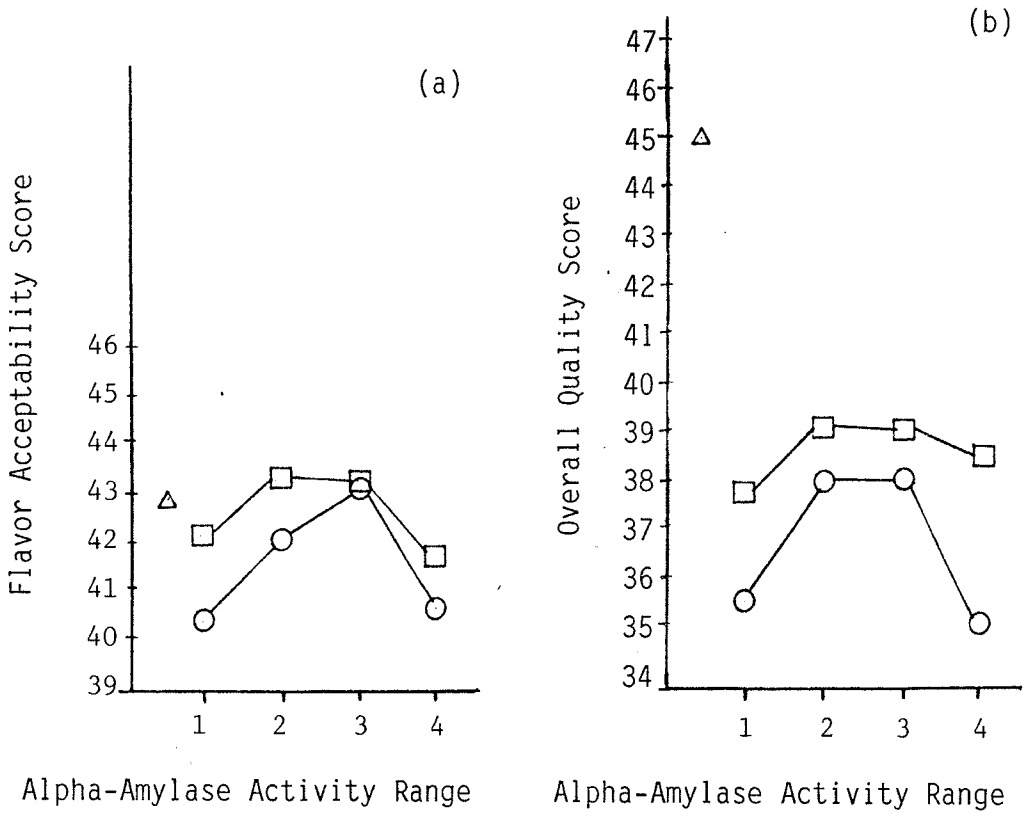


Figure 30 (a,b). Sensory flavor acceptability (a) and overall quality (b) for yeast bread (O low protein, □ high protein, Δ control).

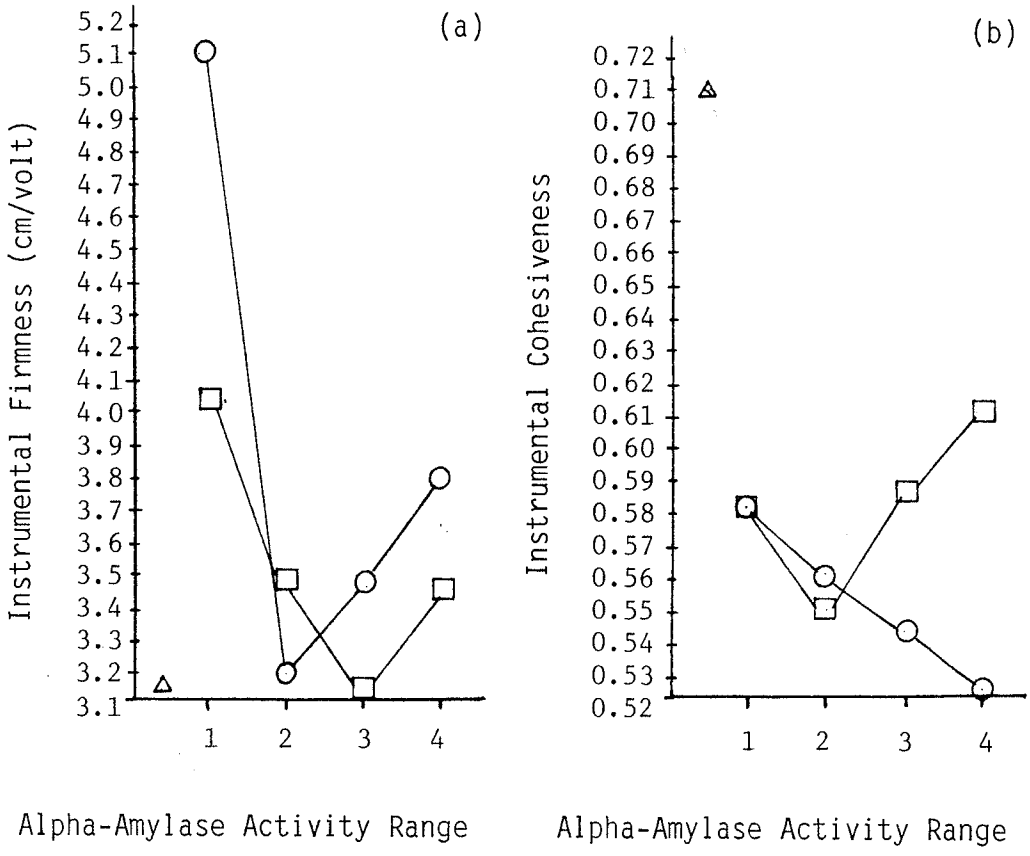


Figure 31 (a,b). Instrumental firmness (a) and cohesiveness (b) for yeast bread (O low protein, □ high protein, Δ control).

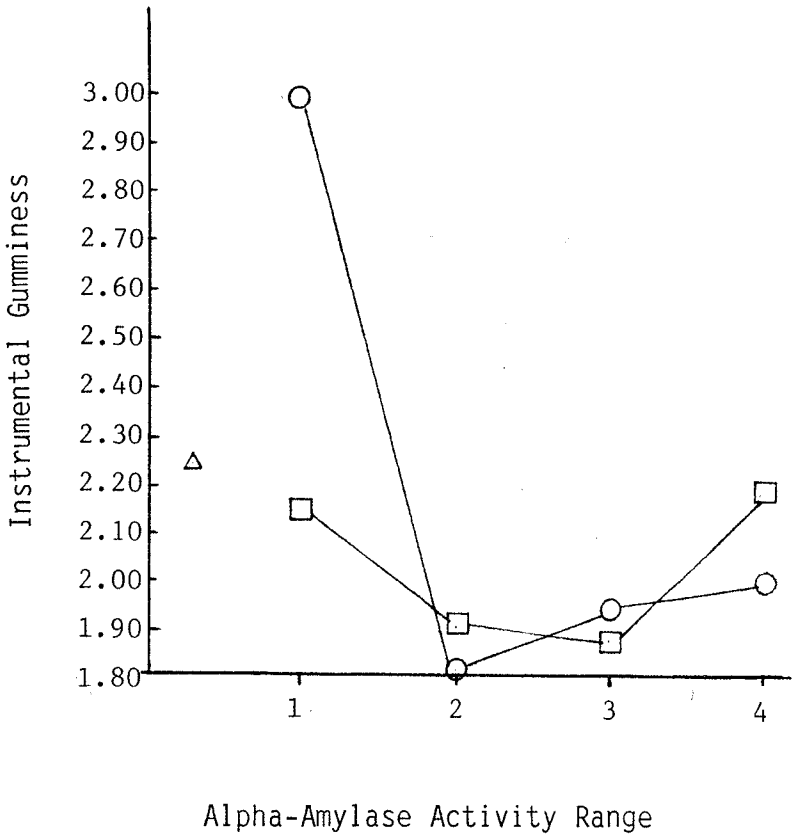
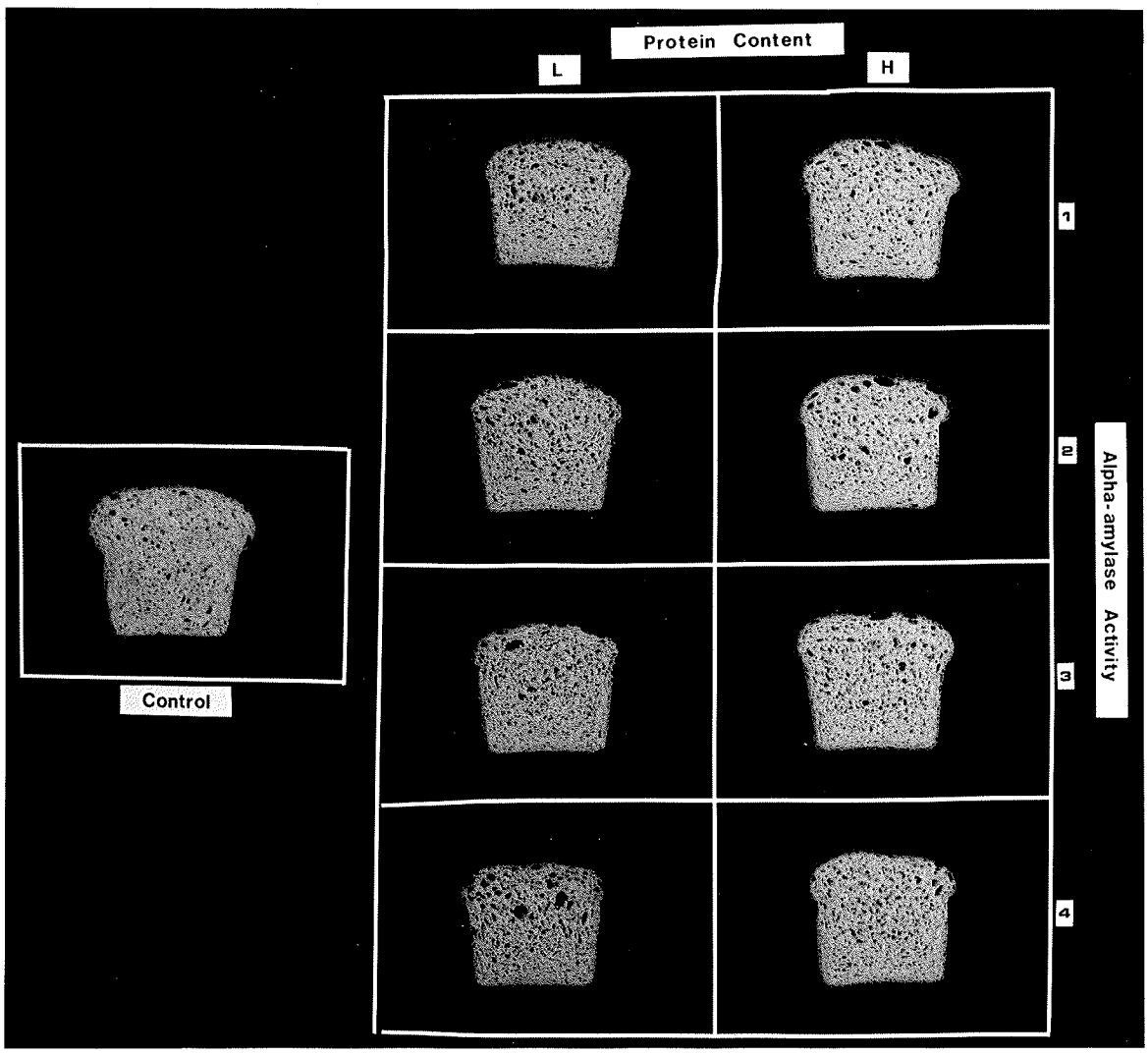


Figure 32. Instrumental gumminess for yeast bread (○ low protein, □ high protein, △ control).

Figure 33. Cross-sections of yeast breads baked from triticale and whole-wheat flours.
L = low protein, H = high protein.
1-4 represent lowest to highest alpha-amylase ranges.
Control = whole-wheat.


Protein Content
L
H
1
2
3
4
Alpha-amylase Activity
Control

presents the Hunter Color Difference meter values for the color of yeast bread crumb. Illustrations of the effects of protein content and alpha-amylase on bread quality are shown in Figures 27 to 32, and a photograph of the internal structure of the baked cakes is presented in Figure 33.

Volumes for yeast breads made with 50% triticale flour and 50% all-purpose flour were significantly affected by both protein and alpha-amylase levels, and all triticale breads had volumes significantly lower than the volumes of the whole wheat control breads (Table 33, Figure 27a). Volumes for triticale breads ranged from approximately 436 to 600 cc less than volumes for the control breads. High protein triticale flours produced significantly higher bread volumes than low protein flours (Table 24); the mean volume for the high protein breads was 1894.2 cc which was significantly greater than the mean value of 1776.2 cc for the low protein breads. Volumes for the high protein breads did not change appreciably with higher alpha-amylase levels, while low protein bread volumes were improved by 70 to 80 cc at alpha-amylase ranges 2 and 3.

Sensory assessment of crumb quality of triticale breads was not significantly affected by protein content of the flours (Table 24), but crumb quality significantly decreased as levels of alpha-amylase increased. Crumb quality deteriorated, even in the low protein breads that

were improved in volume at alpha-amylase ranges 2 and 3. All triticale breads had significantly poorer crumb structure than the whole-wheat breads. The volume effects of protein and alpha-amylase levels, and the deterioration in crumb quality over increasing alpha-amylase ranges in triticale flours are evident in the photograph of bread cross-sections (Figure 33).

Instrumental texture evaluations reflected in part, the volume and crumb characteristics of the breads. Generally the breads were softer (Figure 31a) at alpha-amylase ranges 2 and 3, and became significantly firmer at ranges 1 and 4. Low protein breads were significantly firmer than the high protein breads. The effects of protein and alpha-amylase on instrumental firmness parallel the changes in volume. Cohesiveness (Figure 31b) was affected by protein content (Table 24), the high protein breads being more cohesive. Possibly the protein content or gluten protein content contributed to the cohesiveness characteristic in some way. The wheat control breads were relatively soft, but significantly more cohesive than the triticale breads (Table 23). Firmness readings were generally lower for breads of higher volume, probably reflecting the lesser density or compactness of crumb structure. The wheat breads being more cohesive than the triticale breads, and the high protein triticale breads being more cohesive than the low protein triticale breads, suggests that the cohesiveness characteristic may have reflected the amount of gluten

protein present in the total protein content of the flours.

Sensory panel scores for moistness varied significantly between protein levels, with breads baked from low protein flours being moister than the higher protein breads. Breads baked with higher alpha-amylase flours were scored as being slightly moister than the low alpha-amylase flours, but there was no significant effect of alpha-amylase activity. Overall, triticale breads were similar in sensory moistness to the wheat control (Table 23). Instrumentally determined values for gumminess reflected the volume changes shown with increasing alpha-amylase activity. The measure of instrumental gumminess probably did not measure gumminess in the same manner as the sensory panel evaluated moistness, because instrumental gumminess reflected volume and crumb density. Differences in actual moisture contents and moisture loss were minimal, although there may have been slightly more moisture loss with the low protein, second alpha-amylase level breads which had improved volume.

Crust color as determined by the sensory panel became significantly darker (Figure 27b) as protein content (Table 24) and alpha-amylase activity increased (Table 25). Sensory crumb color (Figure 28a) was darker for high protein breads (Table 24), but was not affected by alpha-amylase activity (Table 25). All triticale breads appeared significantly darker in crumb color than the control breads

(Table 23). When crumb color values were determined instrumentally, high protein bread crumb had slightly lower L values and slightly higher E values as compared to low protein bread crumb, signifying that the higher protein bread crumb was detectably darker. High protein breads also had slightly lower b values, indicating less yellowness in the crumb. Hunter L and E values confirmed that higher levels of alpha-amylase tended to darken the crumb color.

Breads baked from whole-wheat had less intense flavor than the triticale breads, but were similar in flavor acceptability to the triticale breads (Table 23, Figures 29b, 30a). Neither protein content or alpha-amylase activity had a significant effect on flavor intensity and acceptability (Tables 24, 25).

Triticale yeast breads were considered to be of inferior overall quality when compared to wheat yeast breads. Volume and crumb quality may have been the most important factors in the determination of overall quality, since flavor acceptability and other textural parameters were not affected by flour quality to a large extent. Protein content and alpha-amylase activity did not affect the overall quality of the triticale yeast breads (Tables 24, 25).

The effects of higher levels of alpha-amylase were generally to reduce bread volumes, although there was a slight improving effect of alpha-amylase at ranges 2 and 3 for breads baked from flour with low protein content. Breads with greater volume also had a softer and less gummy crumb than did breads with lesser volume. At higher alpha-amylase ranges however, the crumb structure became more fragile and open. The ability of higher protein to produce greater volumes was particularly apparent in yeast breads, which depend primarily on gluten for their structure. Breads baked from low protein flours had lower volumes, and a moister, firmer crumb, which resulted in a less acceptable product when compared to the control.

In this study, it was expected that the effects of alpha-amylase on bread quality would be very apparent, because preparation and baking procedures were relatively long thereby allowing more time for the action of alpha-amylase, as compared to a quick bread or cake.

Farinograph development times (peak times) reported in Table 12 were able to predict the breadmaking quality (volume) of the formulated and wheat flours well. Peak times, stabilities and mixing tolerances were an indication of flour strength and baking potential. Triticale flours had shorter dough development and lower mixing tolerance than wheat flours, which suggest that they had less gluten

for dough development. Thus, smaller volumes for triticale breads resulted because the triticale flours had less gluten to hold and entrap gases during fermentation and baking. High protein triticale flours showed shorter stabilities and lower mixing tolerances than the low protein flours. However, breads baked from high protein triticale flours were equal to or superior in quality to the low protein breads; most likely because the doughs were not subjected to heavy manipulation and fermentation, thus avoiding injury of the gluten.

Results of the consumer-style yeast bread study confirmed previous research, where triticale which has been blended with wheat flour or where sprouted wheat was used. Substitution of up to 30 to 40% triticale for wheat flour did not markedly decrease loaf volume or scores for internal characteristics. Unrau and Jenkins (1964) reported that volume actually increased when 20% triticale was incorporated, while Lorenz (1974a) was able to replace 30% of the wheat flour with triticale meal without decreasing bread volume. Rooney et al (1969) found that substitution of triticale for 30% of the wheat flour was not detrimental to bread quality. Ranhotra et al (1977) also reported improved loaf volume when 5% sprouted wheat flour was incorporated into sound wheat flour, and baked into bread. Volumes for low protein triticale bread in the present study were greatest at alpha-amylase ranges 2 and 3. Apparently

the added alpha-amylase gave a dough in which gas pressure and gluten strength were optimum; at higher levels of alpha-amylase, gassing power was too strong, and smaller volumes resulted.

D. Effects of Protein Content and Alpha-Amylase Activity on Pup Loaves

Data for volume and pup loaf quality scoring have been tabulated in Table 27. Main effects of protein content, alpha-amylase activity and water level on pup loaf quality are presented in Tables 28, 29 and 30 respectively. Illustrations of the effects of protein content, alpha-amylase activity and water level on pup loaf quality are shown in Figures 34, 35 and 36, and photographs showing the internal structure of baked loaves are presented in Figures 37 to 42. In Figures 37 to 42, duplicate loaves from each treatment were cut vertically, thereby showing four halves. It also should be noted that the separation of the crust from crumb in these loaves was due to freezing.

The pup loaf test was developed and carried out firstly in order to determine if it could provide a reliable method to predict the bread-making quality of sprouted flours or flours of unknown alpha-amylase activity. Secondly, it was carried out to determine if the test could produce the same results as the consumer-style yeast bread test.

Table 27. Mean Values[1] for Effect of Protein Content, Alpha-Amylase Range and Water Level on Pup Loaf Quality

Protein Level	Alpha-Amylase Activity Range	Volume (cc)				Cell Size				Cell Distribution				Moistness				Total Score			
		Water Level				Water Level				Water Level				Water Level				Water Level			
		58%	63%	68%	Mean	58%	63%	68%	Mean	58%	63%	68%	Mean	58%	63%	68%	Mean	58%	63%	68%	Mean
Low	1	595.83	624.00	698.75	639.5^{cd}	9.17	9.58	8.83	9.2^{b}	8.67	9.25	8.83	8.9^{a}	8.75	9.08	8.83	8.9^{b}	26.59	27.91	26.49	27.0^{b}
	2	625.83	641.25	706.25	657.8^{bcd}	8.17	8.75	6.33	7.8^{c}	8.17	8.75	6.67	7.9^{c}	8.33	7.33	7.08	7.6^{d}	24.67	24.83	20.08	23.3^{d}
	3	622.92	643.33	699.17	655.1^{bcd}	7.92	6.83	6.50	7.1^{de}	8.65	6.67	6.67	7.3^{de}	8.00	6.92	6.08	7.0^{ef}	24.57	20.42	19.25	21.3^{f}
	4	604.17	625.00	670.00	633.1^{d}	7.58	7.00	5.83	6.6^{e}	7.83	7.58	5.75	6.9^{e}	7.33	6.50	5.25	6.4^{g}	22.74	21.08	16.83	19.8^{g}
High	1	632.08	658.92	741.67	677.6^{bcd}	9.25	9.58	8.58	9.1^{b}	9.00	9.25	8.58	8.9^{b}	9.25	9.58	8.67	9.2^{ab}	27.50	28.41	25.83	27.3^{b}
	2	645.00	672.50	740.83	686.1^{b}	8.67	8.25	7.17	8.0^{c}	8.08	8.58	7.58	8.1^{c}	8.83	8.42	7.75	8.3^{c}	25.58	25.25	22.50	24.4^{c}
	3	641.42	668.33	735.42	681.7^{bc}	8.33	7.92	6.42	7.6^{cd}	8.33	8.17	6.83	7.8^{cd}	7.75	7.58	6.67	7.3^{de}	24.41	23.67	19.92	22.6^{de}
	4	632.08	657.75	698.33	662.7^{bcd}	7.67	7.25	6.42	7.2^{d}	9.25	8.17	7.33	7.9^{c}	7.33	6.75	5.75	6.6^{fg}	23.25	22.17	19.50	21.8^{ef}
Control		806.25	816.00	870.83	831.0^{a}	10.00	10.00	9.17	9.7^{a}	10.00	10.00	9.17	9.6^{a}	9.25	10.00	9.75	9.6^{a}	29.25	30.00	28.09	29.0^{a}

abcdefg Values in the same column bearing the same superscript are not significantly different ($p<0.05$).

[1] Mean of 4 judges X 3 replications.

Table 28. Mean Values for Main Effect of Protein Content on Pup Loaf Quality

	Protein Content	
	Low	High
Volume[1]	646.38[b]	677.03[a]
Scoring[2]		
Cell Size	7.66[b]	7.97[a]
Cell Distribution	7.76[b]	8.17[a]
Moistness	7.46[b]	7.86[a]
Total Score	22.88[b]	24.02[a]

[ab] Values in the same row bearing the same superscript are not significantly different ($p<0.05$).

[1] Mean of 4 alpha-amylase ranges X 3 water levels X 3 replications.

[2] Mean of 4 judges X 4 alpha-amylase ranges X 3 water levels X 3 replications.

Table 29. Mean Values for Main Effect of Alpha-Amylase Range on Pup Loaf Quality

	Alpha-Amylase Range			
	1	2	3	4
Volume[1]	658.54[b]	671.94[a]	668.43[a]	647.89[c]
Scoring[2]				
Cell Size	9.17[a]	7.89[b]	7.32[c]	6.89[d]
Cell Distribution	8.93[a]	7.97[b]	7.52[c]	7.43[c]
Moistness	9.03[a]	7.96[b]	7.17[c]	6.47[d]
Total Score	27.13[a]	23.87[b]	21.97[c]	20.83[d]

[ab] Values in the same row bearing the same superscript are not significantly different ($p<0.05$).

[1] Mean of 2 protein contents X 3 water levels X 3 replications.

[2] Mean of 4 judges X 2 protein contents X 3 water levels X 3 replications.

Table 30. Mean Values for Main Effect of Water Level on Pup Loaf Quality

	Water Level		
	58	63	68
Volume[1]	624.92[c]	648.89[b]	711.30[a]
Scoring[2]			
Cell Size	8.34[a]	8.17[a]	6.94[b]
Cell Distribution	8.35[a]	8.26[a]	7.26[b]
Moistness	8.20[a]	7.77[b]	7.01[c]
Total Score	24.90[a]	24.19[b]	21.27[c]

[ab] Values in the same row bearing the same superscript are not significantly different.

[1] Mean of 2 protein contents X 4 alpha-amylase ranges X 3 replications.

[2] Mean of 4 judges X 2 protein contents X 4 alpha-amylase ranges X 3 replications.

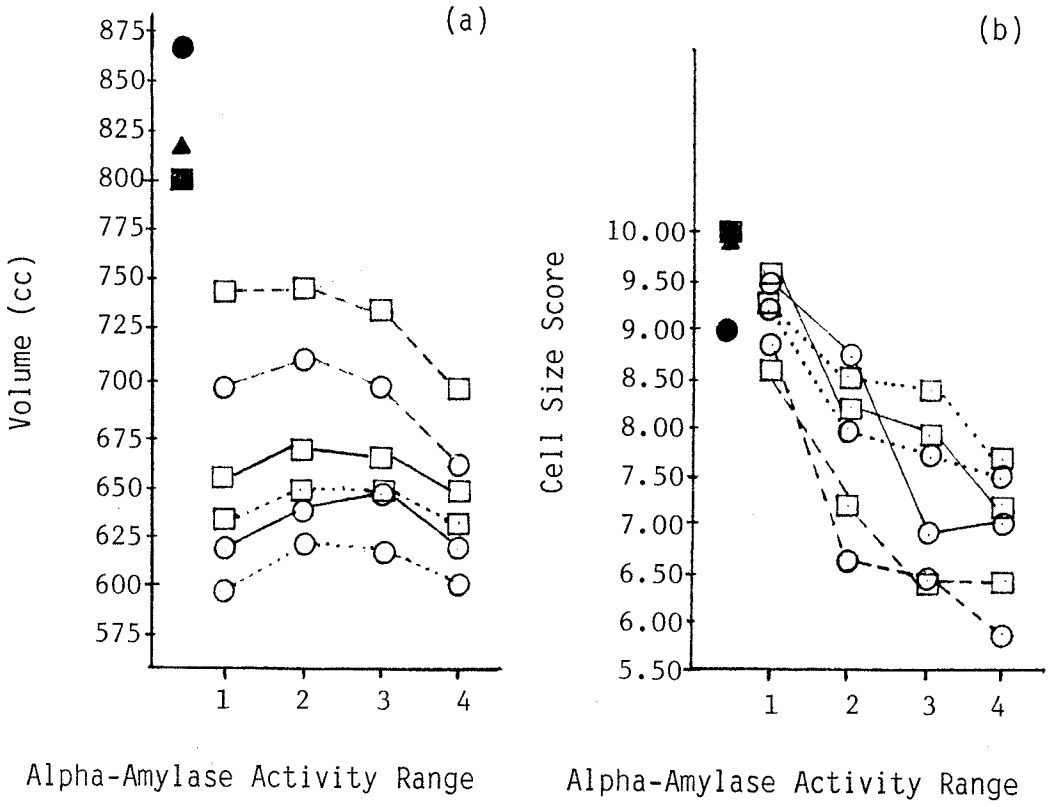


Figure 34 (a,b). Volume (a) and cell size (b) for pup loaves (○···○low protein, □···□high protein, ■ control at 58% water level, ○—○low protein, □—□high protein, ▲control at 63% water level; ○--○low protein, □--□high protein, ● control at 68% water level).

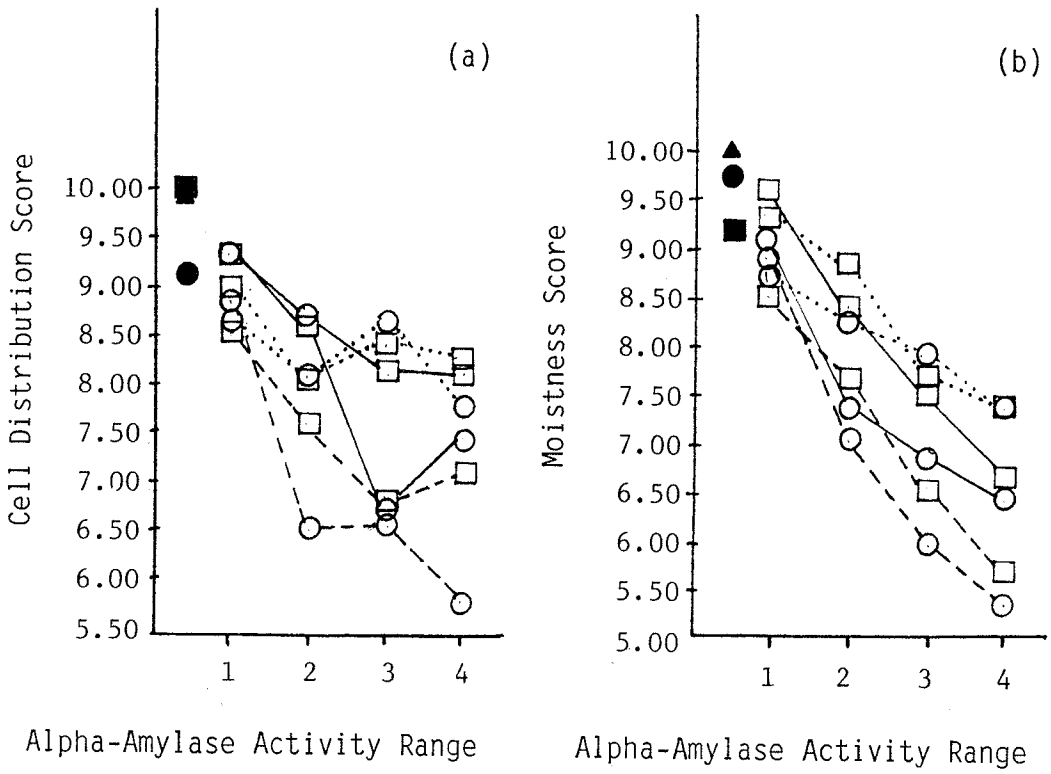


Figure 35 (a,b). Cell distribution (a) and moistness (b) for pup loaves (O···O low protein, □···□ high protein, ■ control at 58% water level; O—O low protein, □—□ high protein, ▲ control at 63% water level; O- -O low protein, □- -□ high protein, ● control at 68% water level).

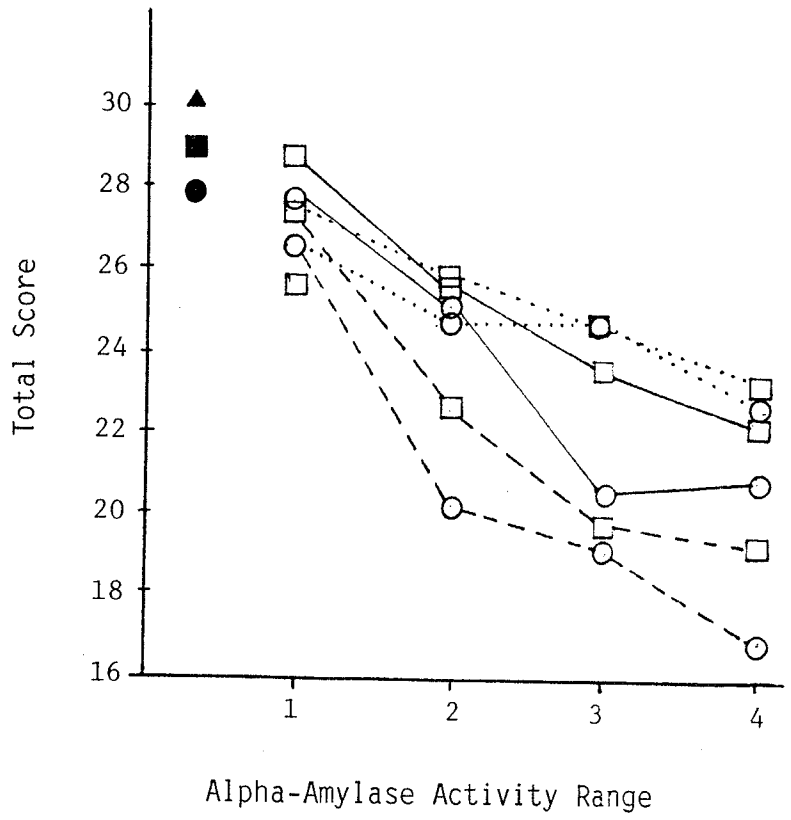


Figure 36. Total score for pup loaves (O···O low protein, □···□ high protein, ■ control at 58% water level; O—O low protein □—□ high protein, ▲ control at 63% water level; O- -O low protein, □- -□ high protein, ● control at 68% water level).

Figure 37. Cross-sections of pup loaves baked from low protein triticale and whole-wheat flours at 58% water level.

1-4 represent lowest to highest alpha-amylase ranges.

Control = whole-wheat.

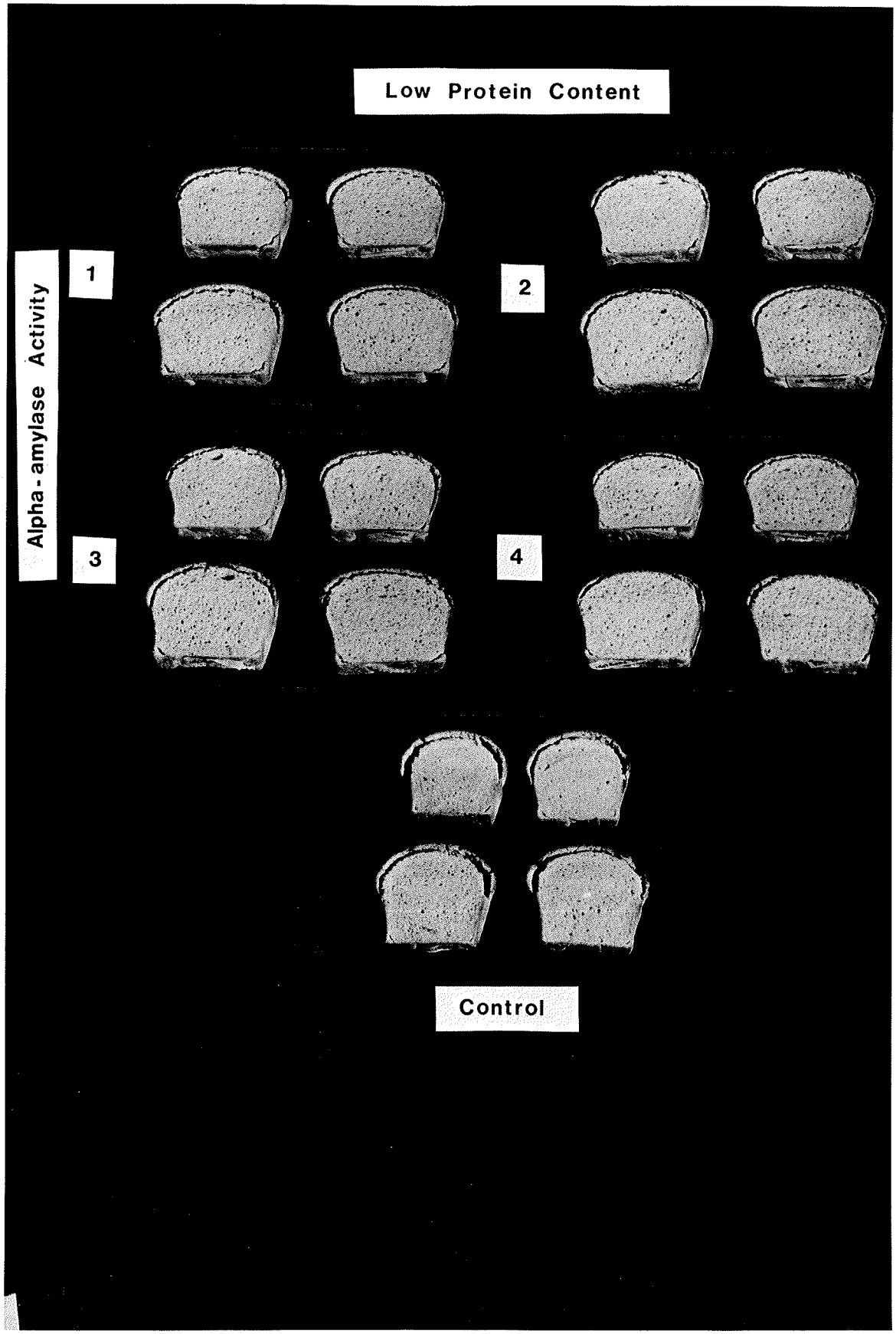

Low Protein Content
Alpha-amylase Activity
1
2
3
4
Control

Figure 38. Cross-sections of pup loaves baked from high protein triticale and whole-wheat flours at 58% water level.

1-4 represent lowest to highest alpha-amylase ranges.

Control = whole-wheat.

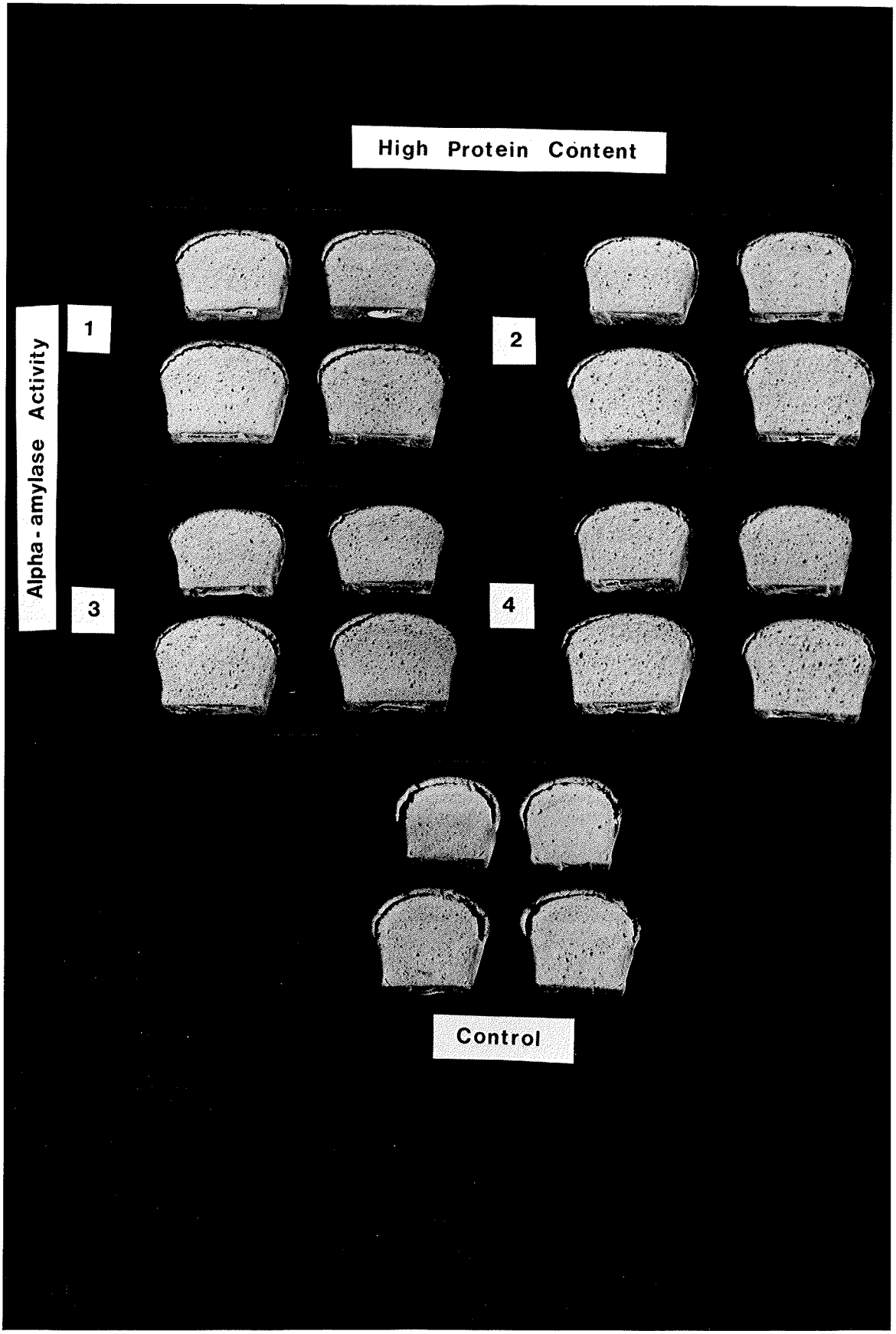

High Protein Content
Alpha-amylase Activity
1
2
3
4
Control

Figure 39. Cross-sections of pup loaves baked from low protein triticale and whole-wheat flours at 63% water level.

1-4 represent lowest to highest alpha-amylase ranges.

Control = whole-wheat.

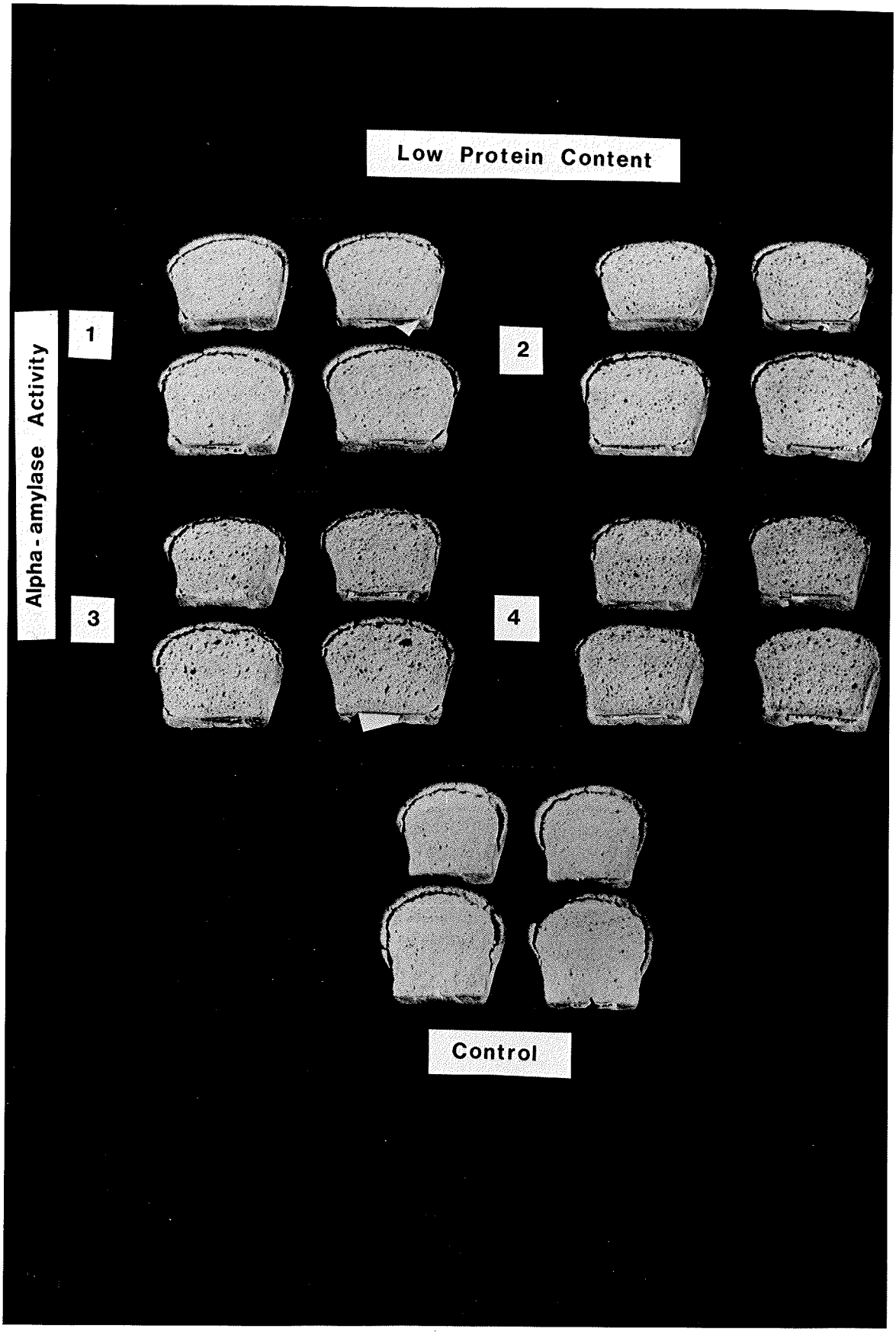

Low Protein Content
Alpha-amylase Activity
1
2
3
4
Control

Figure 40. Cross-sections of pup loaves baked from high protein triticale and whole-wheat flours at 63% water level.

1-4 represent lowest to highest alpha-amylase ranges.

Control = whole-wheat.

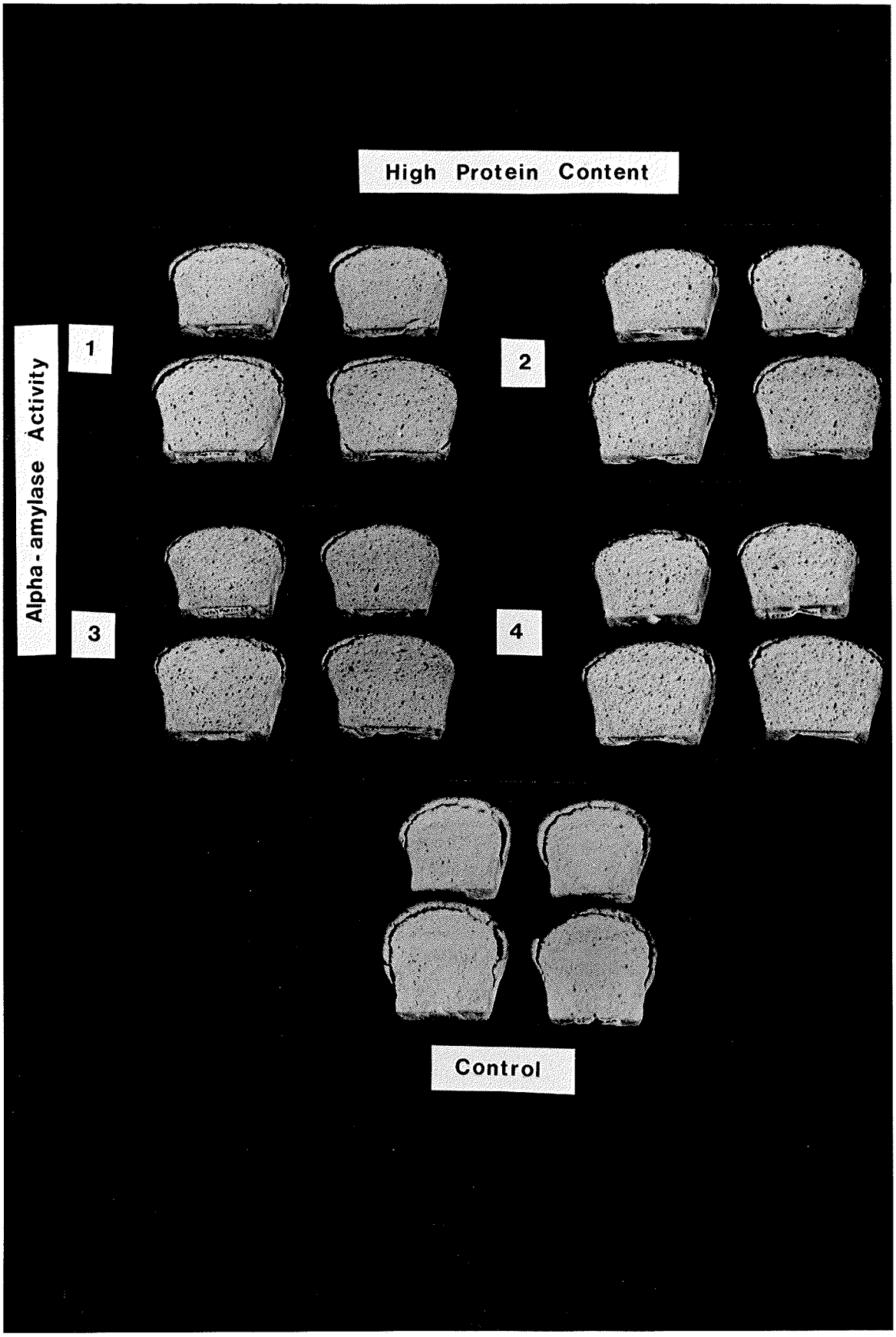

High Protein Content
Alpha-amylase Activity
1
2
3
4
Control

Figure 41. Cross-section of pup loaves baked from low protein triticale and whole-wheat flours at 68% water level.

1-4 represent lowest to highest alpha-amylase ranges.

Control = whole-wheat.

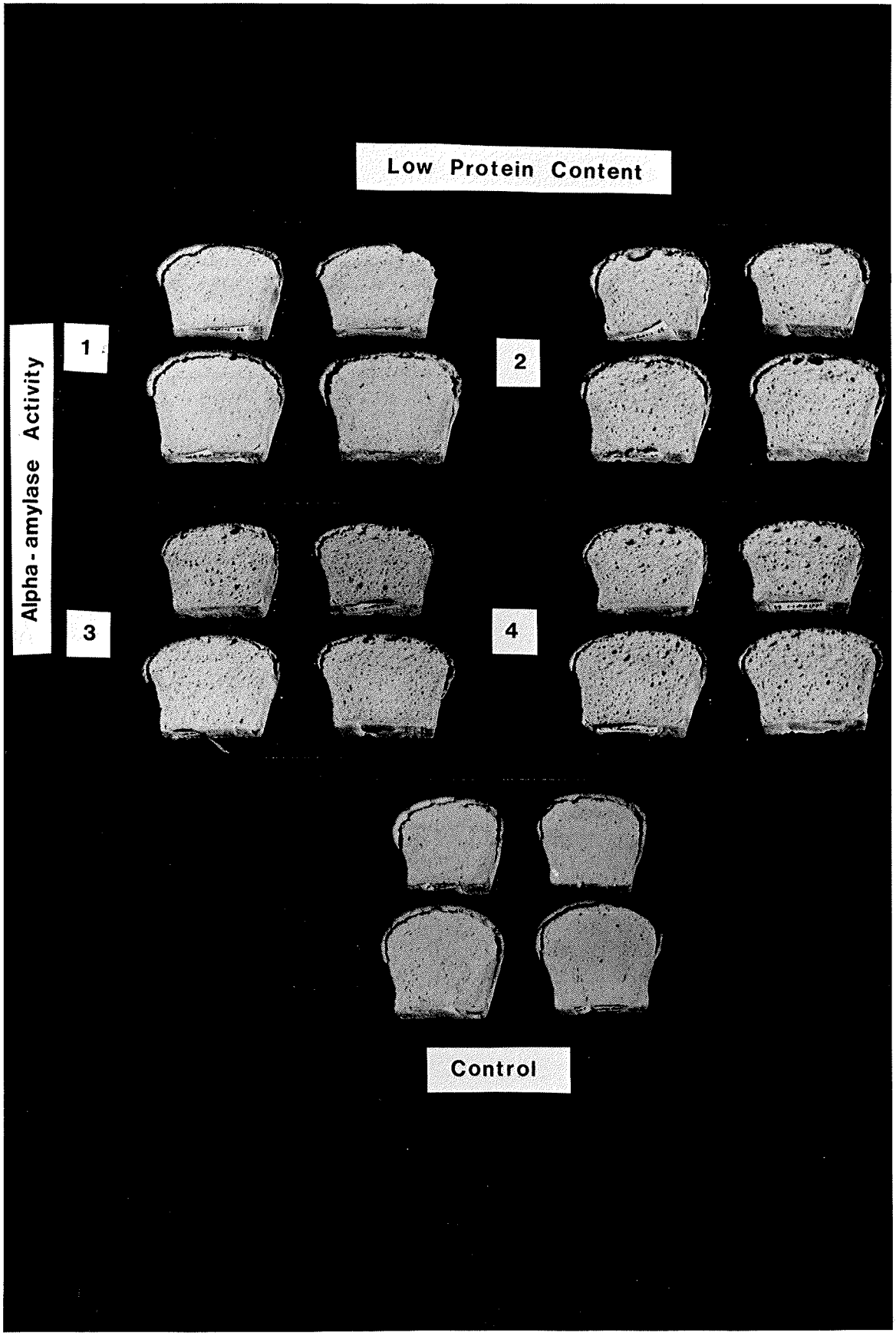
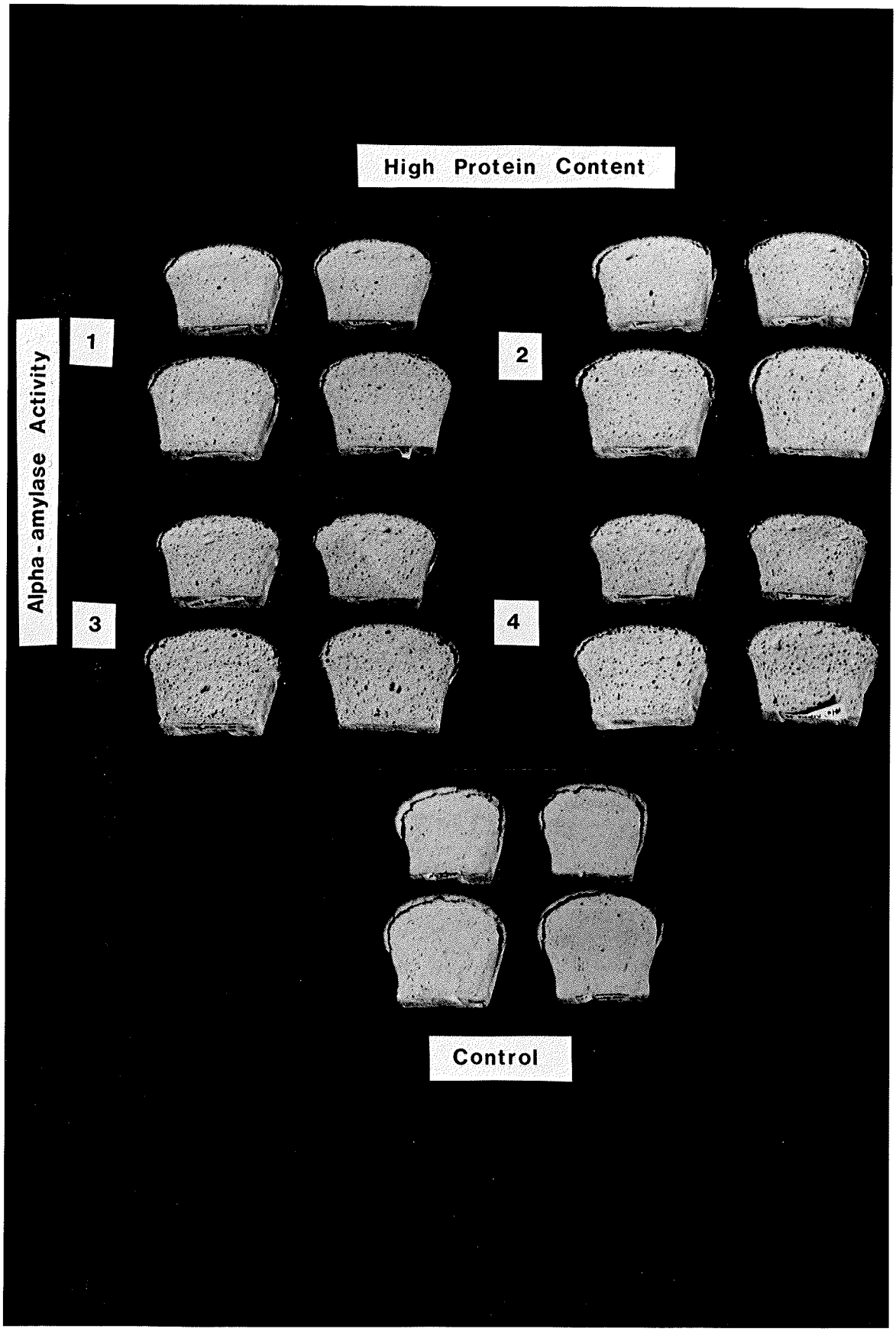

Low Protein Content
Alpha-amylase Activity
1
2
3
4
Control

Figure 42. Cross-section of pup loaves baked from high protein triticale and whole-wheat flours at 68% water level.

1-4 represent lowest to highest alpha-amylase ranges.

Control = whole-wheat.


High Protein Content
Alpha-amylase Activity
1
2
3
4
Control

Thirdly, it was decided to demonstrate the effects of various water levels on yeast bread quality using a standard pup loaf bake test. The amount of water was of interest because consumers experience problems with triticale flour, probably because home preparation results in more variation in ingredient ratios and preparation procedures than would occur in a commercial bakery. Variations in the ratio of water to flour is likely to occur when liquid amounts, flour moisture or amount of flour are not optimized.

Pup loaf breads made with 50% whole-grain flour and 50% bread flour showed significant volume effects when protein content, alpha-amylase activity and water levels were varied. Volumes for the wheat control breads were significantly greater than volumes for triticale breads (Table 27). Wheat bread volumes averaged 831 cc and exceeded high and low protein breads by approximately 130 and 170 cc respectively (Table 28). Volumes for both high and low protein breads at all three water levels, initially increased with an increase in alpha-amylase activity (range 2), then they remained stable, and finally they decreased with the highest range of alpha-amylase activity (Table 27, Table 29, Figure 34). Higher water levels produced significantly higher volumes in pup loaves at both protein levels and at all alpha-amylase ranges.

Wheat pup loaf crumb structure was characterized by uniform cell size and cell distribution. The crumb structure of triticale breads was generally of poorer quality than the whole-wheat pup loaves (Table 27). The

subjective evaluation of cell size showed that cell size in the crumb was significantly larger and more open (Figure 34b) for low than for high protein breads (Table 28) and the trend to larger, more open cells paralleled increases in alpha-amylase activities (Table 29) and increased water levels. Similarly, cell distribution became more uneven, non-uniform (Figure 35a) with low protein, and became progressively worse at higher alpha-amylase ranges (Table 29) and higher water levels (Table 30). Cell size and cell distribution of the bread crumb deteriorated even in breads where volume was improved. The more uneven cell size, and cell distribution that characterize poor crumb quality were evident in the pup loaves made from the higher alpha-amylase flours at the higher water levels (Figures 37 to 42).

Variations in protein level (Table 28), alpha-amylase activity (Table 29) and water level (Table 30) produced significant moistness effects in pup loaf crumb (Figure 35b). Pup loaf bread crumb became significantly moister and gummier with low protein flour, and moistness increased at higher alpha-amylase ranges and higher water levels (Tables 29 and 30). The moistness of the control breads was similar to the triticale breads at the lowest alpha-amylase level (Table 27, Figure 35b).

Total scores for pup loaf characteristics reflected the three crumb characteristics studied. The wheat control

pup loaves had better overall quality than all triticale breads (Table 27, Figure 36), and only deteriorated by 2 points when the water level was not optimum. Total scores were higher when high protein and low alpha-amylase flour was used (Tables 28, 29) in combination with low to moderate water levels in pup loaf formulations.

To summarize, both protein content and alpha-amylase activity had an effect on pup loaf quality, and results were similar to those found for the consumer-style yeast bread test. The effects of higher levels of alpha-amylase activity was to improve bread volume at alpha-amylase ranges 2 and 3 for both protein content flours and to reduce volumes at the highest alpha-amylase activity range. This improving effect was not seen with the high protein flours in the consumer yeast bread study. The consumer yeast bread bake test may have been more rigorous in mixing and fermentation than the pup loaf test which resulted in optimal dough development of the high protein flours but underdevelopment of the low protein flours. Additional, but not excessive alpha-amylase, therefore, improved the volume of breads baked from low protein flours. In addition, farinograph data indicated that the mixing tolerances of the low protein flours were higher than those for high protein flours.

High protein flours produced breads of better volume and crumb quality than did the low protein flours

tested. It would seem likely that high protein flour contributed more gluten for dough development and this helped to mitigate some of the effects of alpha-amylase activity and excess water levels.

Pup loaf crumb structure became worse with increasing alpha-amylase activity. Cell size became larger, cell distribution became more uneven and the crumb became gummier, when additional alpha-amylase affected the starch gelatinization and water absorption. The effects on a product such as yeast bread was very drastic because of the relatively long mixing and baking process in yeast bread production.

Increased amounts of water increased the volume of pup loaves, however crumb quality suffered when the water level was not optimum. The effects on crumb quality were multiplied when a high alpha-amylase, low protein flour was used. Although the optimum water level (63%) showed the same differences in product quality as did 58% or 68% water levels, the use of a higher water level in pup loaf bake tests, may be desirable because this amplifies differences among treatments. This test may be applied to flours when the extent of sprouting or of alpha-amylase activity are to be determined.

The pup loaf test itself, showed larger significant differences in quality parameters than did the consumer

yeast bread test. There are several possible reasons for this finding. Firstly, in the pup loaf test, sound bread flour containing no additives was used as the blending flour; whereas all-purpose flour containing malted barley flour as an additive was used as the blending flour for the consumer-style yeast bread test. Therefore differences due to alpha-amylase should have been more apparent in the pup loaf test because there were no confounding effects of other alpha-amylase sources. Secondly, the pup loaf test was probably less strenuous in dough manipulation than the consumer bake test. Doughs could have been developed to near their maximum in the consumer-style bake test due to the long kneading, fermentation, proofing and baking process, thereby leaving little room to show the effects of flour treatments. In contrast, the pup loaf test had a very short processing time, so that the dough may have not been developed to the maximum, thereby exaggerating the flour treatments. Thirdly, the evaluation of pup loaf quality was probably more controlled in the pup loaf bake test than in the consumer yeast bread test. The number of judges was less in the pup loaf test, therefore variability among judges may have been reduced. Judges also evaluated the same pup loaf surfaces, whereas each judge in the consumer-style yeast bread test received a different slice of bread to evaluate. The judges evaluation was an average of 4 surfaces (i.e.) 2 loaves cut in half, in the pup loaf test. In the consumer-style test, each judge evaluated only one slice of bread, each judge

received a separate slice. For the moistness characteristic in pup loaves, judges evaluated moistness immediately after cutting the loaves; whereas consumer-style breads were cut into thin slices and wrapped, then evaluated within the hour. It is possible that the breads became slightly dry during this process. Fourthly, the pup loaf test required evaluations on only three characteristics, therefore may have been less fatiguing on the judges. In contrast, judges had to evaluate eight characteristics for the consumer-style yeast breads.

As a test to predict the bread-making quality of sprouted flours or flours of unknown alpha-amylase activity, the pup loaf test is recommended over the consumer yeast bread test, as it was faster, easier, and required less flour. In addition, differences due to flour treatment were just as apparent, if not more, than they were in the consumer-style yeast bread test.

E. General Discussion of the Effects of Protein Content and Alpha-Amylase Activity on the Quality of Baked Products

In general, higher protein wheat flours produce better baked product volumes than low protein flours, because higher protein flours contain a larger percentage of

gluten-forming proteins (Finney and Barmore, 1948). This was probably true for the protein levels in triticale flours, because high protein flours had the ability to produce greater volumes in all of the baked products, and it had the ability to mitigate the effects of alpha-amylase on crumb quality characteristics, especially in muffins and yeast breads. The high protein flours, though, may have been of poorer gluten quality. They had less farinograph mixing tolerance than low protein flours, and yeast bread volume was not improved with an initial increase in alpha-amylase activity as it was with the low protein flours.

In all of the baked products, the main effects of increased alpha-amylase were to reduce volume and impair crumb structure. Alpha-amylase activity levels were produced by adding laboratory sprouted triticale material to flours that were initially low in alpha-amylase activity. Grain is sprouted much faster in the laboratory than in the field because conditions for sprouting in the laboratory are optimum. Therefore the effects of alpha-amylase from laboratory sprouted grain on the baking quality of triticale flour may be slightly different than the effects from naturally or field sprouted grain. It would be interesting to bake products from triticale that had different levels of naturally occurring sprout damage, for example, milling samples, to determine the effects of both directly measured alpha-amylase and sprout damage on baking quality. To

supplement this information, a number of commercially available triticale flours should be tested for alpha-amylase activity and evaluated for their baking performance to determine how much variability exists among lots of flour and what effect this has on quality.

For all products tested, the consumer-style muffins, sour cream coffee cakes and yeast breads and the standard bake test, volume and sensory evaluation of crumb quality characteristics were the most important indicators of the effects of alpha-amylase activity and protein content on triticale baking quality. Protein content and alpha-amylase activity produced more drastic effects in yeast breads, than in muffins or cakes, because yeast breads depend to a greater extent on both gluten content and optimum alpha-amylase activity for structure.

V. SUMMARY AND CONCLUSIONS

Selection of triticale for milling is usually made on the basis of grade alone and this criterion may not be sufficient to ensure good baking performance of triticale flour. This study was undertaken to determine whether additional criteria, such as protein content, alpha-amylase activity or percent sprouted kernels would provide more assurance that triticale flours marketed for home baking would have good and consistent baking quality.

In the first part of the study, the relationship of percent sprouted kernels to alpha-amylase activity for 44 milling samples of Canada No. 1 and No. 2 grade triticale was investigated. Grade 1 samples, which may contain up to 0.5% sprout damaged kernels, had a mean activity of 2.38 IDC units/mg, while grade 2 which may contain up to 2.0% sprout damaged kernels had a mean activity of 4.37 IDC units/mg. Although mean activity was higher for the grade 2 samples, the correlation of percent sprouted kernels with alpha-amylase activity was weak ($r = 0.39$). Some samples with low sprout damage had relatively high levels of alpha-amylase activity and conversely, some samples with higher sprout damage had relatively low levels of alpha-amylase activity. Neither grade nor percent sprouting therefore can be used to predict the alpha-amylase activity

of the grain samples. Measuring alpha-amylase activity directly would be useful to ensure that the flour produced has acceptable baking quality.

In the second part of the study, two lots of triticale grain, line 6TA-419, one with a low protein content (11.2%) and one with a high protein content (14.4%) were milled into whole-grain flours. Each lot of flour was divided and supplemented with sprouted triticale grain to produce high and low protein flours with four ranges of alpha-amylase activity. Muffins, coffee cakes, yeast breads, and pup loaves (standard bake test) baked from these eight flours were evaluated by physical, instrumental and sensory methods for a range of quality characteristics.

In all of the baked products, the main effects of alpha-amylase were to reduce volume and impair crumb structure. Because alpha-amylase affects starch granule structure and gelatinization behavior, as alpha-amylase activity increased, less free liquid was absorbed which generally produced products with lower volume and a firmer, moister and more dense crumb. There was a slight volume improving effect of alpha-amylase ranges 2 and 3 for consumer-style yeast breads baked from flours with low protein content, and for pup loaves baked from both protein content flours. The crumb structure, however, became more fragile and open as alpha-amylase activity increased.

In general, higher protein flours contain a larger proportion of gluten forming proteins than lower protein flours. This apparently was true for the protein levels in triticale flours. Protein level significantly affected several characteristics of the baked products. The ability of the higher protein to produce greater volumes was evident in the muffins and was particularly apparent in the yeast breads and pup loaves which depend primarily on gluten for their structure. On the other hand, coffee cakes baked from low protein flour were judged more tender than those baked from high protein flour.

Methods used by consumers in home food preparation result in more variation in ingredient ratios and preparation procedures than would occur when baked products are prepared commercially. Besides the effects of alpha-amylase activity and protein content on triticale baked products, water level is one factor which could compound or exaggerate these effects. Other factors such as mixing or kneading time, and fermentation time may cause similar baking problems to the consumer. Triticale flour marketed for home baking should provide a measure of tolerance to these variables. From this study, it was concluded that triticale with low to moderate levels of alpha-amylase activity and relatively high protein content will ensure better products and supply a greater degree of tolerance to recipe variations than triticale with high alpha-amylase

activity and low protein content. Triticale alpha-amylase levels and protein content should be monitored to ensure that grain used for flour will meet acceptable performance standards. It is also possible that standards for alpha-amylase activity and protein content of triticale grain and flour could be developed.

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Appendix A. Solution preparation for determination of alpha-amylase activity by the iodine dextrin color (IDC) method.

Dextrin Preparation

1. Suspend 20 g of Amioca Pearl Starch[1] in 1 L of 90% dimethyl sulfoxide.
2. Stir for 24 hours at room temperature (21°C) until starch dissolves.
3. Dilute by adding 4.96 L of distilled water and 40 mL of 0.5 M acetate buffer (pH 4.6) (3.28 g Na Acetate $3H_2O$ and 1.56 mL glacial acetic acid taken to 100 mL).[2]
4. Add 0.2 mL of Sweet Potato B-Amylase and stir for 24 hours at room temperature (21°C).
5. Repeat 4.
6. Dialyze[2] against distilled water for 4 to 5 days at 0 - 4°C. Change water frequently.
7. Boil for 5 minutes and freeze-dry. Store in air-tight container. Yield 9 to 12 grams.

Dextrin stock solution

Dissolve 0.75 g of dextrin in 100 mL distilled water by boiling. Store at 0 - 4°C.

Dextrin working solution

Dilute 10 mL of the stock solution to 100 mL using 0.2 M Acetate Buffer (pH 5.5) 0.001 M $CaCl_2$. Store at 0 - 4°C.

I-KI stock solution

Dissolve 2 g Potassium Iodide and 0.2 g iodine in water. First add the KI to as little water as possible to form a solution; then add the iodine and allow it to dissolve. Take to 100 mL. Store in brown bottle at 0 - 4°C.

I-KI working solution

Take 25 mL of stock I-KI solution and 10 mL of 5 N HCI to 1 L with distilled water. Store in a brown bottle.

0.2 M Na Acetate Buffer (pH 5.5) containing 0.001 M CaCl2:

Combine 11.95 g Na Acetate $3H_2O$.0.72 glacial acetate acid and 1 mL $CaCl_2$ stock (0.5 M) (7.36 g $CaCl_2 .2H_2O$ in 100 mL water). Take[2] to 500 mL.

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1 American Maize Product Co.

2 Dialysis tubing, Thomas Lab Specialties 1 7/8 inch.

Appendix B. Weights of common measures

Triticale flour - spooned into 250 mL, levelled with spatula
11.8% protein-116.16, 118.10, 118.12, 117.26, 114.73,
14.4% protein-112.54, 112.09, 114.17, 116.23, 117.59

= 115.70 @ 116.00 g

All-purpose flour - spooned into 250 mL, levelled with spatula
124.81, 125.59, 127.50, 127.30, 126.39, 125.72, 125.48,
126.91, 127.48, 127.26

= 125.44 @ 125.00 g

Whole wheat flour - spooned into 250 mL, levelled with spatula
124.63, 127.70, 127.16, 125.22, 125.72, 126.66, 125.83,
126.92, 124.73, 127.09

= 126.17 @ 126.00 g

Granulated sugar - 250 mL dipped into sugar, levelled spatula
208.08, 206.23, 206.02, 204.91, 206.22
204.94, 207.34, 206.51, 209.53, 210.17

= 207.00 @ 207.00 g

Baking soda - 5 mL
3.68, 3.85, 3.70, 3.70, 3.66
3.65, 3.72, 3.75, 3.31, 3.65

= 3.67 @ 3.70 g

Baking powder - 5 mL
3.09, 3.21, 3.35, 3.30, 3.16
3.55, 3.02, 2.99, 3.23, 3.36

= 3.23 @ 3.20 g

Salt - 5 mL
4.92, 4.77, 5.05, 4.84, 5.22
5.01, 5.18, 4.91, 5.34, 4.96

= 5.02 @ 5.00 g

Yeast - 15 mL
9.44, 9.44, 9.60, 9.41, 9.73
9.81, 9.71, 9.73, 9.37, 9.48

= 9.57 g @ 9.60 g

Brown sugar - 125 mL firmly packed
83.53, 84.33, 81.68, 83.93, 83.05
81.95, 83.44, 83.37, 84.86, 83.01

= 83.32 @ 83.30 g

Appendix B. Continued.

Oil - 75 mL
8 X 75 mL = 463.50 g
75 mL = 57.94 @ 58.00 g

Margarine - 125 mL - spread into 125 mL and levelled
8 X 125 mL = 890 g
125 mL = 111.25 @ 111.00 g

Vanilla - 5 mL
10 X 5 mL = 29.05 g
5 mL = 2.9 g @ 3.0 g

Sour cream - spread in 250 mL and levelled off
10 X 250 mL = 2557.5
250 mL = 255.75 g @ 256.00 g

Shortening - 30 mL
8 X 30 mL = 192.00 g
30 mL = 24.0 g

Egg - 1 large
4 X 1 = 204.44
1 egg = 51.11 @ 51.00 g

Sugar - 5 mL
3.47, 3.36, 3.38, 3.41, 3.25
3.36, 3.31, 3.23, 3.49, 3.34
= 3.36 @ 3.4 g

Sugar - 50 mL
44.76, 45.09, 44.90, 44.77, 44.70
44.84, 44.40, 44.69, 44.64, 44.85
= 44.76 @ 44.8 g

Appendix C1. Ingredients and equipment used for muffins

Ingredients:
All-purpose flour, enriched, pre-sifted, commercial grade
Triticale flour, formulated
Whole wheat flour, commercial grade
Salt, iodized, free running table salt
Baking powder, single action (monocalcium phosphate)
Brown sugar, golden yellow
Milk, whole, homogenized, pasteurized
Oil, vegetable
Egg, large

Equipment:
Mixing bowl, pyrex 1.5 L capacity
Muffin tins, 2 - 6 cup aluminum, volume 75 mL each,
inside dimensions: bottom 5 cm, top 6.7 cm, vertical height 2.3 cm.
Paper liners, 4.45 cm base, 2.54 cm high
Electric oven, controlled at 200°C (Moffat Maitre'D Model # 24R65)
Cooling racks, aluminum 21 X 26 cm
Plastic container, 750 mL capacity
Bowl, 250 mL capacity

Appendix C2. Ingredients and equipment used for sour cream coffee cakes

Ingredients:
Margarine, regular, brick
Sugar, granulated
Eggs, large
Vanilla, pure extract
Triticale flour, formulated
Whole wheat flour, commercial grade
Baking powder, single acting (monocalcium phosphate)
Salt, iodized, free-running table salt
Baking soda, sodium bicarbonate U.S.P.
Sour cream, 14% m.g.

Equipment:
Mixing bowl, pyrex 2 L capacity
Baking pans, aluminum square, 2.5 L capacity
Electric oven, controlled at 180°C
Cooling racks, aluminum 21 X 26 cm
Plastic container, 250 mL capacity

Appendix C3 Ingredients and equipment used for yeast bread

Ingredients:
Sugar, granulated
Water, distilled
Yeast, active dry
All-purpose flour, enriched, presifted
Triticale, formulated
Whole-wheat flour, commercial grade
Milk, whole, homogenized, pasteurized
Salt, iodized, free-running table salt
Shortening, hydrogenated vegetable

Equipment:
Measuring cup, pyrex 250 mL capacity
Thermometer, °C
Stopwatch
Microwave oven
Braun Kitchen Machine, model # 72950, 4 L plastic bowl and dough hook
Fermentation cabinet controlled to maintain a temperature of 35°C and a relative humidity of 85%
Pastry board, wooden, 44.5 X 39.5 cm
Loaf pans, non-stick aluminum, 1.5 L capacity
Baking oven, controlled at 190°C
Cooling racks, aluminum 21 X 26 cm
Water bath, maintained at 30°C for tempering of water.
Erlenmeyer flasks, enough to hold 1.5 L water.
Plastic container, or jug, 1.5 L capacity
Mixing bowls, pyrex, 4 L capacity

Appendix D1. Ballot used for sensory evaluation of muffins

Sample Codes: _____ _____ _____ _____

Evaluate the samples in the order presented. Place a vertical line across the horizontal line at the point that best describes that property in the sample. Identify the scores by writing the sample code near the vertical line. Compare all samples to the reference (R), which has been positioned on the line. For samples that are scored differently from (R), give a reason (where reasons are required). Also note the descriptions of an ideal product. Evaluate all samples for one characteristic before moving on to the next characteristic.

Evaluate samples for EXTERIOR COLOR (Top) and CRUMB COLOR in the MacBeth booth.

Exterior Color (Top)
Ideal: golden brown, not too pale or dark

R
pale golden dark

Crumb Color
Ideal: light beige, not too pale or dark

R
pale light beige moderate beige

Overall Crumb Quality
Ideal: cells fairly uniformly distributed, cell walls of medium thickness, not compact and not too open, few marked tunnels

R
poor ideal

Reasons: _____

Appendix D1. Continued.

For MOISTNESS and TENDERNESS, use the top part of the muffin.

Moistness
Ideal: moist, not too gummy or dry

R

gummy — moist — dry

Tenderness
Ideal: tender and soft, not tough

R

tough — tender — very tender

Flavor Intensity

R

bland — moderate — intense

Reasons: _____

Flavor Acceptability

R

unacceptable — highly acceptable

Reasons: _____

Overall Quality
Keep in mind all of the characteristics above.

R

poor — good — excellent

Comments:

Appendix D2. Ballot used for sensory evaluation of sour cream coffee cakes

Sample Codes: _____ _____ _____ _____

Evaluate the samples in the order presented. Place a vertical line across the horizontal line at the point that best describes that property in the sample. Identify the scores by writing the sample code near the vertical line. Compare all samples to the reference (R), which has been positioned on the line. For samples that are scored differently from (R), give a reason (where reasons are required). Also note the descriptions of an ideal product. Evaluate all samples for one characteristic before moving on to the next characteristic.

Evaluate samples for SURFACE COLOR and CRUMB COLOR in the MacBeth booth.

Exterior Color
Ideal: golden brown, not too pale or dark

R
|
pale golden dark

Crumb Color
Ideal: light beige, not too pale or dark

R
|
light beige moderate beige dark beige

Overall Crumb Quality (cut sides)
Ideal: cells uniformly distributed, thin cell walls, not too compact and not too open, no large spaces.

R
|
poor ideal

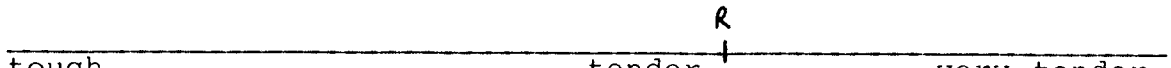
Reasons: _____

Moistness
Ideal: moist, not too gummy or dry

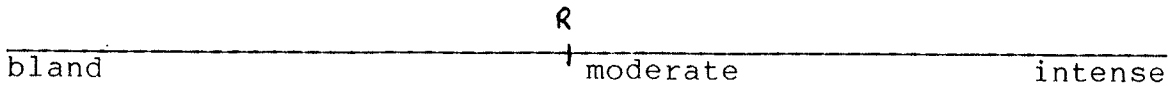
R
|
gummy moist dry

Appendix D2. Continued.

Tenderness
Ideal: tender and soft, not tough



Flavor Intensity



Reasons: _____

Flavor Acceptability

Reasons: _____

Overall Quality
Keep in mind all of the characteristics above.

Comments:

Appendix D3. Ballot used for sensory evaluation of yeast breads

Sample Codes: _____ _____ _____ _____

Evaluate the samples in the order presented. Place a vertical line across the horizontal line at the point that best describes that property in the sample. Identify the scores by writing the sample code near the vertical line. Compare all samples to the reference (R), which has been positioned on the line. For samples that are scored differently from (R), give a reason (where reasons are required). Also note the descriptions of an ideal product. Evaluate all samples for one characteristic before moving on to the next characteristic.

Evaluate samples for CRUST COLOR and CRUMB COLOR in the MacBeth booth.

Crust Color (top only)
Ideal: dark golden-brown, not too light or dark

R

lightly browned golden brown very dark

Crumb Color
Ideal: a light beige, not too pale or dark

R

pale light beige moderate beige

Overall Crumb Quality
Ideal: cells uniformly distributed, thin cell walls, not too compact and not too open, no large spaces.

R

poor ideal

Reasons: _____

Moistness
Ideal: moist, not too gummy or dry

R

gummy moist dry

Reasons: _____

Appendix D3. Continued.

Flavor Intensity

R

bland moderate intense

Reasons: _____

Flavor Acceptability

R

unacceptable highly acceptable

Reasons: _____

Overall Quality

Keep in mind all of the characteristics above.

R

poor good excellent

Comments:

Appendix E1. Ingredients and equipment used for standard pup loaf bake test

Ingredients:

Flour - composite flours consisting of 50% (by weight, on an as is moisture basis) bread flour and 50% of formulated flour.
Yeast compressed yeast. One lot (1 lb.) was purchased for each baking replication
Salt - non-iodized sodium chloride, commercial grade
Sucrose - granulated, commercial grade
Potassium bromate - reagent grade
Ammonium phosphate (monobasic) - reagent grade
L-Ascorbic acid - reagent grade
Skim milk powder - commercial grade
Shortening - all vegetable, commercial grade
Water - distilled for all solutions and dough water.

Equipment and Apparatus

Mixer, GRL having a speed of 132 rpm, with an open bowl.

Thermostatically controlled bath, used to control the temperature of the water-jacketed mixing bowl to produce a dough temperature of 30 $\pm$ 0.2°C at the end of mixing (30°C) (Haake G)

Solution bath, maintained at 30 $\pm$ 1°C for tempering of the yeast suspension, solutions and water (Thelco, Precision Scientific, Model # 85)

Fermentation cabinet controlled to maintain a temperature of 35°C and a relative humidity of 85%. (National Manufacturing Co.)

Fermentation bowls, enough sequentially numbered pyrex bowls to accommodate baking schedule (4 or more).
Dimensions: volume 750 mL, inside diameter (top) 13.5 cm, vertical height 8.3 cm.

Sheeting rolls, one pair of motor-driven sheeting rolls with the distance between rolls being instantly adjustable (7/32, 5/32, 1/8 in). (National Manufacturing Co.)

Molder, rolls up sheeted dough between three rollers. Pressure under which the dough is molded is constant as the top roller can only be lower as far as the stop (6.3 cm). Dough is molded to a fixed length between guides spaced 12 cm apart. (National Manufacturing Co.)

Appendix E1. Continued.

Baking oven, controlled at 220°C, with vapor outlet that can be closed. Moisture is provided by containers of water, in which the water is boiling when baking starts (National Manufacturing Co.)

Baking pans, tin plate, 0.8 mm burnt in; volume 345 cc.
Inside dimensions: bottom 9.5 X 5.2 cm, top 11.7 X 6.9 cm, vertical height 5.0 cm.

Appendix E2. Solution preparation for standard pup loaf bake test

Ingredient Solutions:

Yeast suspension

Weigh 80 g of yeast, place it into a beaker and use a spatula to chop it into small pieces. Add 100 mL of the total water required. Stir with a spatula until no lumps remain. Pour into a 500 mL volumetric flask. Rinse the beaker with remaining water and make up to volume. Shake well and pour suspension into a 500 mL erlenmeyer flask. Attach flask to solution bath. Shake vigorously before pouring and use 25 mL yeast suspension per 100 g flour.

Salt-sugar solution

Weigh out 20 g salt and 50 g sugar into a 500 mL volumetric flask. Make up to volume with water. Shake well until particles are dissolved. Pour solution into a 500 mL erlenmeyer flask. Attach flask to solution bath. Prepare fresh daily. Use 25 mL of solution per 100 g flour.

Bromate-phosphate solution

Combine 3 g of potassium bromate and 50 g of ammonium phosphate in a 500 mL volumetric flask and make up to volume with water. Store in a stoppered bottle at room temperature. Use 1 mL (equivalent to 60 ppm potassium bromate and 0.1% ammonium phosphate based on flour weight) per 100 g flour, and consider that as 1 mL for dough water calculations.

Ascorbic acid solution

Place 0.35 g of L-ascorbic acid in a 50 mL volumetric flask and make up to volume with water. Pour solution into a 50 mL erlenmeyer flask. Attach flask to solution bath. Prepare fresh daily. Use 1 mL (equivalent to 70 ppm based on flour weight) per 100 g flour and consider that as 1 mL for dough water calculations.

Dough water

Amount of dough water is dependent on the handling properties of the dough at the time of panning. Place distilled water in a 500 mL erlenmeyer flask and attach to solution bath. (From preliminary experiments, a baking absorption of 63% was determined to be optimum for handling ability. Absorptions of 58, 63 and 68% were used in this experiment) (See further calculation of dough water).

Appendix F. Alpha-amylase activity and percent sprouted kernels in triticale milling samples.

Grade 1 (0 - 0.5% Sprouted)		Grade 2 (0.5 - 2.0% Sprouted)	
% Sprouted	IDC Units/mg	% Sprouted	IDC Units/mg
0.0	0.13	0.6	0.90
0.0	0.22	0.7	0.61
0.0	0.31	0.8	1.03
0.0	0.42	0.8	2.69
0.0	0.57	0.8	5.33
0.0	0.92	1.0	1.19
0.0	1.26	1.2	2.46
0.0	1.28	1.2	10.03
0.0	1.80	1.3	0.68
0.0	1.86	1.4	4.36
0.0	2.04	1.5	0.50
0.0	2.38	1.5	2.26
0.0	2.46	1.6	0.70
0.1	5.14	1.6	3.66
0.2	0.85	1.6	19.04
0.2	1.00	1.7	3.17
0.2	1.85	1.8	4.76
0.2	2.41	1.8	15.37
0.2	5.14		
0.2	9.99		
0.4	0.44		
0.4	1.59		
0.4	2.19		
0.4	8.33		
0.5	0.71		
0.5	4.16		
Mean 0.15	2.38	1.23	4.37
n 26		18	

Appendix G1. Mean square values for one-way analysis of farinograph characteristics and falling numbers

		Source of Variation	
	d.f.	Flour	Error
Absorption (14%)	10/22	22.25**	0.03
Peak time		1.19**	0.07
Stability		25.17**	0.10
Mixing Tolerance Index		4060.15**	39.39
Falling Number	9/22	148694.99**	692.27

*, ** denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix G2. Mean square values for factorial analysis of variance of farinograph characteristics and falling numbers

Source of Variation	d.f.	Absorption (14% m.b.)	Peak Time	Stability	M.T.I.	Falling Number[1]
Protein	1	155.55**	1.26**	0.84**	24066.67**	748.17**
Amylase	3	0.68**	0.42	0.06*	279.17**	13899.00**
Rep	2	0.07	0.08	0.08	59.38	74.63*
PXA	3	0.23*	0.003	0.07*	41.67	1131.61**
PXR	2	0.005	0.13	0.07*	7.29	10.79
AXR	6	0.02	0.03	0.02	92.71	71.96**
Error	6	0.03	0.04	0.01	23.96	6.24

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

[1] Does not include bread flour in the analysis.

Appendix H1. Mean square values for one-way analysis of variance of muffin characteristics

		Source of Variation	
	d.f.	Flour	Error
Volume	8/21	0.005*	0.002
Sensory Characteristics	8/21		
Exterior color		84.14**	12.52
Interior color		102.04**	12.53
Crumb quality		148.87**	36.41
Moistness		79.63**	24.98
Tenderness		13.25	15.50
Flavor intensity		35.91*	14.47
Flavor acceptability		17.08	11.43
Overall quality		28.34	36.56
Instrumental	8/21		
Firmness		0.06	0.05
Cohesiveness		0.001	0.0009
Gumminess		0.01	0.02
Moisture Content	8/21	0.33	0.46
Moisture Loss			

*, **Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix H2. Mean square values for factorial analysis of variance of sensory muffin characteristics

Source of Variation	df	Exterior Color	Crumb Color	Crumb Quality	Moistness	Tenderness	Flavor Intensity	Flavor Acceptability	Overall Quality
Protein	1	2.15	41.01**	102.15*	1.17	1.52	1.52	2.38	188.60**
Amylase	3	17.61	8.55	90.40*	153.50**	0.29	4.09	5.25	6.33
Judge	6	85.88**	189.91**	353.34**	152.15**	165.28**	190.99**	124.64**	260.14**
Rep	2	47.19**	85.03**	67.37	145.79**	1.63	13.44	27.15**	77.60*
PXA	3	20.66	0.78	12.04	39.91	1.63	1.43	3.51	2.07
JXR	12	26.27**	22.99**	38.70	67.01**	22.84*	29.96**	64.14**	105.19**
PXR	2	19.47	11.03	97.58*	15.61	33.87*	0.94	2.51	80.31*
AXR	6	18.93	6.95	47.59	22.36	17.76	8.78	4.07	40.95
Error	132	8.92	4.60	25.41	17.59	10.20	7.71	3.46	24.22

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix H3. Mean square values for factorial analysis of variance of muffin objective and instrumental tests

Source of Variation	df	Volume	Moisture Content	Moisture Loss	Firmness	Cohesiveness	Gumminess
Protein	1	0.0073*	0.0001	0.0260	0.005	0.0001	0.002
Amylase	3	0.0045	0.3030	0.0628	0.028	0.0002	0.010
Rep	2	0.0011	0.8081	1.1925**	0.106	0.0056*	0.046
PXA	3	0.0025	0.1528	0.0325	0.001	0.0008	0.013
PXR	2	0.0012	1.1152	0.0439	0.066	0.0001	0.025
AXR	6	0.0018	0.3842	0.0217	0.013	0.0007	0.012
Error	6	0.0011	0.2692	0.0205	0.039	0.0005	0.024

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix Il. Mean square values for one way analysis of variance of sour cream coffee cake characteristics

		Source of Variation	
	d.f.	Flour	Error
Volume	8/21	4084.20**	348.65
Sensory Characteristics	8/180		
Surface color		85.51**	7.86
Crumb color		148.46**	15.69
Crumb quality		63.31*	25.11
Moistness		11.50	21.52
Tenderness		14.74	10.03
Flavor intensity		42.33**	14.70
Flavor acceptability		44.13**	14.78
Overall quality		21.35	30.80
Instrumental	8/21		
Firmness		0.12**	0.01
Cohesiveness		0.004**	0.0005
Gumminess		0.03**	0.007
Moisture Content	8/21	0.54	0.58
Moisture Loss		0.03**	0.007

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix I2. Mean square values for factorial analysis of variance of sensory sour cream coffee cake characteristics

Source of Variation	df	Surface Color	Crumb Color	Crumb Quality	Moistness	Tenderness	Flavor Intensity	Flavor Acceptability	Overall Quality
Protein	1	231.01**	6.48	3.42	1.92	65.63**	1.01	7.29	2.63
Amylase	3	131.77**	3.97	136.31**	22.49	10.81	3.53	1.53	29.37
Judge	6	12.38	203.49**	223.04**	300.15**	54.00**	230.11**	227.66**	525.64**
Rep	2	61.41**	53.09**	10.79	23.24	5.47	6.27	15.04	9.74
PXA	3	7.50	0.39	4.68	1.02	5.85	3.15	1.02	4.55
JXR	12	8.37	61.05**	50.65**	26.27*	40.08**	43.75**	32.40**	4.54
PXR	2	48.26**	4.88	3.50	1.36	3.27	6.01	8.26	23.20
AXR	6	22.05**	9.89	9.40	17.87	14.26	4.08	7.88	0.93
Error	132	6.73	5.27	18.86	12.13	6.79	5.23	6.15	16.60

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix I3. Mean square values for factorial analysis of variance of sour cream coffee cake objective and instrumental tests

Source of Variation	df	Volume	Moisture Content	Moisture Loss	Firmness	Cohesiveness	Gumminess
Protein	1	130.67	0.05	0.11	0.01	0.006**	0.08*
Amylase	3	2344.90**	0.32	0.05	0.03	0.0003	0.02
Rep	2	360.20	3.65**	0.63**	0.04	0.0016	0.01
PXA	3	5.53	0.22	0.01	0.01	0.0003	0.01
PXR	2	192.14	0.30	0.03	0.003	0.0005	0.002
AXR	6	297.56	0.18	0.02	0.01	0.0006	0.008
Error	6	196.83	0.18	0.03	0.01	0.0003	0.007

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix J1. Mean square values for one-way analysis of variance of yeast bread characteristics

	d.f.	Source of Variation	
		Flour	Error
Volume	8/21	162614.16**	1133.90
Sensory Characteristics	8/180		
Crust color		157.08**	18.56
Crumb color		256.58**	13.54
Crumb quality		325.07**	38.27
Moistness		26.39	29.91
Flavor intensity		297.16**	42.94
Flavor acceptability		29.20	42.82
Overall quality		165.30*	71.45
Instrumental	8/21		
Firmness		1.17**	0.08
Cohesiveness		0.02**	0.001
Gumminess		0.40**	0.05
Moisture Content	8/21	1.25**	0.12
Moisture Loss		0.31	0.19

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix J2. Mean square values for factorial analysis of variance of sensory yeast bread characteristics

Source of Variation	df	Crust Color	Crumb Color	Crumb Quality	Moistness	Flavor Intensity	Flavor Acceptability	Overall Quality
Protein	1	648.21**	31.72**	6.09	68.15*	12.59	61.92	135.72
Amylase	3	149.82**	2.72	83.66*	26.43	1.31	47.47	52.75
Judge	6	108.30**	213.76**	530.29**	433.15**	883.71**	792.16**	1106.71**
Rep	2	122.88**	108.33**	26.27	74.12**	21.08	43.88	106.93
PXA	3	13.75	4.23	13.54	14.62	32.39	7.47	14.13
JXR	12	56.68**	21.87**	36.78	44.30**	35.18**	14.89	98.58**
PXR	2	42.65*	16.79	15.01	18.97	2.90	2.79	3.52
AXR	6	10.84	8.35	10.83	38.76*	13.20	13.90	24.51
Error	132	12.23	4.49	23.62	13.91	14.23	19.68	35.37

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix J3. Mean square values for factorial analysis of variance of yeast bread objective and instrumental tests

Source of Variation	df	Volume	Moisture Content	Moisture Loss	Firmness	Cohesiveness	Gumminess
Protein	1	83485.01**	0.012	0.135	1.27**	0.006*	0.13
Amylase	3	2063.20	0.034	0.684	1.61**	0.0008	0.67**
Rep	2	3613.34*	0.457*	0.176	0.25*	0.0002	0.10
PXA	3	2445.15	0.077	0.082	0.72**	0.0028	0.29**
PXR	2	331.58	0.057	0.151	0.07	0.0008	0.06
AXR	6	667.58	0.121	0.098	0.13*	0.0021	0.09
Error	6	562.75	0.061	0.153	0.02	0.0007	0.02

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix K1. Mean square values for one-way analysis of variance of pup loaf characteristics

		Source of Variation	
	d.f.	Flour	Error
Volume	8/72	31618.68**	1788.06
Scoring	8/315		
Cell size		42.33**	1.13
Cell distribution		26.57**	1.10
Moistness		49.29**	1.01
Total score		340.99**	5.72

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.

Appendix K2. Mean square values for factorial analysis of variance of pup loaf characteristics

Source of Variation	df	Volume	Cell Size	Cell Distribution	Moistness	Total Score
Protein	1	16912.67**	7.03**	12.50**	11.68**	93.39**
Amylase	3	6317.48**	70.46**	33.82**	85.95**	545.21**
Judge	3	-	3.32**	2.64**	5.06**	25.13**
Water	2	95462.25**	56.32**	33.90**	34.74**	354.39**
Rep	2	1349.67**	9.85**	26.59**	17.82**	9.38*
PXA	3	347.86	1.32*	2.99**	0.99	7.86*
PXW	2	304.72	0.20	2.01*	1.15	6.68
PXR	2	67.72	3.29**	1.53	7.36**	29.49**
AXW	6	3006.73**	3.17**	4.83**	3.25**	28.00**
AXR	6	299.93	1.97**	0.59	1.29*	2.98
WXR	4	12979.17**	11.16**	6.52**	0.34	30.74**
JXR	6	-	0.83	0.58	0.56	2.89
Error[1]	40	99.03	99.03	-	-	-
Error[2]	247	-	0.48	0.56	0.54	2.26

1 Volume
2 Scoring

*, ** Denotes a significant difference at $p<0.05$ and $p<0.01$ respectively.