EFFECTS OF SINGLE CELL PROTEIN
ON NUTRITIVE CONTENT AND
ORGANOLEPTIC QUALITIES
OF MUFFINS

By

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Bachelor of Science

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1976

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1979

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ACKNOWLEDGMENTS

The author wishes to express her sincere thanks and grateful appreciation to Dr. Lea Ebro, major adviser, for her valuable assistance and encouragement throughout the course of this work.

Appreciation is also expressed to the members of the advisory committee, Dr. Esther Winterfeldt, Dr. Anna Gorman, and Dr. Robert Morrison, for their assistance and support during the course of the research and in preparing the final manuscript.

Thanks are also expressed to the eight panel members, for their constant cooperation and support, for without them this study would not have been possible. The advice and laboratory assistance provided by those in the Food, Nutrition and Institution Administration Department was greatly appreciated, and the author wishes to thank each of them. A special note of appreciation is also extended to Amoco Oil Company, for making available the single cell protein samples and literature.

To my parents, Mr. and Mrs. Samuel Zouranjian, sister JoAnn, and brother Scott, many thanks are given for your constant support, encouragement, and love during all my college years. It is that support that has enabled me to come this far.

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CHAPTER I

INTRODUCTION

The primary source of protein in developed countries is animal protein. Food costs as well as population size are constantly increasing, which may make it desirable to use lower costing sources of protein as supplements and extenders to foods already familiar and accepted, such as breads or pastas. Plant, fish, and vegetable proteins are examples of low-cost sources found in developing countries (Table I). These substitutes and extenders for animal protein are now at the threshold of their greatest growth. There are two major areas in which the growth of protein will progress to meet the consumers' needs; first, towards the leisure-oriented citizen of affluent nations, and secondly, as an aid to protein deficient inhabitants of developing countries (1).

Plant foods, as carbohydrates, constitute an important source of protein for many areas of the world, not only for those areas with a short supply, but also those regions where animal protein is forbidden for consumption due to cultural or religious beliefs. These foods are low in protein content which puts these people at a definite disadvantage. According to Scrimshaw (2),

TABLE I

NUTRITIONAL INTAKES OF PROTEINS IN RURAL AREAS OF SELECTED DEVELOPING COUNTRIES, 1960-1970[a]

Country	Proteins[b]		
	Total	Animal	Vegetable
Tunisa	63.7	7.4	56.3
Chad	90.1	10.5	79.6
Dohomey	51.0	7.0	44.0
Morocco	84.0	12.0	72.0
Brazil	79.2	29.7	49.5
Pakistan	69.8	7.9	61.9
Trinidad	81.7	31.8	49.9
United States (Missouri)	92.0	69.0	23.0

[a]Edmondson, J. E., Graham, D. M., Animal protein-substitutes and extenders, J. of Animal Science, 41:698, 1975.

[b]Values expressed in grams per capita per day.

> The world is entering a period when the relationship between food availability in low-income countries and rising population is increasingly perilous and, for some countries, has already reached crisis proportions. The technology symbolized by the term 'Green Revolution' brought hope and sharply increased cereal yields to several of the most populous under-developed countries . . . [but will not] provide more than temporary relief.
>
> Little attention has been paid until recently to the fact that some affluent populations consume as much as 1800 lb of cereal per person per year because 80% of it is used for animal feed, while populations of developing countries subsisting largely on rice, wheat, or maize use less than 400 lb per person per year (p. 25).

Protein malnutrition is prevalent in the developing countries of the world. The major reason for this malnutrition is the consumption of low protein plant foodstuffs as the major source of dietary intake (3).

The intent of this research is to develop a food product high in protein using a yeast single cell protein flour. The characteristics of color, texture, moisture, and flavor will also be considered for consumer acceptance of the product. It has been repeatedly pointed out by several surveys that most people do not ingest nutrients; they consume a food (1). Therefore, this research is to fabricate a food system, specifically a bread, which will be acceptable to the consumer. Acceptance of such a product will vary from country to country, area to area, and person to person. Each group has its own protein need, food tastes, and food preferences.

Purpose and Objectives

The purpose of this research was to discern the effects of yeast single cell protein flours on appearance, texture, moisture content, flavor, and overall acceptance of muffins containing this food ingredient. Specific objectives were as follows:

1. To identify the effects on appearance, texture, moisture content, flavor, and overall acceptability and nutritional content (based on amino acid tables) of yeast single cell protein when incorporated in a bread product.

2. To judge which level of each yeast single cell protein flour incorporated in a bread product is most acceptable to the consumer.

3. To make recommendations for future research in this field.

Hypotheses

The following hypotheses were postulated for this research:

H_1: There will be a significant difference in the nutritional content (based on amino acid tables) when a specified proportion of a single cell protein flour is substituted for all-purpose and wheat flour in bread products.

H_2: There will be no difference in appearance, texture, moisture content, flavor, and overall acceptability in muffins made with all-purpose flour, or whole wheat flour only, and those incorporating one of three types of single cell protein flours.

Assumptions

The assumptions made for this study were:

1. The test panel will be trained to detect differences in each product, and will remain objective in their evaluation.

2. Each type of muffin will be prepared in the same food laboratory under the same laboratory conditions.

Limitations

The following limitations were accepted in this research study:

1. The yeast protein flour used in the study was from Amoco Oil Company, Naperville, Illinois.

2. Only muffins were used for testing yeast single cell protein flour.

Definitions

The following definitions were used in this study:

Single cell protein. "cells of algae, bacteria, yeasts, and fungi grown for their protein content" (4:175).

Algae. any of a group of chiefly aquatic nonvascular plants (seaweeds, pond scums) with chlorophyll often masked by a brown or red pigment (5).

Color. "determination of hue, purity, and lightness which correlates well with human perception of color" (6:57).

Texture. "the characteristic consistency: overall structure includes hardness, cohesiveness, viscosity, and elasticity" (7:728).

Moisture content. a measurement of texture which looks at the liquid diffused in a small area (7).

CHAPTER II

REVIEW OF LITERATURE

There have been many theories and ideas proposed and investigations completed on the use and acceptability of single cell protein, as well as other sources of significant unconventional protein. When developing food products which incorporate nontraditional sources of protein, there are certain criteria which researchers attempt to ascertain. The following are guidelines for nutritional improvement of conventional foods:

1. The potential intake of a nutrient considered for addition to food should be judged to be below a desirable quantity in the diets of a significant number of people.

2. The food that is to carry the nutrient should be consumed by the segment of the population in need, and the added nutrient should make an important contribution to the diet.

3. The addition of the nutrient should not create a dietary imbalance.

4. The nutrient added should be stable under customary conditions of storage and use.

5. The additional cost should be reasonable for the intended consumer (11:69).

This research is searching for a bread product which incorporates these guidelines and results in an acceptable product. The acceptance of baked products supplemented with unconventional proteins depends on the source, amount, and

and type of supplement (8). The literature available is insufficient to develop a complete assessment of the problem.

Historical Background

> Single cell protein products can be considered either as a protein supplement to human diets on nutritional grounds or as a potential source of protein concentrates and isolates having functional utilities in food products (4:177).

The use of algae, bacteria, and yeasts as food for humans has been the subject of discussion in both the scientific and technological literature and popular press in the recent years (9). What are the prospects of these single cell proteins grown for their protein content?

The world protein deficit demands that there be an expanded effort devoted to the production and utilization of the unconventional proteins. The unconventional proteins offer the world's exploding population a virtually untapped resource for its growing food requirements. There has to be research prior to utilizing these sources. One must consider the nutritional quality, toxicological factors, organoleptic properties of taste, aroma, texture, and color, and finally, the acceptability and protein functionality in food systems (9). Only recently has nutrition become a motivating tool (10).

The world population is now increasing by two percent per annum, a doubling every 35 years.

> In 1967, Altschul estimated that the world would be ten million tons short of its protein need by 1970. In addition, Ledden reported that

> 400 million tons of protein would be required in 1974 to provide a minimum diet for everyone. Assuming 50g of protein per day per individual, a population of 60,000 million by 2100 would require trebling the annual protein production to 1.2 billion tons.
>
> In developing countries, proteins of vegetable origin constitute about 83.3% of overall available proteins with cereals alone providing 57% and pulses, oilseeds, and nuts supplying 16.8%. . . . animal protein requires a relatively long time to produce and is expensive [and] is limited to satisfy world needs. [It is] evident that all underutilized food protein sources must be scrutinized to supplement the world protein supply both in quantity and quality (9:152).

During the 1960's, there had been an increased development of single cell protein based on substrates from renewable resources as well as nonrenewable sources. Nonrenewable sources, such as methane, petroleum hydrocarbons, and petrochemicals, are chosen for their cost and large availability in certain areas (3). Cellulose, a renewable source, can be used for the production of single cell protein. There are definite advantages and disadvantages in using either the renewable or nonrenewable sources in single cell protein production. Renewable sources have sugars and starches readily available from tropical crops, sugar cane, and cassava; cellulose is readily available in agriculture (4). Some of these products may also be available only seasonally, thus causing production problems.

The main argument in favor of nonrenewable sources, such as petroleum hydrocarbons, is the availability at low cost in the producing areas. The Near East is a major producer, and is conveniently close to Europe where the market for such products has been favorable and fluctuating in cost (3). The past two years have seen a change in the pricing of petroleum hydrocarbons, a definite rise. The rise is due to the increases set by the Organization of Petroleum Exporting Countries (OPEC) and an increase due to inflation of plant construction costs. Current trends seem to favor renewable sources for protein usage, depending on their availability, nature, and requirements for additional processing before they are a usable single cell protein product (3).

Experimental Results of Using Single Cell Protein in Food Products

> New foods are being developed to increase the total food supply, meet specific needs of certain groups of people and to provide more convenient forms of foods. In the future, many people may depend upon these foods to supply essential nutrients.
>
> Scientific and technological advances have made it possible to produce a variety of new foods that combine acceptability and good nutritional values. These products frequently use as a base blended cereal grains, oil seeds, legumes, roots, or tubers as sources of protein and of energy. . . . These various types of new products offer maximum opportunities for the design of nutritionally beneficial foods utilizing industrially produced nutrients, e.g., novel protein sources (11:67).

Bird (12) reported that soy and other nonconventional sources of protein will be in greater use in the future in products such as processed meat, dairy, and baked products. He also predicted that in the future one-third to one-half of the world's protein will be derived from nontraditional protein, particularly plant protein.

The incorporation of single cell proteins in baked products has begun to be tested and analyzed. Evans, Volpe, and Zabik (13) have conducted such a study, analyzing the ultrastructure of bread dough which incorporates single cell protein. Findings indicated that single cell protein disrupted typical gluten development, causing a web-like structure over the starch granules.

Patel and Johnson (8) also have studied an alternate protein source, horsebean protein, and its effects on physical dough properties and baking quality. They analyzed the dough from three blends--strong, medium, and weak--of wheat flour. Horsebean flour created a dough of low elasticity and an inferior quality product, while the horsebean flour protein isolate with a protein equivalent of 20 percent horsebean flour, produced a satisfactory physical dough to sell as acceptable bread. Medium-to-strong wheat flours are suggested as carriers of nongluten protein supplements. The addition of either the horsebean flour or the horsebean flour protein isolate greatly increased the protein content of bread and improved the essential amino acid composition when compared to a control.

Patel, Caul, and Johnson (14) continued the study of horsebean flour as a source of alternate protein. These researchers were testing flavor and aroma as limiting factors. They felt that flavor was the main drawback limiting the use of alternate proteins in baked products. The findings indicated that horsebean flour breads were sweeter, more bitter, beanier, and less wheaty than breads with equivalent levels of horsebean protein isolate. It was indicated that both the type and content of the protein supplement affected the loss of bread-like flavor, aroma, and taste of the enriched breads. The horsebean protein isolate breads at all levels, retained their bread-like identity and also showed less detrimental influence on crumb and crust texture than horsebean flour. It did appear that horsebean flour protein isolate would most likely meet with greater consumer acceptance than horsebean flour.

Another study had been conducted supplementing Chapati, and unleavened bread prepared from wheat flour and water, with plant and vegetable proteins. Chapati, a staple food in West Pakistan among the poor, constitutes 90 percent of the total food intake (15). Bass and Caul (15) have found that fish protein concentrate had atypical flour and dough properties as well as atypical eating qualities (15). The use of cottonseed flour blend would probably be limiting due to the dough appearance, dryness, and inelasticity. Aroma was acceptable in the cottonseed flour blends. Soy protein concentrate flours reduce elasticity but is unnoticeable by the consumer. The lowest level of soy supplementation, five percent, would be the most acceptable. This study indicated the diverse possibilities for supplementing wheat products.

There are many desirable physical-chemical properties of a protein concentrate for use in foods (4). These qualities include water and fat binding, emulsion stability, dispersibility, gel formation, whippability, and thickening. The economic aspects of single cell protein production are higher for concentrates, isolates, and textures or functional products. The costs will vary with source and availability, depending on geographic region (4). The functional single cell protein will have to compete in functional value with existing functional ingredients, such as soybean protein concentrate or isolate, casein, and egg albumin. If the price of animal proteins continues to escalate at projected rates, the vegetable protein products can be marketed with the dual advantage of lower price coupled with health and nutritional benefits. The successful development of a protein supplemented bread ultimately requires acceptance of the product; if not accepted, the most nutritious food is of no value to the malnourished (15). No protein source, regardless of its value, can compensate for poor product quality or concept.

Justification of the Importance of Single Cell Protein

The dramatic increases in the price of meat products has caused a renewed interest in the area of single cell protein just at a time when many observers had reached the conclusion that a large scale use of single cell protein was not economically competitive with conventional sources (16). Single cell proteins are microbial cells, unicellular or simple multicellular organisms, from algae, bacteria, fungi, and yeasts to be used as a source of protein (17). Microorganisms are an interesting new source of protein. They have a high protein content and grow with a high growth rate on a wide variety of substrates (18). Some of the nutritional factors influencing the choice of a microorganism for single cell protein production are amino acid pattern, protein digestability, effects of extraneous materials such as cell wall, nucleic acid and others, and protein content (17). Most types of single cell protein are considered to be good sources of lysine.

Development of Yeast Proteins

In developing countries the urgent need for low cost nutritious foods has long been recognized. Along with meeting the daily requirement, such foods should contain substantial amounts of good quality protein as low in price as possible, attempting to match the low per capita income (19).

A careful examination of this situation indicates that to achieve progress within a reasonable time span, inputs from private food industries, government, food science institutions, and external agencies are all necessary.

Single cell protein is one of the few potential foods having no dependency on agricultural input or other harvesting operations. It can be a synthetic, yet complete source of food whose composition is controllable. Table II indicates how raw materials are transformed into cells (17).

TABLE II

MATERIALS INVOLVED IN THE MANUFACTURE OF SINGLE CELL PROTEIN

Input ⟶	Output
Water	Waste Water
Carbon Source	<u>Cells</u>
Nitrogen Source	Carbon Dioxide
Minerals (P, K, S, etc.)	Metabolites
Cooling Water	Heat
Oxygen	
Power	

Choosing a process, including the organism and substrates, is difficult. There are a great many processes for producing single cell protein from petroleum fractions, for example, hydrocarbon fermentation and carbohydrate fermentation. Table III indicates the materials necessary to produce 100 pounds of cells by both methods. Gas oil is a complex substrate that can use yeast or bacteria as its organism (17). Other factors to consider, along with the organism choice, for determining the ultimate choice of a single cell protein process are nutritional, sociological, and food technological factors.

TABLE III

MATERIAL BALANCE FOR PRODUCING SINGLE CELL PROTEIN BY HYDROCARBON AND CARBOHYDRATE FERMENTATION PROCESSES

Process	Input		Output
	Substrate (lbs)	Oxygen (lbs)	Cells (lbs)
Hydrocarbon	100	200	100
Carbohydrate	200	67	100

Amoco Oil Company has developed yeast products grown on pure ethyl alcohol. The particular yeast used is *Candida utilis*. Amoco uses only raw ingredients to grow this uniform, natural food ingredient. The process for development is simple. Ethyl alcohol, certain vitamins, and minerals are sterilized and metered into an aseptic fermentation vessel. A pure culture of yeast is introduced and, as it grows, it is continuously withdrawn, centrifuged, pasteurized, and then spray dried. All the yeast concentrates manufactured by Amoco are high in lysine content, making their use in wheat products a natural (20).

Application of Yeast Proteins

Single cell protein has been suggested for use as ground meat in frankfurter extenders, in fabricated foods resembling those currently made from soy fibers, as well as a protein enrichment for baked goods (16). The successful development of any of these applications will require treatment of the single cell protein to reduce the non-protein nitrogen content. The acceptance of fabricated foods based on spun soy protein fibers has led to the investigation of similar processes using yeast protein.

Yeasts seem to have acceptable functional properties in bread products (16). The use of baked goods as a convenient vehicle for improving nutrition for those in developing countries has received increasing research emphasis in the past decade (21). Research indicates that an appreciable percentage of wheat flour can be replaced by yeast concentrates due to their amino acid composition. The supplementation of wheat flour with yeast protein before baking should improve the nutritional value of the bread (21). A significant increase in the PER (protein efficiency ratio) of bread has been shown when Candida yeast is added to the flour. In baking experiments done by Lindbloom (18), 10-12 percent yeast protein concentrate was substituted for the wheat flour. The protein content in the resulting mixture was one-third yeast, and the overall protein content of the bread increased 20-40 percent compared to the unenriched bread. However, there was a slight yeast-like taste in the bread.

When adding protein concentrates to bread products, the majority of the protein should be insolubilized. According to Pomeranz and Finney (18), large amounts of water soluble proteins in dough are undesirable. Insolubilization of yeast proteins are achieved during the nucleic acid reduction process. Best breadmaking properties are obtained if the concentrate still has some solubility.

The consumer acceptance is growing for baked products, even in areas where rice has been a traditional food and major source of energy (19). For example, in Bangkok, a traditional wedding gift is a specially shaped bread. This then constitutes an acceptable means of providing improved nutrition in developing countries. The level of worldwide interest in more nutritive baked goods is high. By designing protein ingredients for specific applications, both the consuming public and food processing industry will benefit (10). A growing consumer awareness of nutrition indicates that nutritional benefits would be a good selling point. One must be aware of the power of the consumer once he has become aware of a basic issue.

New evidence indicates that mass media (radio, television, newspaper advertising) can be effectively used in urban areas for consumer motivation (19). However, in developing countries, the use of mass media for this purpose must be government assisted. Formal nutrition education is not accessible to rural people. They must be reached where they are, at home, in public market places, etc.

There is at present a lack of coordination and communication between government agencies, universities, and the private sector. The food industry lacks the personnel to conduct the necessary research and development. Business then turns to government and university resources for technical assistance (19). The university people need aid in planning and funding the products that are relevant to the private sector.

The lack of consumer marketing research and development is of utmost importance. To succeed in marketing low-cost nutritious foods, which are designed to meet organoleptic properties of proper packaging and good keeping quality needs of the consumer, an inventory must be made in advance of all applicable constraints and appropriate resources to overcome them (19). In the long run, emphasis should be on the use of local enterprises and in-country technology resources. This is the most efficient way to keep costs at their minimum and to identify the local needs that marketing must always encounter and adapt to.

CHAPTER III

RESEARCH DESIGN

The purpose of the study was to determine the effects of each of the three yeast protein concentrates on appearance, texture, moisture content, flavor, and overall acceptability of plain and whole wheat muffins when used at four, seven, and nine percent levels. An eight member trained attribute panel evaluated both types of muffins. The Instron Universal Testing Instrument Model 1122 was used to measure tenderness. The research design, experimental procedures, and data analysis used are outlined in this chapter.

Type of Research

The research was conducted using the experimental design. In experimental research one deliberately manipulates an independent variable under highly controlled conditions, with the outcome explaining how and why a particular event occurs. The conditions that were controlled in regard to the food product were those of product ingredients, preparation procedures, oven type, oven temperature, and baking time (22). There were also conditions to be controlled with respect to the taste panel and their environment. The conditions, which remained constant, were time of day, room, and room temperature, privacy in sampling, and noise levels.

The specific statistical designs used were the randomized block design, rank analysis, and analysis of variance. The randomized block design is appropriate when no sources of variation, other than treatment are known or can be anticipated. When using this method of analysis, the number of units in a group will be equal to the number of treatments or some multiple of it (23).

Experimental Procedure

The three yeast cell protein flours used were obtained from Amoco Oil Company of Chicago, Illinois. Each of the yeasts has a different composition and amino acid content (Appendixes A and B). Boost-100 is a natural primary yeast with significantly higher levels of thiamine, riboflavin, niacin, and other minerals, as well as a low sodium content (17). Boost-100 flour is 49 percent protein. Torutein-LF is a multifunctional food yeast (Candida utilis) characterized by a mild flavor. It increases the extensibility of doughs without slackening to reduce mixing time. The composition of Torutein-LF is 52 percent protein. Toruway-49 is a specially processed combination of Amoco's Torutein yeast and sweet dairy whey. This combination results in a pleasant, light flavor. The protein content found in Toruway-49 is 37 percent (17).

The percentages of three different single cell protein samples most acceptable to the taste panel when incorporated in a bread product were tested. The bread product chosen for this research was a drop batter muffin. Two types of flour were used: all-purpose and whole wheat. The reference muffin formula used to represent a standard product was taken from the Oklahoma State Food Preparation Manual, 1979 (24). The formula was selected based on taste, baking quality, and appearance (Table IV). The attribute panel members convened for six days. On the first and fourth days, Boost-100 was substituted for a portion of the flours. Toruway-49 was substituted in the muffins on the second and fifth days, while Torutein-LF was substituted on the third and sixth days.

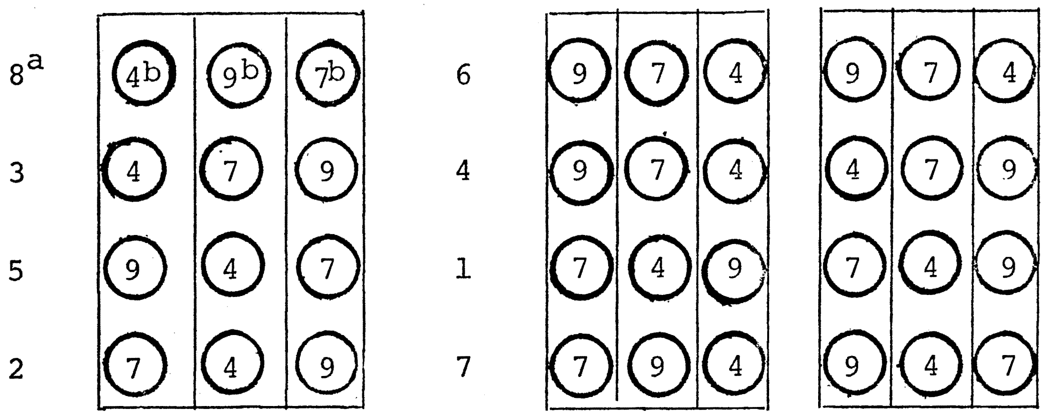
Prior to the arrival of the eight attribute panel members each day, 36 all-purpose muffins were placed in the oven, in three batches. There were 12 muffins with four percent yeast flour, 12 with seven percent yeast flour, and 12 with nine percent yeast flour. The muffins were placed in the three muffin tins in a randomized order by judge and by yeast level (Figure 1). Each judge was assigned a number by alphabetical order. The computer was utilized to achieve each day's randomization for both muffin types. Each judge received three to evaluate. The panel of judges, therefore, required 24 of the 36 muffins. Of the remaining 12 muffins, two four percent, two seven percent, and two nine percent muffins were randomly chosen for Instron measure of tenderness. While the judges were evaluating the all-purpose muffins, the three batches of whole wheat muffins were placed in the three muffin tins in a randomized order by judge and by yeast level. The procedure for both muffin types was identical.

TABLE IV

FORMULA FOR REFERENCE DROP BATTER MUFFINS

Ingredient	Weight (gms)
Flour[a]	
All-Purpose	260
Whole Wheat	230
Sugar	124
Salt	5
Baking Powder	12
Milk	168
Egg	100
Oil	72

[a]Substituted for flour in this experiment were 4, 7, and 9% yeast protein, by weight.



[a]Judge number.

[b]Percentage of yeast substitution.

Figure 1. Example of One-Day Random Placement of Muffins by Judge and Yeast Level

The Instron Universal Testing Instrument Model 1122 was used to measure tenderness. In this measurement, tenderness is measured by the peak force (kg/g) required to shear top and bottom crusts of muffins. Two muffins, randomly chosen, from each baking were reserved for this objective test.

To ensure a qualified taste panel, training and screening processes were conducted. Training of the taste panel was accomplished according to recommendations of Amerine et al. (25), Carlin and Harrison (26), and the American Meat Science Association (27). The panel was first trained to look for set characteristics on which they were to evaluate the muffins. The purpose of the taste panel evaluations was to determine if differences in the selected quality characteristics occurred in the muffins with the different yeast products and levels used. Eight panel members were trained and selected to participate in the evaluations of the muffins.

Data Collection and Analysis

The evaluation instrument used for this research was entitled the "Sensory Evaluation Tool" (Appendix C). The tool is a ranking scale which had been used in food research (6, 28). Ranking scales eliminate errors caused by different scoring levels used by different judges (26). The ranking scale simplifies the work of the judges. Scaling systems are versatile and are easily analyzed by statistical methods. Using this scale, the panel members were asked to rank a series of samples in decreasing or increasing order, based on specific characteristics, such as appearance, mouthfeel, and flavor (6). This scale is especially useful when an entire series of samples are available at the same time for ranking (26). The instructions necessary for this scale were minimal, with a twofold function: to describe the mechanism of the test and to allow freedom in response.

Each characteristic the attribute panel was using for ranking the muffins had been defined on the "Sensory Evaluation of Muffins" sheet (Appendix C). A value of one was assigned to the product closest to the standard, and a three was assigned to the product having the greatest difference. There were four major areas covered on the "Sensory Evaluation Tool": appearance, mouthfeel, flavor, and overall impression. The panel was given the opportunity to comment on the products at the end of each section.

Validity was determined by item selection, description, even or balanced measure of items and presentation. The validity of the instrument had been assured in that it did measure what was being looked for in this research. The characteristics were appropriate for ranking the muffins. The reliability and clarity of the instrument had been evaluated and approved by research faculty within the Food, Nutrition, and Institution Administration Department, as well as by the consulting statistician. The tool has been used by other attribute panels (26), therefore posing no problems of clarity or consistency.

To assure the randomness in presenting samples, the computer was utilized to set up the arrangement of the three muffins on the plate for each panel member. Data were analyzed using the randomized block design. Friedman rank analysis was used to test the difference among treatments (29). The Statistical Analysis System was used to make the calculations (30). A table of differences of ranks of the three treatments was made to test the null hypothesis of no treatment differences among samples. The procedure for making these tests is outlined by T. C. Coburn (31). This method is a multiple comparison of means procedure for using rank totals. The formula (31) for obtaining the least significant difference (LSD) between any two treatment effects is:

$$\text{LSD} = q(.05,\ 3,\ \infty)\left[\frac{n(h)(h+1)}{12}\right]^{1/2}$$

For this study the LSD was:

$$\text{LSD} = 3.314\left[\frac{16(3)(4)}{12}\right]^{1/2}$$

$$= 3.314\sqrt{16}$$

$$= 3.314\ (4)$$

$$= 13.256$$

If there were any differences greater than 13.256, then the effects of the two treatments were significantly different at the five percent level.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter includes the data analysis to indicate if there were differences in appearance, texture, moisture content, flavor, and overall acceptability of muffins made with all-purpose flour or whole wheat flour only, and those incorporating one of three types of single cell protein flours. A trained attribute panel evaluated the sensory properties of the products prepared. The Instron Universal Testing Instrument Model 1122 was used to measure tender ness objectively.

Assessment of Nutritional Quality

The protein content of muffins was hypothesized to be enhanced as yeast flours were added to the formula. As expected, the protein content of the muffins increased as the amount of each particular yeast flour, substituted for a portion of the all-purpose or whole wheat flour, was increased. The protein and amino acid levels for each yeast at each of the three percentages is shown in Table V for the all-purpose flour muffin. Table VI depicts the protein and amino acid data for the muffins made with whole wheat flour.

TABLE V

PROTEIN AND AMINO ACID CONTENT OF ALL-PURPOSE FLOUR MUFFINS[a] (grams/50 gram muffins)[b]

Level of Supplementation	Protein	Tryptophan	Phenylalanine	Leucine	Isoleucine	Lysine	Valine	Methionine	Threonine	Cystine	Tyrosine
Reference - 0%	3.82	.20	1.94	2.91	1.71	1.46	2.22	.77	1.28	.75	1.20
Boost-100											
4%	8.84	.24	1.95	3.20	2.03	1.79	2.45	.82	1.49	.76	1.32
7%	12.55	.28	1.95	3.42	2.04	2.04	2.62	.87	1.66	.77	1.41
9%	15.08	.30	1.96	3.57	2.14	2.20	2.73	.89	1.77	.78	1.47
Torutein-LF											
4%	9.12	.25	2.12	3.21	1.91	1.81	2.48	.82	1.52	.76	1.35
7%	13.15	.28	2.26	3.44	2.07	2.07	2.67	.86	1.70	.78	1.46
9%	15.81	.30	2.35	3.60	2.17	2.24	2.79	.89	1.82	.79	1.54
Toruway-49											
4%	7.54	.24	2.04	3.16	1.88	1.74	2.40	.81	1.47	.76	1.34
7%	10.35	.27	2.10	3.35	2.02	1.94	2.54	.84	1.61	.78	1.44
9%	12.31	.30	2.20	3.47	2.10	2.07	2.63	.86	1.70	.79	1.51

[a]Protein and amino acid content of flour, egg, and milk based on Food and Agriculture Organization values (1970). Yeast flour values based on Amoco Oil Company data.

[b]Recipe makes 12 muffins. Average weight: 50 grams.

TABLE VI

PROTEIN AND AMINO ACID CONTENT OF WHOLE WHEAT MUFFINS[a] (grams/50 gram muffins)[b]

Level of Supplementation	Protein	Tryptophan	Phenylalanine	Leucine	Iso-Leucine	Lysine	Valine	Methionine	Threonine	Cystine	Tyrosine
Reference-0%	3.86	--	2.05	3.18	1.77	1.78	2.48	.84	1.47	.89	1.48
Boost-100											
4%	8.26	.05	2.05	3.42	1.93	2.06	2.67	.89	1.66	.89	1.58
7%	11.59	.08	2.05	3.61	2.05	2.27	2.81	.92	1.79	.90	1.65
9%	13.75	.10	2.05	3.73	2.13	2.41	2.90	.93	1.88	.90	1.70
Torutein-LF											
4%	8.56	.05	2.21	3.43	1.90	2.08	2.69	.89	1.68	.90	1.61
7%	12.09	.09	2.32	3.62	2.07	2.30	2.85	.92	1.83	.90	1.70
9%	14.45	.11	2.40	3.75	2.16	2.44	2.95	.93	1.94	.90	1.76
Toruway-49											
4%	7.16	.04	2.13	3.39	1.92	2.01	2.63	.87	1.63	.90	1.60
7%	9.69	.08	2.19	3.54	2.03	2.18	2.74	.89	1.75	.90	1.68
9%	11.35	.10	2.23	3.64	2.10	2.29	2.81	.90	1.83	.91	1.74

[a]Protein and amino acid content of flour, egg, and milk based on Food and Agriculture Organization values (1970). Yeast flour values based on Amoco Oil Company data.

[b]Recipe makes 12 muffins. Average weight: 50 grams.

Boost-100, when substituted for a portion of the all-purpose flour, was found, at the four percent level, to increase the protein content more than twofold over the reference muffin. When seven percent Boost-100 was used, the protein content tripled. The total protein is quadrupled when nine percent Boost-100 was substituted (Table V). When replacing Boost-100 for whole wheat flour, the results were similar. At the four percent level, the total protein had more than doubled. The level of protein tripled when seven percent Boost-100 was used for replacement, and increased fourfold when nine percent Boost-100 was used (Table VI).

Torutein-LF was also found to be an exceptional source of added protein. According to the typical composition, Torutein-LF has 52 percent protein (Appendix A). The muffin, composed of 96 percent all-purpose flour and four percent Torutein-LF, was found to have had an increase in total protein by greater than two and one-half times over the reference product. When seven percent and nine percent Torutein-LF replaced the all-purpose flour, the protein level more than tripled and quadrupled, respectively. The whole wheat muffin, incorporating Torutein-LF, also resulted in increased protein content. At the four percent level, the protein content of a single 50 gram muffin more than doubled. The protein content tripled at the seven percent level. When nine percent Torutein-LF was substituted for the whole wheat flour, the protein increased over threefold.

The third yeast studied was Toruway-49. The protein content of this yeast is less than that of Boost-100 and Torutein-LF (Appendix A). When Toruway-49 yeast flour was substituted for four percent of the all-purpose flour, the protein level was increased twofold. The replacement of seven percent of the flour resulted in a protein increase of two and one-half times. At the nine percent level, protein content reached more than three times that of the reference muffin. When replacing Toruway-49 for four percent of the whole wheat flour, it was found that the protein level almost doubled. At the seven percent and nine percent levels, the protein more than doubled and tripled, respectively.

In terms of amino acid content, each of the different yeast protein flours was a complete source (Appendix B). The values for the essential amino acids and some non-essential amino acids can be found in Tables V and VI for all-purpose and whole wheat muffins. Looking at leucine, the all-purpose reference muffin contained 2.91 grams. This level was increased with each increase in yeast level. At the nine percent level of Boost-100, Torutein-LF and Toruway-49, the improved levels of leucine were 3.57 grams, 3.60 grams, and 3.47 grams, respectively. The whole wheat reference muffin contained 3.18 grams of leucine. This level showed a marked increase to 3.73 grams, 3.75 grams, and 3.64 grams when Boost-100, Torutein-LF, and Toruway-49, respectively, were substituted for the whole wheat flour at the nine percent level. The content of the amino acid tryptophan was also increased in the muffins as the levels of yeast protein flours were increased. Tryptophan content in the all-purpose reference muffin was 0.20 grams. At the nine percent level of each of the three yeast protein flours, the tryptophan content increased to 0.30 grams. The whole wheat reference muffin contained no tryptophan. All of the yeast flours contained tryptophan. At the nine percent level of Boost-100, Torutein-LF, and Toruway-49, the tryptophan levels of each whole wheat muffin were 0.10 grams, 0.11 grams, and 0.10 grams, respectively.

From the data on Tables V and VI, it can be seen that the nutritional quality of plain muffins can be greatly improved by substituting a yeast protein flour for either all-purpose flour or whole wheat flour.

Assessment of Sensory Quality

The results of the sensory quality evaluation were transposed into tables of differences (Tables VII and VIII). The all-purpose flour muffin containing Boost-100, at all three levels, showed no significant differences ($p<0.05$) for color (appearance), texture (appearance), moisture (mouthfeel), texture (mouthfeel). There was, however, significant differences ($p<0.05$) in the flavor and off-flavor

TABLE VII

RANK TOTAL OF ALL-PURPOSE FLOUR MUFFINS AND BOOST-100, TORUTEIN-LF, AND TORUWAY-49

Variable: Color (Appearance)

Yeast Flour					
Boost-100			9	7	4
			33	34	29
	4[a]	29[b]	4[c]	5	
	7	34	1		
	9	33			
Torutein-LF			9	7	4
			32	29	35
	4	35	3	6	
	7	29	3		
	9	32			
Toruway-49			9	7	4
			37	28	31
	4	31	6	3	
	7	28	9		
	9	37			

Variable: Texture (Appearance)

Yeast Flour					
Boost-100			9	7	4
			36	35	25
	4	25	11	10	
	7	35	1		
	9	36			
Torutein-LF			4	7	4
			33	31	32
	4	32	1	1	
	7	31	2		
	9	33			
Toruway-49			9	7	4
			34	31	31
	4	31	3	0	
	7	31	3		
	9	34			

Variable: Moisture (Mouthfeel)

Yeast Flour					
Boost-100			9	7	4
			34	32	30
	4	30	4	2	
	7	32	2		
	9	34			
Torutein-LF			9	7	4
			34	31	31
	4	31	3	0	
	7	31	3		
	9	34			
Toruway-49			9	7	4
			36	31	29
	4	29	7	2	
	7	31	5		
	9	36			

Variable: Texture (Mouthfeel)

Yeast Flour					
Boost-100			9	7	4
			32	36	28
	4	28	4	8	
	7	36	4		
	9	32			
Torutein-LF			9	7	4
			35	32	29
	4	29	6	3	
	7	32	3		
	9	35			
Toruway-49			9	7	4
			36	29	31
	4	31	5	2	
	7	29	7		
	9	36			

TABLE VII (Continued)

Yeast Flour	Variable														
	Flavor					Off-Flavor					Overall Impression				
Boost-100			9	7	4			9	7	4			9	7	4
			46	27	23			43	28	25			45	28	23
	4	23	23*	4		4	25	18*	3		4	23	22*	5	
	7	27	19*			7	28	15*			7	28	17*		
	9	46				9	43				9	45			
Torutein-LF			9	7	4			9	7	4			9	7	4
			40	28	28			40	28	28			40	30	26
	4	28	12	0		4	28	12	0		4	26	14*	4	
	7	28	12			7	28	12			7	30	10		
	9	40				9	40				9	40			
Toruway-49			9	7	4			9	7	4			9	7	4
			39	32	25			36	33	27			39	29	28
	4	25	14*	7		4	27	9	6		4	28	11	1	
	7	32	7			7	33	3			7	29	10		
	9	39				9	36				9	39			

[a]Denotes the level of yeast substitution.

[b]Rank total for the treatment.

[c]Difference of two totals, i.e., |33-29| = 4.

*Differences denoting a five percent significance.

TABLE VIII

RANK TOTAL OF WHOLE WHEAT FLOUR MUFFINS AND BOOST-100, TORUTEIN-LF, AND TORUWAY-49

Yeast Flour	Variable					
Boost 100	Color (Appearance)			9	7	4
				35	29	32
		4[a]	32[b]	3[c]	3	
		7	29	6		
		9	35			
	Texture (Appearance)			9	7	4
				32	38	26
		4	26	6	12	
		7	38	6		
		9	32			
	Moisture (Mouthfeel)			9	7	4
				25	28	33
		4	33	8	5	
		7	28	3		
		9	25			
	Texture (Mouthfeel)			9	7	4
				39	28	29
		4	29	10	1	
		7	28	11		
		9	39			
Torutein-LF	Color (Appearance)			9	7	4
				40	30	26
		4	26	14*	4	
		7	30	10		
		9	40			
	Texture (Appearance)			9	7	4
				39	30	27
		4	27	12	3	
		7	30	9		
		9	39			
	Moisture (Mouthfeel)			9	7	4
				36	25	35
		4	35	1	10	
		7	25	11		
		9	36			
	Texture (Mouthfeel)			9	7	4
				38	35	23
		4	23	15*	12	
		7	35	3		
		9	38			
Toruway-49	Color (Appearance)			9	7	4
				35	33	28
		4	28	7	5	
		7	33	2		
		9	35			
	Texture (Appearance)			9	7	4
				42	31	23
		4	23	19*	8	
		7	31	11		
		9	42			
	Moisture (Mouthfeel)			9	7	4
				33	34	29
		4	29	4	5	
		7	34	1		
		9	33			
	Texture (Mouthfeel)			9	7	4
				26	33	37
		4	37	11	4	
		7	33	7		
		9	26			

TABLE VIII (Continued)

Yeast Flour	Variable														
	Flavor					Off-Flavor					Overall Impression				
Boost-100			9	7	4			9	7	4			9	7	4
			38	34	24			36	34	26			36	34	27
	4	24	14*	10		4	26	10	8		4	27	9	7	
	7	34	4			7	34	2			7	34	2		
	9	38				9	36				9	36			
Torutein-LF			9	7	4			9	9	9			9	7	4
			36	33	27			37	33	28			39	33	24
	4	27	9	6		4	28	9	5		4	24	15*	9	
	7	33	3			7	33	4			7	33	6		
	9	36				9	37				9	39			
Toruway-49			9	7	4			9	7	4			9	7	4
			34	29	33			36	29	31			38	27	38
	4	33	1	4		4	31	5	2		4	31	7	4	
	7	29	5			7	29	7			7	27	11		
	9	34				9	36				9	38			

[a]Denotes the level of yeast substitution.
[b]Rank total for the treatment.
[c]Difference of two totals, i.e., $|35-32| = 3$.
*Differences denoting a five percent significance.

(Table VII). Panelists could detect a flavor difference between the four percent and nine percent muffins, as well as between the seven percent and nine percent muffins. No flavor difference could be detected between the four and seven percent levels. Similar results were obtained when analyzing the off-flavor data. There was a significant difference ($p<0.05$) between the four percent and nine percent level muffins and the seven percent and nine percent level muffins. Again, no detection of difference between four and seven percent level was discerned. When looking at the overall impression of the muffins made with all-purpose flour and Boost-100, it could be seen that the four percent and nine percent levels and the seven percent and nine percent levels did show some significant differences ($p<0.05$). Boost-100 could be substituted up to the seven percent level in an all-purpose muffin without significantly affecting the overall impression of the muffin (Table VII). When Boost-100 was substituted for whole wheat flour, no significant differences ($p<0.05$) were found in regard to color (appearance), texture (appearance), moisture (mouthfeel), texture (mouthfeel), or off-flavor at any level. There was a significant difference ($p<0.05$) detected, however, in flavor between the four percent and nine percent levels. The results concerning the overall impression revealed no significance ($p<0.05$) for any level. Boost-100 could be substituted for up to nine percent of the whole wheat flour without significantly ($p<0.05$) affecting the overall impression of the muffin (Table VIII).

The second yeast studied was Torutein-LF. The all-purpose flour muffin containing Torutein-LF at all three levels showed no significant differences ($p<0.05$) in color (appearance), texture (appearance), moisture (mouthfeel), texture (mouthfeel), flavor or off-flavor. The overall impression of the Torutein-LF muffin did, however, show a significant difference ($p<0.05$); panelists could detect a difference between the four percent and nine percent levels. They could not detect any significant differences ($p<0.05$) between the four percent and seven percent level, or the seven percent and nine percent level. Torutein-LF could be substituted for all-purpose flour to at least the seven percent level without significantly ($p<0.05$) affecting the overall impression of the muffin (Table VII). When substituting Torutein-LF for whole wheat flour, it was found that texture (appearance), moisture (mouthfeel), flavor and off-flavor revealed no significant differences ($p<0.05$). The color (appearance) variable did show a significant difference ($p<0.05$) between the four percent and nine percent levels only. A significant difference ($p<0.05$) for texture (mouthfeel) was seen between the four and seven percent levels. When looking at the overall impression of these muffins, a significant difference ($p<0.05$) was detected between the four and nine percent level muffins.

In the whole wheat flour muffins containing Torutein-LF, up to at least seven percent of the yeast can be substituted without significantly ($p<0.05$) affecting the overall impression of the muffin (Table VIII).

The third yeast studied was Toruway-49. The all-purpose flour muffin containing Toruway-49 at all three levels, revealed no significant differences ($p<0.05$) in color (appearance), texture (appearance), moisture (mouthfeel), texture (mouthfeel), or off-flavor. Significant difference ($p<0.05$) was found in regard to flavor between the four percent and nine percent level muffins. The overall impression of these muffins showed no significant differences ($p<0.05$) at any level (Table VII). The use of Toruway-49 with whole wheat flour had similar results. Color (appearance), moisture (mouthfeel), texture (mouthfeel), flavor and off-flavor revealed no significant differences ($p<0.05$) at any levels. A significant difference ($p<0.05$) between the four and nine percent levels was found in relation to texture (appearance). The overall impression of this muffin was favorable. No significant differences ($p<0.05$) were detected. Toruway-49 could be substituted in either an all-purpose or whole wheat flour muffin up to at least the nine percent level without significantly ($p<0.05$) affecting the overall impression of the muffins (Tables VII and VIII).

Assessment of Texture by Objective Evaluation

Texture characteristics of muffins, by shear force (kg/g) evaluation, are shown in Figures 2, 3, and 4. These figures, averages for two top and bottom crusts, were averaged separately for each yeast level. The shear force (kg/g) for muffins made with Boost-100 indicated that those incorporating the highest percentage of yeast flour were also the most tender (Figure 2). All-purpose and whole wheat muffins incorporating nine percent Torutein-LF were also shown to be the most tender by shear force (kg/g) (Figure 3). In the whole wheat muffin, the tenderness increased as the amount of Torutein-LF in the muffin increased. The all-purpose muffin incorporating nine percent Toruway-49 did prove to be the most tender (Figure 4). All-purpose and whole wheat muffins made with Toruway-49 were the most tender when nine percent yeast flour was incorporated.

There seemed to be a pattern indicating that the more yeast flours were substituted for either the all-purpose or whole wheat flours, the more tender the muffin. The four percent and seven percent substitution level results were similar, while at the nine percent level of substitution, the muffins were more tender, indicating a significant difference ($p<0.05$).

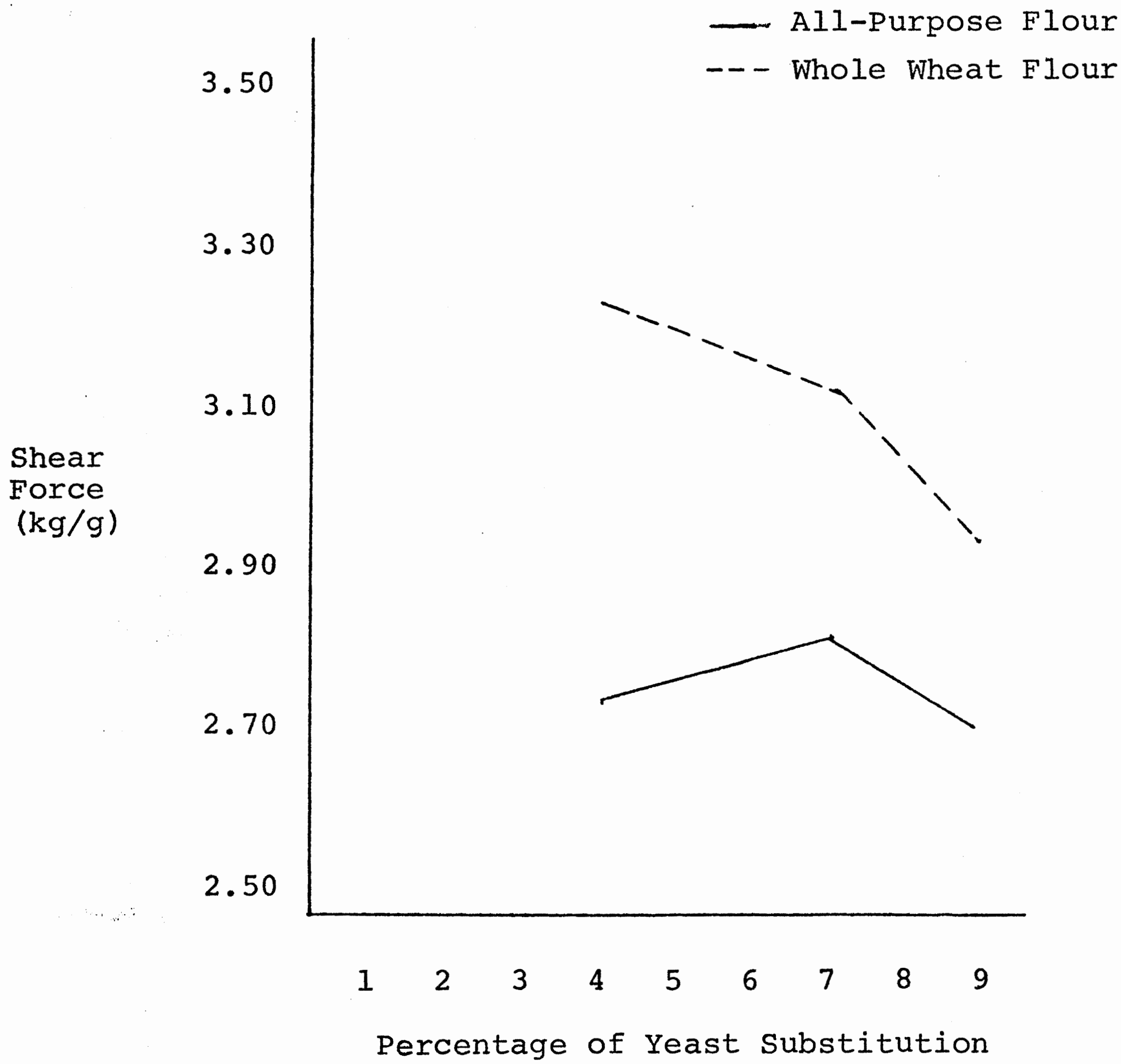


Figure 2. Tenderness by Shear Force (kg/g) in Muffins with Boost-100

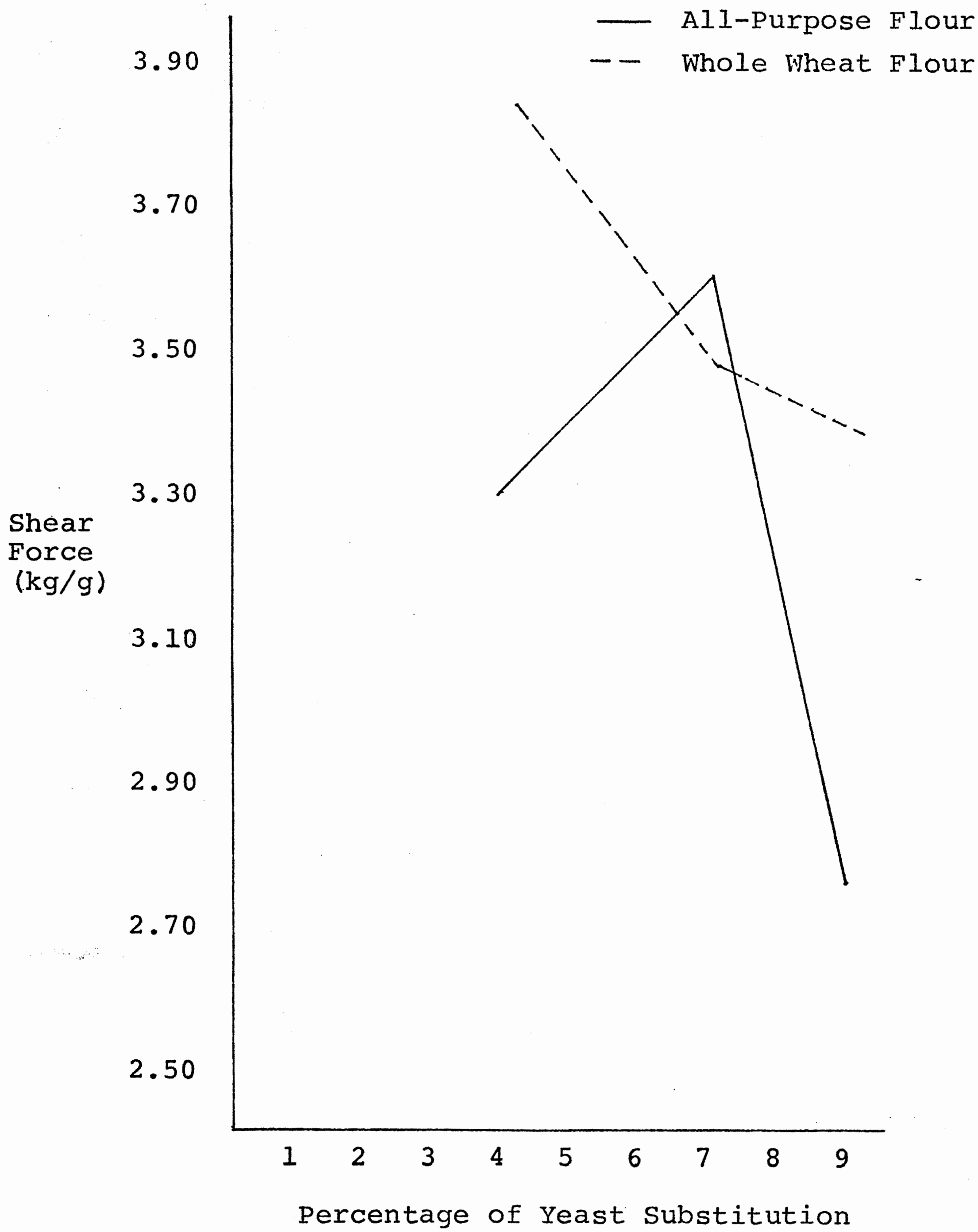


Figure 3. Tenderness by Shear Force (kg/g) in Muffins with Torutein-LF

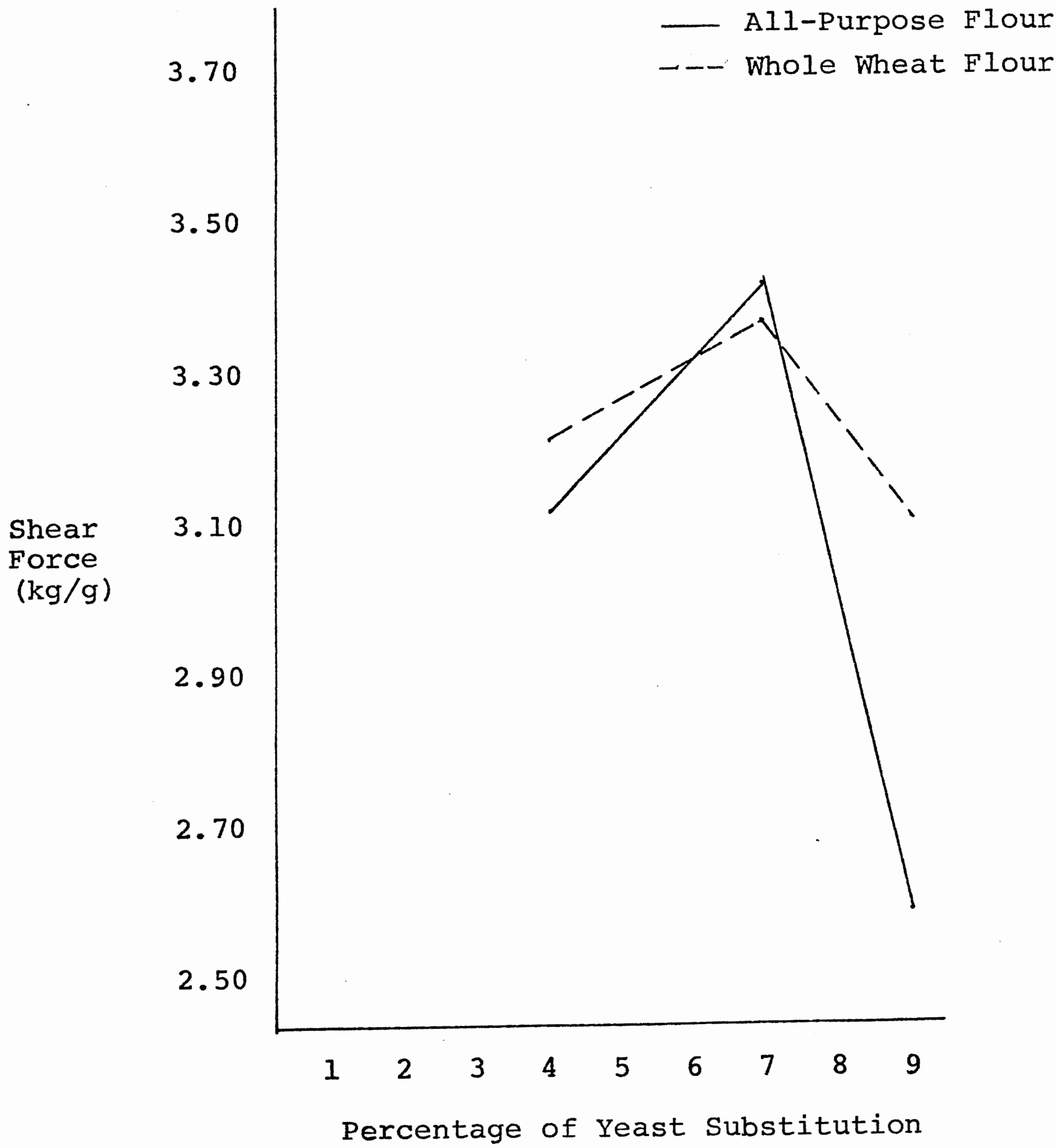


Figure 4. Tenderness by Shear Force (kg/g) in Muffins with Toruway-49

A composite of all the variables was analyzed using the analyses of variance (23) to determine which variables had significant effects on the tenderness by shear force (kg/g) on the muffins. Results indicated that the flour type significantly ($p<0.05$) affected the tenderness of the muffins incorporating the three types of yeast flours (Table IX). Muffins made with whole wheat flour at all three levels incorporating three different yeasts were less tender than muffins made with all-purpose flour (Figures 2, 3, and 4). The type of yeast also significantly affected ($p<0.05$) the tenderness of the top and bottom crusts of the muffins (Table IX). Figures 5, 6, and 7 indicated the differences detected by crusts, top and bottom. Yeast level was found to also significantly ($p<0.05$) affect the crusts (Table IX).

TABLE IX

ANALYSIS OF VARIANCE FOR TENDERNESS BY SHEAR FORCE (kg/g)

Source of Variation for Treatment/Source of Variation for Error	df's	Mean Squares	F Value	Observed Significance Level
Yeast Type/Replication (YT/R)	2/3[a]	2.45/5.54[b]	0.44	0.68
Yeast Level/Error B[1] (YL/B)	2/15	1.81/0.54	3.37	0.06
Flour Type/B (FT/B)	1/15	3.14/0.54	5.94	0.03
(YL*FT)/B	2/15	0.45/0.54	0.84	0.55
(YT*YL)/B	4/15	0.22/0.54	0.41	0.80
(YT*FT)/B	2/15	0.14/0.54	0.26	0.78
(YT*YL*FT)/B	4/15	0.20/0.54	0.37	0.83
Location (Top and Bottom) by Error C[2] (L/C)	1/18	0.75/0.01	52.50	<0.01
(YT*L)/C	2/18	0.06/0.01	3.91	0.04
(YL*L)/C	2/18	0.01/0.01	0.38	0.70
(YT*YL*L)/C	4/18	0.01/0.01	0.44	0.78
(L*FT)/C	1/18	0.00/0.01	0.06	0.81
(YT*L*FT)/C	2/18	0.04/0.01	3.01	0.07

TABLE IX (Continued)

Source of Variation for Treatment/Source of Variation for Error	df's	Mean Squares	F Value	Observed Significance Level
(YL*L*FT)/C	2/18	0.01/0.01	0.95	0.59
(YT*YL*L*FT)/C	4/18	0.01/0.01	1.01	0.43

[a]Numerator df is for the source of variation for treatment; denominator df is for the source of variation for error.

[b]Numerator mean square is for the source of variation for treatment; denominator mean square is for the source of variation for error.

[1](Replication by Yeast Level by Yeast Type) + (Replication by Flour Type by Yeast Type) + (Replication by Yeast Level by Flour Type by Yeast Type).

[2]Replication by Location within (Yeast Type by Yeast Level by Yeast Flour).

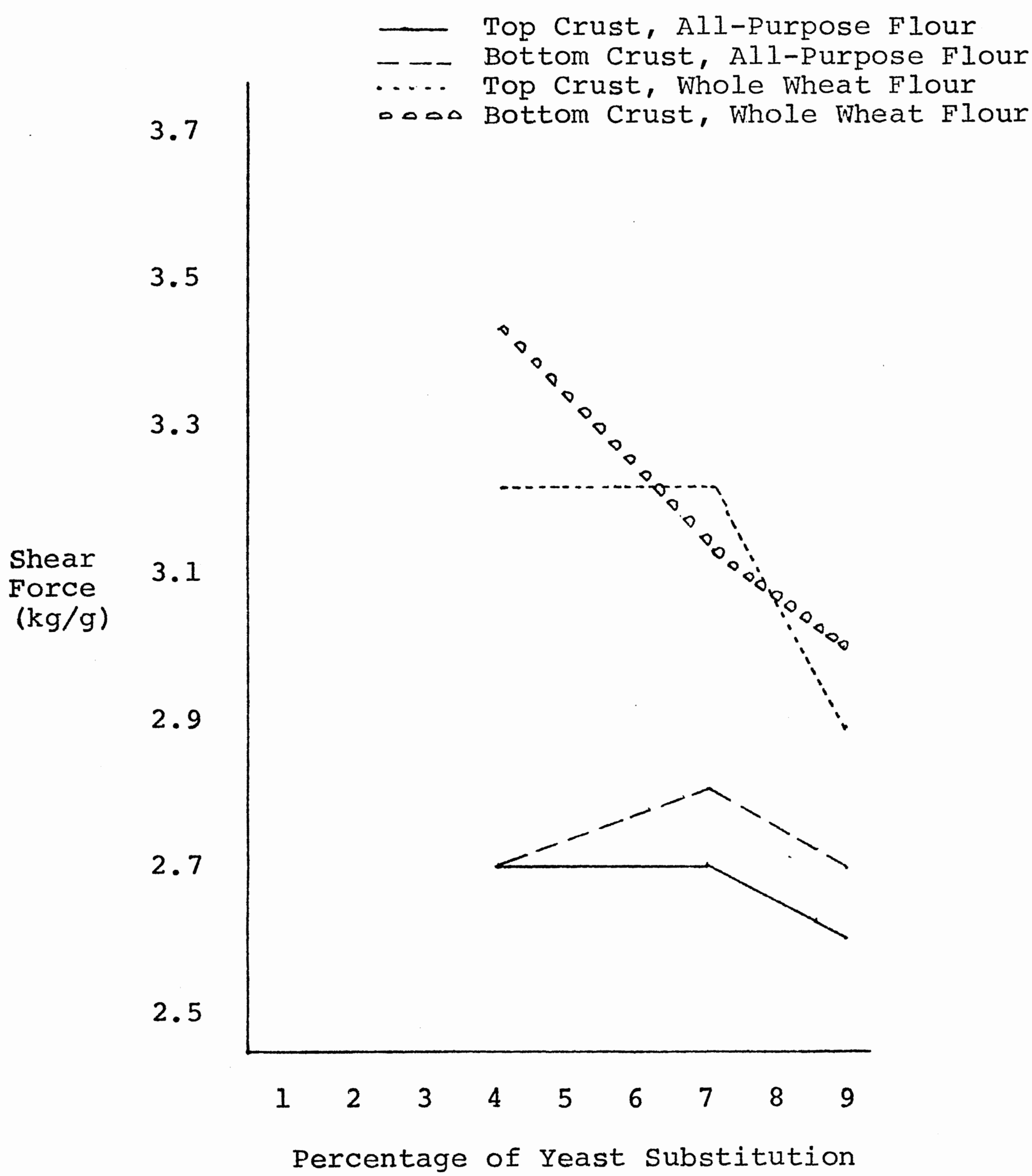


Figure 5. Tenderness by Shear Force (kg/g) for Top and Bottom Crusts in Muffins with Boost-100

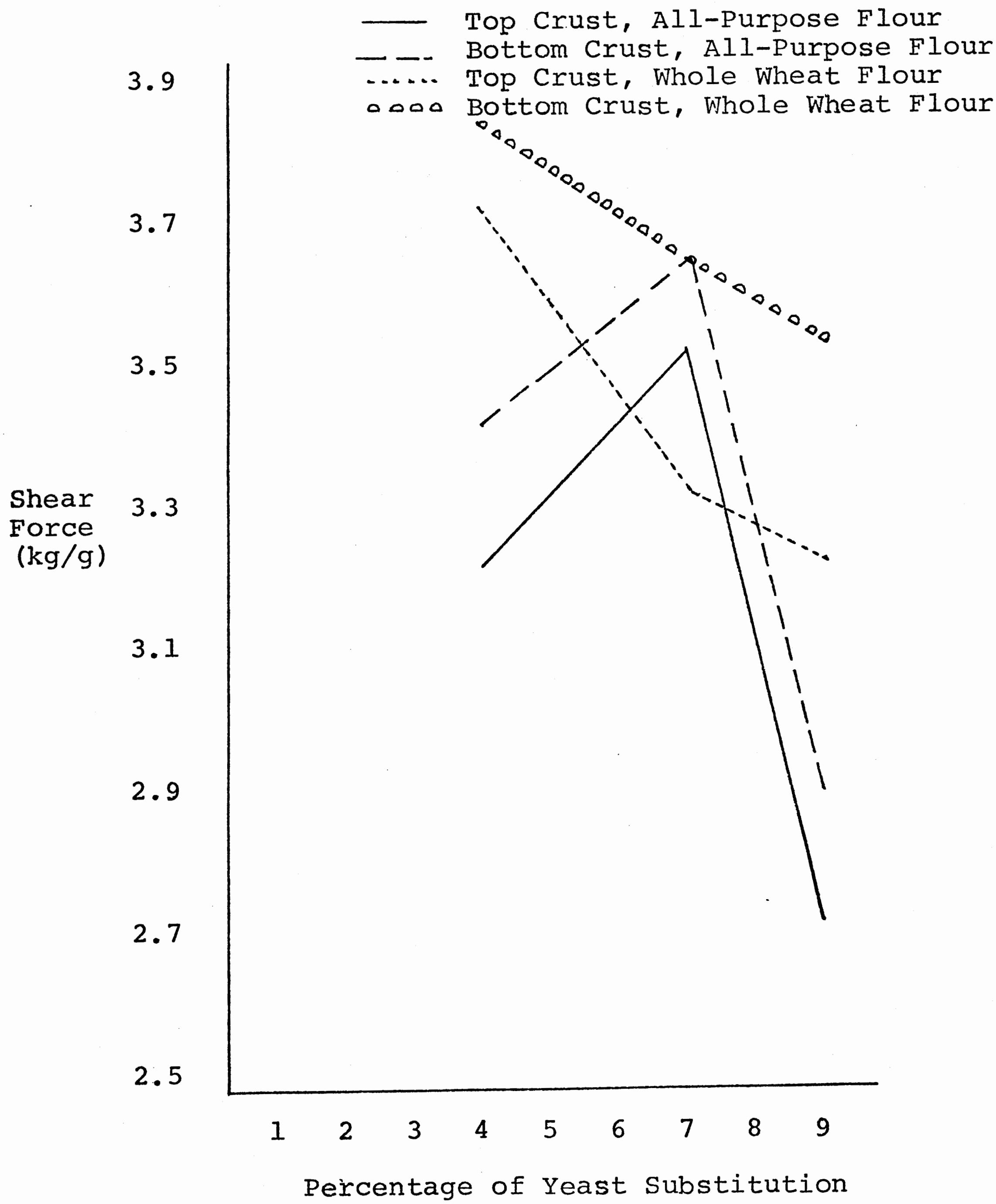


Figure 6. Tenderness by Shear Force (kg/g) for Top and Bottom Crusts in Muffins with Torutein-LF

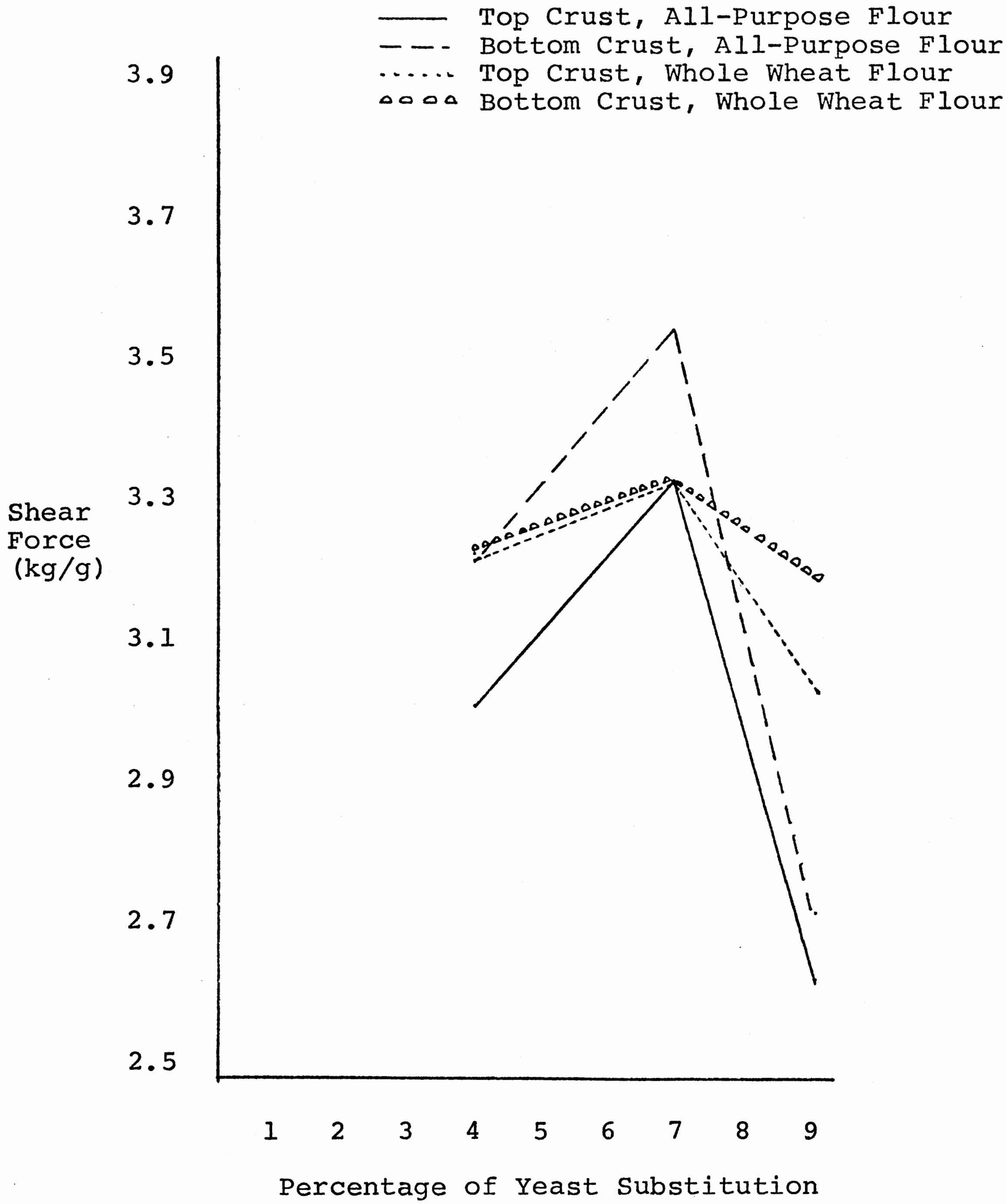


Figure 7. Tenderness by Shear Force (kg/g) for Top and Bottom Crusts in Muffins with Toruway-49

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this research was to discern the effects of yeast single cell protein flours on appearance, texture, moisture content, flavor, and overall acceptance of muffins. A reference muffin's protein and amino acid content was compared to those incorporating yeast protein flours. Three different yeast single cell protein flours were used: Boost-100, Toruway-49, and Torutein-LF. Each of the yeast flours was incorporated into both an all-purpose flour and whole wheat flour muffins at three different percentage levels: four percent, seven percent, and nine percent.

A review of the literature revealed the need for an expanded effort devoted to the production and utilization of unconventional protein sources. The incorporation of soy and other unconventional proteins will be in great use in the future in food systems such as processed meats, breads, and dairy products (12). The use of single cell proteins in baked products has been tested and analyzed. Findings from other studies indicated that single cell protein flours increased the protein and amino acid contents of baked products. The economic aspects of single cell protein production are higher for isolates, concentrates, and textures or functional products. The costs will vary with source and availability, depending on geographic area.

The research was conducted under experimental procedures. The criteria related to product and laboratory conditions were controlled to ensure uniform environmental conditions. An eight member attribute panel was used to evaluate the muffins. The subjective characteristics used for ranking were appearance, mouthfeel, flavor, and overall impression. Panelists used the "Sensory Evaluation Tool." The Instron Universal Testing Instrument Model 1122 was used to measure tenderness objectively. The research activities involving a taste panel were conducted in six days, with each of the yeasts being evaluated twice. Data were analyzed using the randomized block design, rank analyses, and analysis of variance, using the Statistical Analysis System (29).

Protein and amino acid analyses were determined through the use of data from the Food and Agriculture Organization and from literature provided by Amoco Oil Company. The reference muffin mean values were compared with values for each muffin which incorporated the single cell protein flours. Amino acid values were determined for leucine, lysine, methionine, cystine, phenylalanine, tyrosine, threonine, and valine.

Conclusions

Results indicated that the protein and amino acid content of the reference muffin was improved at all levels, four, seven, and nine percent, when one of three different types of yeast single cell flours, obtained from Amoco Oil Company, was incorporated.

Boost-100 yeast single cell protein flour was found to increase the protein content of the reference muffin, when substituted for nine percent of the all-purpose flour, or whole wheat flour, by four times. When Torutein-LF is substituted for nine percent of the all-purpose flour, the protein content was again quadrupled. When nine percent Torutein-LF was substituted for whole wheat flour, the protein content was increased threefold. Toruway-49 increased the protein content more than three times in all-purpose and whole wheat muffins at the nine percent substitution level. Based on these results, hypothesis one (H_1) was accepted. There was a difference in nutritional quality between the reference muffins and muffins with Boost-100, Torutein-LF, or Toruway-49, based on amino acid tables (Tables V and VI).

Sensory assessment revealed that Boost-100 could be substituted for up to the seven percent level in all-purpose muffins, and up to the nine percent level in whole wheat muffins without significantly ($p<0.05$) affecting the overall impression of the muffins. Torutein-LF was found to be acceptable up to the seven percent substitution level in all-purpose and whole wheat muffins without significantly ($p<0.05$) affecting the overall impression of the muffins. In both all-purpose and whole wheat muffins, Toruway-49 was found to be acceptable up to at least the nine percent level without significantly ($p<0.05$) affecting the overall impression of the muffins. Hypothesis two (H_2) stated that there would be no difference in appearance, texture, moisture content, flavor, and overall acceptability in the reference muffins and those incorporating one of the three types of single cell protein flours. This hypothesis was accepted when each of the three yeasts was substituted for up to seven percent of the all-purpose or whole wheat flour. The acceptance of this hypothesis was based solely on overall impression evaluation. When individual characteristics, at all levels, in each of the flours, was evaluated, results indicated that the hypothesis be rejected (Tables VII and VIII).

The objective evaluation of tenderness by shear force (kg/g) revealed the most tender muffin was that which incorporated nine percent of any of the three yeast flours in either all-purpose flour or whole wheat flour. Flour type also showed a significant ($p<0.05$) affect on the tenderness of muffins incorporating yeast flours. Whole wheat muffins were less tender than all-purpose muffins.

Recommendations

The incorporation of single cell proteins into bread products is a relatively new process. There is still much to be learned in regard to the practical use of yeast single cell protein flours. It is recommended that they be used to supplement other food systems besides muffins. Single cell protein flours have many possible uses. Food systems that should be studied include processed breads, cakes, pasta products, cookies, chips, and other snack foods.

Other objective tests could also be used, such as volume index, sheer press, objective measurement of moisture and color, spectrophotometric analysis, viscosity, elasticity, and adhesion. In accomplishing these tests, it would be possible to determine more completely and objectively the full effects of a yeast single cell protein flour on a baked product.

There are many sources of unconventional protein available today. Yeast flour is effective in raising the protein and amino acid content in both all-purpose and whole wheat muffins. The elevation of both the protein and amino acids will be beneficial to many, as the world protein deficit demands unconventional sources. When utilizing these new protein sources, one should consider nutritional quality, toxicological factors, organoleptic properties, and consumer acceptance.

To promote consumer acceptance of nonconventional protein sources as a nutritive enhancer for baked products, there needs to be reliable and convincing literature verifying the saftey, nutritional significance, and sensory acceptance of these products. The use of various media techniques, to create a positive appeal, must be used as a motivating factor before any consumer will utilize these forms of nonconventional proteins.

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APPENDIXES

APPENDIX A

TYPICAL COMPOSITION OF YEAST SINGLE CELL PROTEIN FLOURS

Typical Composition of Boost-100

Protein (N x 6.25)	49%
Fat	5%
Crude Fiber	4%
Carbohydrates (by difference)	26%
Moisture	6%
Minerals	10%
Sulfite, Total	None detected

Typical Composition of Torutein-LF

Protein (N x 6.25)	52%
Fat* (add hydrolysis)	7%
Crude fiber	5%
Carbohydrates (by difference)	22%
Moisture	6%
Minerals	8%
pH	6
Sulfite, total	< 10 ppm**

*Ether-extractable fat is about 0.2%.

**Limit of detection by method used.

Typical Composition of Toruway-49

Protein (N x 6.25)	37%
Fat* (acid hydrolysis)	5.5%
Crude fiber	5%
Carbohydrates (by difference)	39%

Moisture		6%
Minerals		7.5%
Phosphorus	1.2%	
Potassium	2.1%	
Magnesium	0.2%	
Calcium	0.27%	
Sodium	0.3%	
Iron	55 ppm	
Zinc	50 ppm	
pH		6
Sulfite, total**		< 10 ppm

*Ether-extractable fat is about 0.2%.

**Limit of detection by method used.

(Source: Amoco Oil Company.)

APPENDIX B

TYPICAL AMINO ACID ANALYSES (g/16gn) IN BOOST-100, TORUTEIN-LF, AND TORUWAY-49

TABLE X

TYPICAL AMINO ACID ANALYSIS (g/16g)
IN BOOST-100, TORUTEIN-LF, AND
TORUWAY-49

Amino Acid	Boost-100	Torutein-LF	Toruway-49
Lysine	6.8	6.7	7.5
Hestidine	1.8	2.1	2.0
Arginine	5.7	5.5	5.5
Aspartic Acid	8.3	8.5	8.7
Threonine	4.7	4.9	5.5
Serine	4.2	4.4	4.7
Glutamic Acid	16.0	16.3	17.9
Proline	3.3	2.9	3.7
Glycine	4.3	4.3	4.0
Alanine	5.1	5.2	5.3
Cystine	0.7	0.7	1.0
Valine	5.1	5.3	5.6
Methionine	1.3	1.2	1.3
Isoleucine	4.3	4.3	5.3
Leucine	6.9	6.7	8.0
Tyrosine	2.8	3.2	4.2
Phenylalanine	3.8	4.1	3.6
Tryptophan	1.0	1.0	1.3

APPENDIX C

SENSORY EVALUATION OF MUFFINS

Instructions to Panel Members

You are being asked to sample and evaluate three formulations of muffins. After tasting each product, rank them against each other on the scales indicated. There can be no ties. You will be looking at the appearance, mouthfeel, flavor, and overall impressions of each. Filtered water is provided for rinsing purposes between samples. Please use it to rid the flavor of one product before scoring the next.

1. Appearance

Please look at the surface of the products. Judge and rank them looking at the color, using a very light to very dark scale. The lightest color product will receive a one (1) score and the darkest a three (3) score.

Now look at the inner texture. Judge and rank its appearance on a very fine to a very coarse scel. The finer texture will receive a score of 1 while the coarsest muffin will receive a 3.

2. Mouthfeel

Taste each sample and determine the moisture content of each using a scale of very moist as a 1 and very dry as a 3.

Then, retaste each and rank them considering the texture. The most tender product will receive a score of 1 while the less tender product will receive a score of 3.

3. Flavor

Next, you are asked to sample and rank the flavor of each product. The scale for ranking is a 1 for the most pleasing taste and a 3 for the most disagreeable.

Now, retaste each product and evaluate for an off-flavor. The product with the faintest off-flavor will receive a score of 1, and the product with the strongest will receive a 3.

4. Overall Impression

Finally, indicate your overall impressions of each product by ranking them on a scale of 1 to 3, one being the product you find most favorable and four the product you find least favorable. Should you find further differences between samples, please indicate those on the line for comments.

Sensory Evaluation of Muffins

Please rank order the products. Remember there can be no ties.

Sample Code ________ ________ ________

1. Appearance
   a) Color ________ ________ ________
   b) Texture ________ ________ ________
   c) Comments ________________________________

2. Mouthfeel
   a) Moisture ________ ________ ________
   b) Texture ________ ________ ________
   c) Comments ________________________________

3. Flavor
   a) Flavor ________ ________ ________
   b) Off-flavor ________ ________ ________
   c) Comments ________________________________

4. Overall Impression ________ ________ ________

   Comments ________________________________

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