THE UTILIZATION AND PERFORMANCE OF
CARBOHYDRATE-BASED FAT REPLACERS IN SOUTHERN-
STYLE BAKING POWDER BISCUITS

By

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(ABSTRACT)

Performance of three carbohydrate-based fat replacers (pectin, gum, and oat fiber) in a Southern-style baking powder biscuit was evaluated at substituted levels of 33%, 66%, and 100%. Objectives and sensory tests were conducted on all samples. Results were compared to the control for the determination of significant differences at (p<0.05).

Overall objective test results suggested that there was an increase in the degree of expansion as the level of fat replacement increased. Significantly (p<0.05) softer crusts and crumbs were observed with the fat replaced variations. All fat-substituted biscuits had significantly (p<0.05) higher moisture contents. Upon 24 and 48 hours of storage, staling was observed in all variations with the 100% variations having the most staling. There was a significant (p<0.05) caloric reduction as the level of fat replacement increased. However, this was an over-estimation of the calories provided upon human utilization. Also, the L and b values of the crust color significantly (p<0.05) decreased with fat substitution.

The QDA results indicated that the panelists observed the
degree of browning, cell size, dryness, and tenderness significantly (p<0.05) decreased whereas, perceived cohesiveness significantly (p<0.05) increased as the level of fat replacement increased. Bitterness also increased as the fat replacement level increased.

The general population with an Appalachian influence "moderately liked" the control and oat-based 33% and 66% variations which were selected on the basis of the QDA results.

Overall, the fat substituted variations with the most desirable characteristics were the pectin and oat-based 33% biscuits. The 100% variations would be the most beneficial in caloric reduction, however their attributes would not be representative of an "ideal" Southern-style baking powder biscuit.
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TABLE OF CONTENTS

ABSTRACT ii

ACKNOWLEDGEMENTS iv

TABLE OF CONTENTS v

LIST OF TABLES viii

LIST OF FIGURES ix

I. INTRODUCTION 1

II. REVIEW OF LITERATURE 7

2.1 Historical Review of Biscuits in the Southern Diet 7

2.2 Biscuit Formulation: Ingredient Functionality & Manipulation 8

2.2.1 Flour 9

2.2.2 Salt 9

2.2.3 Leavening Agent 10

2.2.4 Milk 10

2.2.5 Fat 11

2.2.5.1 Nutritional Aspects of Fat 12

2.2.5.2 Characteristics of Fat 13

2.2.5.3 Functions of Fat 14

2.2.5.4 Fat Usage in Biscuits: Selection and Usage 15

2.2.6 Manipulation of the Biscuit Dough 17

2.3 Fat Reduction in Food: The Emergence of Fat Replacers 19

2.3.1 Early Studies on the Fat Reduction in Biscuits 19

2.3.2 Fat Replacers 21

2.3.2.1 Lipid-based Fat Replacers 22

2.3.2.1.1 Emulsifiers 22

2.3.2.1.2 Synthetic Fats 23

2.3.2.2 Carbohydrate-based Fat Replacers 24

2.3.2.2.1 Gums 24

2.3.2.2.2 Hemicellulose 29

2.3.2.2.3 Maltodextrins 32

2.3.2.2.4 Soluble Bulking Agents 32

2.3.2.2.5 Pectins 33

2.3.2.3 Microparticulate Fat Replacers 35

2.3.2.4 Composite Materials 35

2.3.2.4.1 Composite Blends 35

2.3.2.4.2 Functional Blends 36
2.3.2.5 Uses of Fat Replacers 36
2.3.2.6 Nutritional Aspects of Fat Replacers 37
2.3.2.6.1 Lipid-based Replacers 37
2.3.2.6.2 Carbohydrate-based Replacers 37
2.4 Physical Measurements of Food Properties 41
2.5 Sensory Evaluation 41
2.5.1 Quantitative Descriptive Analysis (QDA) 43
2.5.1.1 Panelist Training 43
2.5.2 Central Location Testing 45
2.5.2.1 Panelists 45
2.5.2.2 Rating Scale 46
2.5.2.3 Testing Procedures 47
2.5.3 Sources of Error in Sensory Evaluation 47

III. MATERIALS AND METHODOLOGY 48
3.1 Experimental Design 48
3.2 Ingredients for Biscuit Formulation 48
3.3 Manipulation of Biscuit Dough 49
3.4 Physical Properties 50
3.4.1 Degree of Expansion 51
3.4.2 Texture 51
3.4.3 Moisture 52
3.4.4 Degree of Staling 52
3.4.5 Color 53
3.4.6 Total Caloric Value 53
3.5 Sensory Evaluation 54
3.5.1 Modified Quantitative Descriptive Analysis (QDA) 54
3.5.1.1 Training 54
3.5.2.2 Testing Procedures 55
3.5.2 Consumer Acceptance 55
3.5.2.1 Testing Procedures 56
3.6 Statistical Analysis 57

IV. RESULTS AND DISCUSSION 59
4.1 Degree of Expansion 59
4.1.1 Change in Volume Upon Baking 59
4.2 Biscuit Crust and Crumb Tenderness 62
4.3 Percentage Moisture Content 66
4.4 Differential Scanning Calorimetry 69
4.5 Biscuit Crust Color 75
4.6 Bomb Calorimetry 77
4.7 Perceived Degree of Browning 80
4.8 Perceived Cell Size 82
4.9 Perceived Cohesiveness, Dryness, and Tenderness 84
4.10 Perceived Bitterness
4.11 The Determination of the Consumer Acceptance of the Baking Powder Biscuit Formulations
4.12 Central Location Test
4.12.1 The Acceptance Levels of Local Consumers
4.12.2 The Effect of Demographical Information on Hedonic Ratings
4.12.3 General Knowledge About Biscuits and Nutrition
4.12.4 Frequency of Consumption of Lard-Produced Baking Powder Biscuits
4.12.5 Desire to Choose a Similar Low-Fat Biscuit
4.12.6 Sources of Error

V. SUMMARY, CONCLUSIONS, AND FUTURE RESEARCH RECOMMENDATIONS

REFERENCES

APPENDIX A: BISCUIT FORMULATIONS
APPENDIX B: EXPERIMENTAL DESIGN
APPENDIX C: INGREDIENTS
APPENDIX D: DEGREE OF EXPANSION
APPENDIX E: TEXTURE ANALYSIS
APPENDIX F: MOISTURE CONTENT
APPENDIX G: DIFFERENTIAL SCANNING CALORIMETER
APPENDIX H: COLORIMETER
APPENDIX I: BOMB CALORIMETRY
APPENDIX J: MODIFIED QUANTITATIVE DESCRIPTIVE ANALYSIS TRAINING
APPENDIX K: MODIFIED QUANTITATIVE DESCRIPTIVE ANALYSIS SCORECARD
APPENDIX L: MODIFIED QUANTITATIVE DESCRIPTIVE ANALYSIS TESTING PROCEDURES
APPENDIX M: CENTRAL LOCATION TESTING
APPENDIX N: CENTRAL LOCATION TESTING SCORECARD
APPENDIX O: SAS PROGRAM

VITA
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:</td>
<td>Volume Changes in Fat Substituted Baking Powder Biscuits Before and After Baking</td>
<td>60</td>
</tr>
<tr>
<td>2:</td>
<td>The Effect of Fat Substitutes on Crust and Crumb Tenderness in Baking Powder Biscuits</td>
<td>64</td>
</tr>
<tr>
<td>3:</td>
<td>The Effect of Fat Substitutes on the Percent Moisture Content in Baking Powder Biscuits</td>
<td>68</td>
</tr>
<tr>
<td>4:</td>
<td>The Effect of Fat Substitutes on the Staling Rates (24-48 hours) of Baking Powder Biscuits</td>
<td>73</td>
</tr>
<tr>
<td>5:</td>
<td>The Effect of Fat Substitutes on the Crust Color of Baking Powder Biscuits</td>
<td>76</td>
</tr>
<tr>
<td>6:</td>
<td>The Effect of Fat Substitutes on the Caloric Content of Baking Powder Biscuits</td>
<td>79</td>
</tr>
<tr>
<td>7:</td>
<td>The Effect of Fat Substitutes on the Perceived Degree of Browning of Baking Powder Biscuits</td>
<td>81</td>
</tr>
<tr>
<td>8:</td>
<td>The Effect of Fat Substitutes on the Perceived Cell Size of Baking Powder Biscuits</td>
<td>83</td>
</tr>
<tr>
<td>9:</td>
<td>The Effect of Fat Substitutes on the Perceived Cohesiveness, Dryness, and Tenderness of Baking Powder Biscuits</td>
<td>86</td>
</tr>
<tr>
<td>10:</td>
<td>The Effect of Fat Substitutes on the Perceived Bitterness of Baking Powder Biscuits</td>
<td>89</td>
</tr>
<tr>
<td>11:</td>
<td>The Effect of Fat Substitutes on the Acceptance of Baking Powder Biscuits by Appalachian Consumers</td>
<td>92</td>
</tr>
</tbody>
</table>
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:</td>
<td>Amylopectin peak areas derived from the effect of fat substitutes at a 33% level on the staling rate (24-48 hours) in baking powder biscuits.</td>
<td>70</td>
</tr>
<tr>
<td>2:</td>
<td>Amylopectin peak areas derived from the effect of fat substitutes at a 66% level on the staling rate (24-48 hours) in baking powder biscuits.</td>
<td>71</td>
</tr>
<tr>
<td>3:</td>
<td>Amylopectin peak areas derived from the effect of fat substitutes at a 100% level on the staling rate (24-48 hours) in baking powder biscuits.</td>
<td>72</td>
</tr>
</tbody>
</table>
Chapter 1
Introduction

Fat consumption in the American diet, particularly that of saturated and hydrogenated fats is becoming more of a concern with the increasing prevalence of obesity, coronary heart disease, atherosclerosis, gallbladder disease, hypertension, and cancer. According to the U.S. Senate’s Report of the Select Committee on Nutrition and Human Needs (1977), the American diet consists of 40% total dietary fat. It is particularly rich in saturated fats and cholesterol. The American population consumes more than 500 billion calories of food a day with an average daily fat intake of six tablespoons of fat, approximately 700 calories (Baird, 1990). The Committee suggests that, in correlation with the U.S. Dietary Goals, one’s total energy intake from fat be reduced to 30% with 10% being derived from saturated fats, 10% or less from polyunsaturated fats, and approximately 10 to 13% from monounsaturated fats.

In The Kellogg Report, it was stated that "Over 70 percent of all deaths in the United States in 1973 were caused by diseases linked to certain foods in the diet, including high levels of fat, sugar, and salt. The leading causes of death, heart disease, and stroke, are related to the types of food we eat and overeat," (Beasley and Swift, 1989). It has been reported that there is a link between nutritional
depletion and obesity in that the individual's body will continue to crave food until the need for essential nutrients has been satisfied by dietary intake.

In populations such as low income families, there are no resources both monetarily and supply-wise to provide inexpensive foods that are high in needed nutrients. These families, therefore, purchase inexpensive foods which are low in nutrients and high in fat, sugar, and salt. The degree of malnutrition in this demographic group leads to a high prevalence of obesity (Krehl, 1976). Low income families usually are required to eliminate fresh products and are required to rely on the "mush-and-gravy" routine which is high in animal-derived fats such as lard (Choate, 1973). Any extra money is used for the purchase of television-advertised convenience foods.

One such area is the Appalachian region of the U.S. which has been reported to have one of the highest percentages of low-income families in the regional population (Beaulieu, 1988). The central part of this region consists of portions of Kentucky, Tennessee, West Virginia, North and South Carolina, Virginia, and Maryland (Raitz et al., 1984). In 1980, the poverty levels of this region were 6% higher than any other U.S. region (Beaulieu, 1988). The U.S. Food & Drug Administration's Nutrition Knowledge Survey (1974 & 1975) determined that shoppers of low income levels were more
uninformed about nutrition than those in middle and high income levels (Beasley and Swift, 1989). The low incomes coupled with low levels of education in this region lend themselves to high mortality rates, due in part to poor dietary habits which produce risks of obesity and related chronic diseases (Raitz et al., 1984).

In the Appalachian region, particularly within low-income families, there is a high incidence of obesity. This prevalence of obese individuals and its related diseases is in part due to an increased consumption of dietary fats. The sources of these dietary fats, especially saturated fats, within this region, have been attributed to a number of prepared foods, specifically biscuits. Stern and Hermann-Zaidins (1992) state that the American Dietetic Association recommends the use of fat reduced foods in one’s diet to obtain positive health outcomes.

The biscuit has been and continues to be a large part of the Appalachian diet. According to Farr (1983), tradition still holds, "Mountain food and how it is cooked is very much a part of this sense of place. Ask any displaced Appalachian what he misses most about being away from the mountains...‘homemade biscuits every morning of the world.’" Most Southern meals still consist of biscuits at least at breakfast and sometimes dinner. The biscuit has become a part of the fast food and convenience industry due to a changing
economy, a faster paced society and the preference of the Appalachians to have biscuits as part of their meals.

It may be unrealistic to reduce or remove the majority or all of the fat from the Appalachian diet. However, if fat was removed or reduced from some of the more popular foods, this would reduce total dietary fat intake and its subsequential risk of related diseases. Since biscuits are a popular food in the Appalachian diet and are high in fat, an attempt should be made to reduce and/or replace their fat content. If the fat reduced or replaced biscuit is acceptable to the Appalachian consumer, manufacturers and retailers will be able to provide biscuits which contribute to lowering the daily fat intake. As Shields and Young (1990) state: "The fast-food industry and individuals will have the ability to lower the fat content, of their food products with the potential of reducing the fat content of the American diet". Hundall et al., (1991) observes that fat intake could be reduced up to 10 grams per day if equal amounts of fat-free alternatives are substituted for fat in frozen desserts, sweet baked goods, salad dressings, and dairy products. This would be a decrease in energy intake by 110 kcal/day.

One in every twenty five Americans consumes some type of home prepared or commercial biscuit (Hogbin and Fulton, 1992). This increase in quick bread consumption along with the increase in rising health concerns has forced food
manufacturers to reduce the amount or change the type of fat used in the product. In order to meet these challenges, the manufacturers are developing fat substitutes and/or fat mimetics for use in these quick breads.

Characteristics of these fat replacers need to be considered when they are to be used in a biscuit reformulation. In the selection of a fat replacer, one should consider its health benefits, bulking properties, solubility, water absorbing capacity, stability, particle size distribution, and enzymatic activity (Blenford, 1992). One should identify all of the product attributes influenced by the fat and attempt to replace them with an agent that produces the same attributes (Hewitt, 1993). This study investigated the possibility of partially or totally replacing the fat in a Southern-style biscuit with carbohydrate-based replacers.

Therefore, the main objectives of the study were:

1. to develop a biscuit formula with a fat content that is partially and/or totally replaced with a selected carbohydrate-based fat replacer

2. to evaluate the effect of the substitution on the physical attributes of the biscuit: volume expansion upon baking, color, texture, degree of staling, moisture and caloric content

3. to evaluate the acceptability of the fat-replaced
biscuit through quantitative descriptive analysis and consumer acceptance sensory evaluation.
Chapter 2

Review of Literature

2.1 Historical Review of Biscuits in the Southern Diet

The Appalachian meals had to be large and energy dense in order to fuel the body for the hard labor in the fields and factories (Egerton, 1987). Due to poverty, the various menus had to consist of foods that were inexpensive and easily attainable. Historically, the Appalachian region has been an area of severe poverty. The people in this area were isolated from much of civilization and were dependent on subsistent farming. Due to their inexpensive and available ingredients, a variety of quick breads were a staple at every meal. Prior to the Civil War, families would "give anything" for cornmeal and fatback for cornbread and hoecakes (Egerton, 1987). One of the quick breads people consumed was unleavened beaten biscuits. According to Hess and Hess (1977), these biscuits were also known as Apoquiniminc cakes. The biscuits consisted of: "Put a little salt, one egg beated, and four ounces of butter, in a quart of flour-make it into a paste with new milk, beat it for half an hour with a pestle, roll the paste thin, and cut it into round cakes; bake them on a grid iron, and be careful not to burn them." After the Civil War with the development of baking powder and baking soda, chemically leavened biscuits became as popular as cornbread. The biscuit was eaten at least three times a day, at every meal (Taylor,
1982). The biscuits served were either yeast leavened angel biscuits, or chemically leavened baking powder and buttermilk biscuits. The Southern biscuit has specific characteristic attributes. It has some body with a subtle taste (Lambert, 1988). Daniels (1941) remarks "In...1875...he had zeal left over for the denunciation of 'something called biscuits which was in fact rather warm dough with much grease in it.'"

Jack Fulk from North Carolina, a franchisee of a Hardees in the early 1970s, made the first acceptable fast food biscuit. In 1977, he adjusted the recipe and introduced it in his Southern-style restaurant, Bojangles. Biscuits are now available in almost any fast food chain and can be found in the refrigerator department of the supermarkets. The made-from-scratch biscuits are smaller, lighter, flakier and more delicate than the fast food biscuit. The new Southern-style fast food biscuit has become a light, fluffy, tender, cake-like biscuit (Egerton, 1987).

2.2 Biscuit Formulation: Ingredient Functionality and Manipulation

One of the staples in the Appalachian diet has been and continues to be a baking powder biscuit. It has the attributes of a light color crust, tender crumb and bland flavor (Matz, 1987). According to Hogbin and Fulton (1992), a baking powder biscuit formula consists of all-purpose
biscuit flour, shortening, baking powder, salt and milk. Each of these ingredients is critical to the production of a light and fluffy biscuit.

2.2.1 Flour

The flour best suited for biscuit making is a soft all-purpose wheat flour. This type of flour has a low level of glutenins and gliadins which allows sufficient gluten development upon hydration (Bennion, 1985). Sultan (1986) states that a soft wheat flour tends to absorb and retain moisture within the product throughout processing. Matz (1987) suggests that as the strength of the flour increases, the biscuit’s height will increase and width will decrease. The soft flour produces uniform contours of the crust and deep furrows around the middle of the biscuit. Low protein content also contributes to product tenderness (Yamazaki, 1987).

2.2.2 Salt

Salt is not only a flavor enhancer but is used to help strengthen the gluten structure of certain products by causing it to be more stretchable. This helps to improve the bread’s texture (Gisslen, 1989). In biscuits, only a small amount of salt is used, therefore, the contribution is mainly for flavor enhancement.
2.2.3 Leavening Agent

Gisslen (1989) states that quick breads are given the name "quick" due to the fact they are chemically leavened in a short period of time. In baking powder biscuits, double-acting baking powder is the chemical leavening agent. Double-acting baking powder is composed of a dry acid salt (monocalcium phosphate monohydrate) and baking soda which are dispersed in a starch. Double-acting baking powder also contains SAS or sodium aluminum sulfate. Its first reaction involves the release of carbon dioxide and water upon hydration of the monocalcium phosphate monohydrate and part of the baking soda. The SAS reacts with the water upon heating to produce sulfuric acid. Its second reaction involves the combining of the sulfuric acid with the remaining sodium bicarbonate (soda) to produce CO$_2$, water, and sodium sulfate. The released carbon dioxide and water vapors contribute to the volume and cell structure of the biscuit (Bennion, 1985). Hoseney (1988) remarks that the chemical leaveners contribute a thick cell wall and coarse grain to the biscuit. The yellowish crust color of the biscuit is due to an alkaline pH of the dough. This pH is produced by the baking powder (Bennion, 1980). The baking powder adds flavor and causes the biscuit to spread and flatten upon baking (Sultan, 1977).

2.2.4 Milk
Milk contributes flavor, nutritional value, moisture and assists in the leavening process by the production of water vapor upon baking. The proteins and sugars in the milk also contribute to the Maillard browning of the crust. According to Bennion (1980), the milk lends to the dispersion of the ingredients throughout the dough and also to the gelatinization of the starch for the development of structure. It will also participate in the hydration of fat replacers and gums. Biscuits made with fresh whole milk were observed to be a "more tender, more compressible, higher in volume, and had a better flavor than biscuits made with diluted evaporated milk, reconstituted dry whole milk, or water" (Bennion, 1980).

2.2.5 Fat

A shortening's physical properties perform various functions in baked goods. The properties of importance in food production are melting point, softness or hardness at varying temperatures, flavor and the ability to form emulsions (Gisslen, 1985). Amendola (1972) and Pyler (1973) suggest considering the fat's plasticity or "shortening" ability which directly affects its creaming ability, color, odor, stability and keeping quality. The physical properties of a fat also influence the fat's mouthfeel, viscosity, lubricity, oiliness, and cohesiveness (Anonymous, 1992a).

For biscuits, an ideal shortening is odorless, colorless,
has a plastic consistency, a high melting point and forms emulsions. Waring (1988) states that the fat should contribute flakiness, a uniform cell structure and a fine texture in the final product. The flavor is contingent upon the consumer’s tastes. In Southern-style biscuits, the buttermilk, the yeast, the baking powder, and the baking soda furnish distinct flavors to the product. Therefore, it is not desirable for the fat to have a strong characteristic flavor as would be found in lard.

Not only is the type of fat used in biscuit production important but, the amount used and its incorporation with the other ingredients has to be considered. Fat is one of the major functional ingredients found in biscuits. The amount of fat based on the total weight of the flour is usually less than 15% however, for a more "home-style" biscuit this amount may be doubled to 30 to 40%. Method of incorporation is also crucial for an acceptable biscuit (Sultan, 1977). For biscuit production, Matz (1987) states that the shortening is "cut into" or "rubbed together" with the dry ingredients to produce a homogeneous mass resembling "coarse cornmeal." This process provides a tender and fine texture, volume, uniform cell structure, and flakiness.

2.2.5.1 Nutritional Aspects of Fat

Fats provide the most concentrated source of dietary
energy, nine kcal per gram (Dziezak, 1989). Fats are sources of essential fatty acids, linolenic and linoleic acids; and carriers for fat-soluble vitamins such as vitamins A, D, E, and K (Mela, 1992). The fat-soluble vitamins are essential for the protection of cellular membranes from oxidative damage (Beasley and Swift, 1989). Fats are also a source of energy in storage and oxidation. Ernst (1991) reported that dietary fats also are a component of tissue lipids. The nutritional implications of dietary fats need to be considered especially when attempting to replace them in products.

2.2.5.2 Characteristics of Fat

Fat influences flavor, mouthfeel, texture, appearance, storage stability, handling considerations, and processing concerns of food products (Anonymous, 1993a). The type of fat and its physical and chemical properties influence its performance in baked goods. Gisslen (1985) remarks when selecting a fat for baking, one needs to consider its melting point, softness or hardness at varying temperatures, flavor and odor. Also, plasticity or "shortening" value, ease of handling, a consistency which allows the fat to combine easily and uniformly, color, and keeping qualities (Amendola, 1972) are other criteria to be considered. According to Pyler (1973), one should consider its free fatty acid value and stability to oxidation. The fat should possess a sufficient
creaming value (ability to incorporate air during the combining of the ingredients) and emulsification value (ability to hold the liquid and solid particles in a uniform colloidal dispersion).

2.2.5.3 Functions of Fat

According to Pyler (1973), fats shorten or tenderize, aerate, stabilize, emulsify, provide eating qualities, and prevent staling of baked goods. The fat’s shortening ability is influenced by its plasticity. This depends on its solid and liquid phases. The solid particles need to be in proportion, around 20 to 30%, to the liquid phase so there is a "free flow of mass." The plasticity is influenced by the size and formation of these solid particles. The degree of shortening produced by a fat or oil in a given product depends primarily upon the surface area of the flour particles covered by the fat. The more the flour particles are coated by the liquid phase of the fat, the less chance the flour proteins have in forming a strong gluten structure (Hornstein et al., 1942). The plasticity produces tenderness in the baked goods.

Fats function as stabilizers in batters and doughs. The more the fat’s solid particles are dispersed, the more stable the batter/dough becomes. When a plastic fat is used, it’s solid particles tend to form large agglomerates, reducing the stability of the batter/dough (Pyler, 1973). Amendola (1972)
reports that fats also emulsify the ingredients in batters/doughs. The fats do not dissolve in the liquid phase of the batter/dough like the other ingredients. By maintaining its form, the fat is able to be dispersed and form an emulsion with the other ingredients.

The eating and keeping qualities are also related to functions of fat. Fats provide characteristic flavors and odors to products. Fats assist in moisture retention through the reduction of water evaporation which delays the staling of a product (Pyler, 1973; Sher, 1984).

2.2.5.4 Fat Usage in Biscuits: Selection and Usage

Of the four types of biscuits, the baking powder and buttermilk biscuit are the more popular types due to an easy and short preparation technique. The type and amount of fat give the biscuit its Southern-style characteristics. The fats used in southern-style biscuits are usually lard and/or hydrogenated vegetable shortenings. Before the invention of hydrogenation, lard was the fat primarily used in biscuits for its characteristic flavor and plasticity at room temperature (Pyler, 1973). Since the Appalachian population had to be self-sufficient, pork lard was the selected fat used for biscuits (Lambert, 1988). When the pigs were slaughtered, every ounce of fat was spared. Rendering of the lard was a process in which the internal fatty tissue of the internal
organs was melted down in a large kettle or under steam pressure into leaf lard (Denton et al., 1921).

For biscuits, pure refined lard with antioxidants was determined to be the best fat for a tender, high volume product. Knightly (1981) states that the low solids content of lard allows it to be dispersed uniformly thereby, shortening the gluten strands in the dough and tenderizing the finished product. Lard also has a B crystalline form which produces flakiness in a baked good (Bennion, 1980).

Lard was the most widely used shortening in America's baking industry (Knightly, 1981). Then in the late 19th century, manufacturers had to find new types of shortenings due to low pork supplies and high bakery demands. The first compound developed in the early 1900's for bakery use was a "compound shortening". It was made of 80% cottonseed oil and 20% oleastearine from tallow. Then in 1910, (Pyler, 1973), due to the invention of catalytic hydrogenation, 100% all-vegetable shortenings were produced. According to Gisslen (1985), regular shortenings and emulsified or high-ratio shortenings are the most common. Regular shortenings are 100% hydrogenated vegetable shortenings that have a tough waxy texture, melt at high temperatures, hold their shape in doughs and have good creaming abilities. They are usually a blend of cottonseed and soybean oils (Pyler, 1973). The other type of shortening used is emulsified shortenings or "high ratio"
shortenings. The emulsified shortenings contain mono and diglycerides which will promote uniform dispersions of the fat (Pyler, 1973). These shortenings also have a soft consistency which allows rapid coating of the flour particles. This produces increased tenderness and flakiness in a product (Gisslen, 1985). The beta prime crystals in these shortenings are important for functionality such as good aeration, smooth appearance and creaming properties (Dziezak, 1989).

In the production of a tender, flaky biscuit, not only the type of fat used, but the amount is critical. The percentage of fat in a biscuit is usually less than 15% based on total flour weight. The fat content needed in a "home-style" biscuit for flakiness is approximately 50% flour weight (Sultan, 1977). According to Matthews and Dawson (1963), emulsified vegetable shortenings performed better than lard in tenderizing biscuits. Since the hydrogenated shortening has "smaller stable crystals" it is able to cover more surface area of the ingredients. These shortenings produced flakier biscuits and were observed to retain more moisture than lard. The shortenings used in biscuits need to be able to keep their form especially at high baking temperatures in order to produce flakiness.

2.2.6 Manipulation of the Biscuit Dough

The characteristics of biscuits are influenced by the
method of fat incorporation. Flakiness is obtained by the process of "cutting" or "rubbing" the fat into the flour until it resembles "coarse cornmeal" (Bennion, 1980), and then the mixture is hydrated to form a dough. This method is known as the "biscuit or pastry" method (Sultan, 1977). The traditional Southern-style baking powder biscuit uses the "pastry" method for producing a flaky, tender product. If one desires a fluffy "home-style" biscuit, the creaming method is used. This method uses an increased amount of shortening compared to the "pastry" method. In the formula, the sugar is creamed with the fat and then added to the hydrated flour. A complete manipulation of the dough ensures a soft, cake-like interior.

The degree of kneading of the dough and the rolling out process are important in producing a flaky and tender biscuit. Bennion (1980) suggests that a biscuit dough should be kneaded gently approximately 10-20 times. This manipulation is necessary for the development of some gluten and to orient the gluten strands so that they are positioned in the same direction. The kneading and rolling stages also lead to an even dispersion of the fat among the flour particles. It is desired to roll out the biscuits to a degree of thickness which allows for multiple layers of fat and flour. Upon baking, the fat particles melt and with the production of steam separating these layers of fat and flour, flakiness and
tenderness is produced in the finished product. If the biscuit is rolled without kneading, the biscuit is very tender with a crisp crust, coarse texture, and small volume. If the biscuit is kneaded, then it has a fine texture with layering, a large volume and a smooth crust (Bennion, 1985). Gisslen (1989) suggests that the dough should be rolled to a thickness of 0.5 inch thick, making sure it rolled evenly and uniformly. According to Medved (1986), the rolling of the biscuit dough causes the fat particles to flatten and form layers between the gluten layers thereby, producing flakiness.

Overmanipulation causes excessive gluten development on the dough. With an extensive gluten structure, the leavening action produced from the baking powder is not able to expand the cell structure within the dough thereby, producing a tough biscuit (Gisslen, 1989). According to Matz (1987), over development of the dough will cause shrinkage and the formation of abnormal contours upon baking.

2.3 Fat Reduction in Food: The Emergence of Fat Replacers

2.3.1 Early Studies on the Fat Reduction in Biscuits

Early work conducted on biscuits studied the effect of lowering the percentage of fat in the biscuit formula. One study conducted by Matthews and Dawson (1963) used five levels of corn oil, cottonseed oil, soybean oil, lard, and two
hydrogenated vegetable shortenings in baking powder biscuits. The biscuits were evaluated on tenderness, flakiness, moisture, and flavor. Tenderness was measured objectively by observing the shear force needed to break the top crust by a Warner-Bratzler Shear Machine and the shear force needed to penetrate the entire biscuit using a Kramer shear press. Moisture content was determined by a Cenco moisture balance. According to the shear readings, the tenderness of both the crust and the whole biscuit increased as the level of fat increased from 6 to 51%. At 25%, the solid fats produced more tender products than the oils. The oils produced more tender biscuits at 38% and 51% levels. The moisture content from the fats/oils were the same at all levels. The tenderness, flakiness and richness of flavor were rated by a trained panel. The panel observed as the fat level increased with optimum levels between 25-38%, the tenderness of both the crust and crumb increased. They observed the oils to produce as flaky and tender biscuit as the solid fats. The panel observed the richest flavors in all of the fats at the 38% level. According to the objective measurements and sensory panel the optimum fat levels for a baking powder biscuit are 25% to 38%.

A study conducted by Hogbin and Fulton (1992) observed the effects of reduced levels of margarine as compared to a hydrogenated shortening in a biscuit. Both objective and
sensory measurements were taken and compared. The objective tests included tenderness, performed by a Kramer shear press with an integrating texture recorder; standing height; and moisture loss, determined by the weight before and after baking. The panel evaluated the biscuits on texture, tenderness, flavor, and appearance. The objective test determined that a decrease in fat usage levels caused a decrease in tenderness, increase in moisture loss, and no changes in standing height. The sensory panel observed low levels of fat to produce no significant differences in appearance, texture, and tenderness. Flavor, however, was reduced with the low usage levels. A similar study conducted by Fulton and Davis (1987) produced similar results as Hogbin and Fulton (1992).

2.3.2 Fat Replacers

Due to the health implications regarding high intake of dietary fat, food manufacturers are replacing the fats used in bakery production with the newest products in food technology: fat substitutes and fat mimetics. According to Thayer (1992), in 1991 fat replacers had a market value of 100 million dollars and the U.S. demand for fat replacers are predicted to increase 4.5% annually to $1.9 billion in 1996 (Anonymous, 1993b). A true fat substitute is a substance or compound whose physical and thermal properties resemble fat, and can be
used to replace all the fat in the product. A fat mimetic is a compound that replaces the mouthfeel of fat but, cannot be totally substituted for a fat on a pound-for-pound basis (Anonymous, 1991). Fat reduction systems involve fat mimicking, water stabilization, bulking, mouthfeel stimulation, and flavor enhancement (Anonymous, 1993a). Fat reduction systems presently in use include: lipid-based replacers; emulsifiers and synthetic fat substitutes; starch-based replacers: hydrocolloids, starch derivatives, hemicellulose, β-glucans, and soluble bulking agents; microparticulates including protein-based replacers; composites and functional blends (Anonymous, 1992a).

2.3.2.1 Lipid-based Fat Replacers

2.3.2.1.1 Emulsifiers

Lipid-based replacers which include emulsifiers and synthetic fats are made from chemically-altered fatty acids (Hunter, 1992). Emulsifiers according to Grinsted Products Inc., (1992), act as an interface between two immiscible substances. They are usually esterified molecules of common fatty acids. They have been observed to act as starch complexers, crumb softeners, dough strengtheners, aerators, and foam stabilizers (Glicksman, 1991). Emulsifiers help "bridge the gap between the full-fat and the fat-replaced
product" (Anonymous, 1992a). They assist fat replacement systems in duplicating mouthfeel properties, shelf stability, flavors and texture of fat in baked goods. Morris (1991) proposes that emulsifiers can be used in addition to water and a hydrocolloid to reduce fat levels. Emulsifiers perform best at levels less than 0.5%. Higher usage can cause perceivable off flavors in the product (Glicksman, 1991). A disadvantage of emulsifiers is their caloric content of 9 kcal per gram. Some examples of emulsifiers used as fat replacers are lecithin, distilled monoglycerides, diglyceride shortening, acetylated monoglycerides, propyleneglycol monoesters, polyglycerol esters, and polysorbate 60,80. Other replacers are N-Flate®, a blend of mono and diglyceride emulsifiers, guar gum, and modified food starch in a nonfat dried milk base produced by National Starch and Chemical Corp., and Dur-Lo®, a mono diglyceride emulsifier made from vegetable oils produced by Durkee Foods (Hundall et al., 1991).

2.3.2.1.2 Synthetic Fats

These fat replacers are of two molecular structures, one being fatty acids attached to a molecular backbone. This protects the fatty acid's functional properties while deeming it nonabsorbable. The other is a glycerol backbone with attached nonabsorbable substances (Anonymous, 1992b). Some examples of these fat replacers are Olestra®, a sucrose
polyester produced by Procter and Gamble, Co.; EPG, an esterified propoxylated glycerol produced by ARCO Chemical Company; DDM, a diakyl dihexadecymalonate produced by Frito-Lay; and TATCA, a trialkoxytricarballate produced by CPC International, Inc. (Anonymous, 1990). The problem with synthetic fats is the majority have yet to be FDA approved. There are concerns about the toxicology and metabolism of these compounds at macronutrient usage levels (Hassel, 1993).

2.3.2.2 Carbohydrate-based Fat Replacers

Carbohydrate-based fat replacers are also known as hydrocolloids. Hydrocolloids are substances which are "all long-chain polymers, predominately carbohydrate in structure, and are all soluble or swellable in aqueous systems to give the slippery, creamy viscosity that makes them useful" (Glicksman, 1991). These substances include gums, hemicelluloses, B-glucans, maltodextrins, soluble bulking agents and pectins.

2.3.2.2.1 Gums

Gums are long-chain, high molecular weight polymers which are soluble in water or form colloidal dispersions. Upon hydration, they thicken (gel) and impart viscosity, and produce a stable emulsion of the ingredients. They are best used in levels of 0.1-0.5% (Anonymous, 1990). According to
Glicksman (1991), gums are edible; non-toxic; and provide the slippery, creamy, lubricous mouthfeel of fats in products. They are non-caloric because they are only digestible upon fermentation by microflora that resides in the lower intestine (Hundall et al., 1991). Some examples of these gums are xanthan and guar gum.

Xanthan gum is produced by the fermentation of the microbe, Xanthomonas campestris which uses glucose as a substrate (Rocks, 1971). The culture solution is purified by the recovery of isopropyl alcohol, dried and milled (Anonymous, 1985). Its structure consists of a backbone which is constructed of Beta-D-glucose units linked in 1-and 4-positions. The backbone consists of blocks of five sugar units: two glucose units, two mannose units and one glucuronic acid unit (Betz, 1979). According to Rocks (1971), the structure is somewhat acetylated (4.7%) and has some pyruvate groupings attached by ketal linkages. Xanthan gum can be produced in the form of a potassium, sodium, or calcium salt (Betz, 1979).

In solution, the structure of the gum exists as a rigid rod which is stabilized by the noncovalent interactions between the backbone and the side chain. This rigid structure allows the gum to be soluble in both hot and cold water (Sanderson, 1981), and at the same time allows for gel formation within solution. The gel is due to the "buildup of
complex networks in which polymer molecules form highly ordered intermolecular associated regions known as junction zones," (Kovacs, 1973).

The structure is the basis for xanthan gum being the most pseudoplastic of all of the hydrocolloid gums. When shear force is applied to the structure, the junction zones dissociate which in turn reduce the viscosity of the solution. However, when the shear force is removed, the junction zones reassociate, allowing for a highly viscous solution to reform (Betz, 1979). It produces a highly viscous solution at low concentrations, usually between 0.1% and 1.0% (Rocks, 1971).

Xanthan is thermal and pH stable and increases in viscosity when combined with guar gum (Whistler and Daniel, 1985). Due to xanthan's stability at high temperatures, the moisture retention in baked goods is increased (Pettitt, 1982). When complexed with starches, xanthan gum may inhibit the staling process thereby, increasing the product's shelf-life and improving its eating qualities. Xanthan gum is also used in baked goods to stabilize the gases which are produced, causing an increase in "finely textured breads, crusts, and cakes," (Andres, 1987). Sanderson (1981) states that usually when polysaccharides are incorporated into food products, there is a masking of flavor. However, due to xanthan's shear thinning in the mouth (in solution), there is increased flavor release and mouthfeel.
Guar gum is produced from *Cyamopsis tetragonolobus'* endosperm. It consists of a backbone consisting of a 2:1 ratio of B(1-4) D-mannose units and alpha(1-6)-D-galactopyranosyl units as side chains (Enriquez et al., 1989). It is this rigid structure with much branching that is responsible for its functional properties of high solubility and great hydrogen bonding activity (Glicksman, 1969).

According to Enriquez et al., (1989), guar forms highly viscous solutions at concentrations less than 1.0%. Since it is soluble in cold water guar gum hydrates faster and increases in viscosity when the solution is heated to higher temperatures (Glicksman, 1969). Guar gum solutions are pseudoplastic and will produce gels only when used with borate, calcium, and aluminum. When guar is combined with xanthan gum, it increases the viscosity of the solution as compared to either gum in solution alone (Enriquez et al., 1989).

Guar gum is pH and thermal stable and when used in combination with other gums improves consistency and rheological properties of foods (Whistler, 1969). Guar gum has functional properties of water-binding, thickening and stabilizing (Sanderson, 1981). Due to its water binding abilities, guar gum has been used at a maximum level of 0.35% in breads in order to increase moisture retention during baking and storage. Consequent soft texture and improved
shelf-life are the results. In combination with the gluten, loaf volume is increased upon baking (Herald, 1986). When added to biscuits at a concentration below 0.1%, the biscuits are softer, moisture, have an improved distribution of ingredients, and produce less crumbling upon slicing of the product. Guar gum has also been incorporated into biscuits at a level of 4-6% thereby, producing a high-soluble fiber product that can be used to reduce serum cholesterol. These products can also be used for diabetic diets (Enriquez et al., 1989).

Unlike xanthan gum, at high viscosities the perception of flavors in the products are masked due to the entangled galactomannan network. This network suppresses the flavor molecules being transported to the taste buds from the solution (Enriquez et al., 1989).

One replacer used today is KEL-LITE BR which is a blend of xanthan gum and guar gum produced by Kelco Division of Merck and Co., Inc., (Duxbury, 1993). It contains cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides. It has the following advantages: disperses readily in products, is pH stable, controls for syneresis, binds water and thickens. The mixture has a usage level of 0.2-0.3% and can be incorporated directly into the dry ingredients or hydrated into a gel and then incorporated (Kelco, Division of Merck & Co., Inc., 1992a). KEL-LITE BR
has been observed to replace up to 50% of the fat in a "traditional Southern-style baking powder biscuit" while still maintaining a soft texture, acceptable mouthfeel and moisture retention for a longer shelf-life of the baked good (Kelco, Division of Mereck Co., Inc., 1992b).

2.3.2.2.2 Hemicellulose

Hemicelluloses are defined as "plant polysaccharides that are extractable by aqueous alkali solutions, with the exclusion of the typical water-soluble gums and starches" (Glicksman, 1991). They are usually made from a heterogeneous sugar with xylose, mannose, or galactose as a backbone and sidechains of arabinose, galactose, and glucose. Hemicellulose has been used in Fibrex®, a sugar beet fiber produced by Delta Fibre Foods; Fbrim®, a soy fiber produced by Protein Technologies International; and AF Fiber®, an almond fruit fiber produced by ITD Corp. A cellulose-based fat replacer is Avicel® produced by FMC.

Beta-glucans are a subcategory of hemicellulose (Glicksman, 1991). They are found in wheat, sorghum, oats, barley, brewer's and baker's yeast. Beta-glucans are located in oat gum which is the soluble dietary fiber in oat bran (Dawkins and Ninanna, 1993). Beta-glucans are "homopolysaccharides composed of glucopyranosyl units with (1-3) and (1-4) linkages in a ratio of 1:2:5," (Wang et al.,
1992). Ranhotra et al., (1991) states that oats contain somewhere between 2.2 and 4.2% beta-glucans. According to Faridi and Faubion (1990), upon hydration the beta-glucans form a gummy mass. Other functional properties include: the ability to form a highly viscous solution at low concentrations is pseudoplastic at a concentration of 0.5% or less, and is stable to salt and sucrose (Dawkins and Ninanna, 1993). The degree of viscosity appears to depend on the beta-glucan concentration (Wang et al., 1992). Examples of B-glucans in fat replacers are Oatrim®, a soluble oat fiber derivative produced by A.E. Staley; extraction from edible yeasts produced by Alpha Beta Co., and Anheuser-Bush Co.; and possibly a barley extract. According to Thayer (1992), the B-glucans in Oatrim® are believed to produce a creamier taste and texture than other replacers.

Oatrim® known as TrimChoice® or oat beta-glucan-amylopectin is produced from oat starch present in oat flour and bran (Inglett and Grismore, 1991). The starch is converted into maltodextrins, B-glucans, and insoluble fibers by an enzymatic process which uses alpha-amylase enzymes for the liquefaction of the starch. The enzyme cleaves the amylose and amylopectin chains and then is subjected to conditions in which the soluble fibers are liberated from the substrate. The soluble materials of maltodextrins and B-glucans are separated from the insoluble fiber and dried.
TrimChoice® is a soluble fiber blend of these dried B-glucans and low dextrose equivalent maltodextrins. The success of this replacer is determined by the degree of polymerization of the maltodextrin. Oat flour has been determined to yield 70% Oatrim® and oat bran yields 60% Oatrim® (Duxbury, 1990).

TrimChoice® consists of three types: Oatrim-1®, Oatrim-5®, and Oatrim-10® (Inglett and Grismore, 1991). Oatrim-1® is derived from de-branned whole oat flour; Oatrim-5® is derived from whole oat flour with the bran; and Oatrim-10® is derived from oat bran. The number following the name is an indication of the percentage of B-glucans present on an approximate dry basis. TrimChoice® can tolerate high baking temperatures; be incorporated into high heat candies; easily dissolved into batters, and incorporated into extruded cereals (Duxbury, 1990; A.E. Staley Manufacturing Company, 1993). TrimChoice® is dilute in an alkali medium (Seibert, 1987). TrimChoice® can be incorporated directly into the dry ingredients or it can be hydrated with hot or cold water and incorporated as a gel (Duxbury, 1990). The dry powder contributes four kcal per gram while the gel contributes one kcal per gram (Anonymous, 1993a). TrimChoice® has been observed to be able to replace all of the fat in certain cookies; 75% of the fat in layer cakes; and 25-100% of the fat in other bakery products (A.E. Staley, 1992).
2.3.2.2.3 Maltodextrins

This group of replacers includes dextrins, low dextrose equivalents, and modified starch hydrolysates. Starches are degraded to lower-molecular weight compounds with lower dextrose equivalents (Glicksman, 1991). These derivatives possess structures which when hydrated, bind water and position it in a way that provides the mouthfeel similar to fats (Yackel and Cox, 1992). These derivatives contribute approximately one calorie per gram and can be used to replace up to 100% of the fat in a product (Thayer, 1992). Dextrins according to Hundall et al., (1991), are "bland nonsweet carbohydrates" which are hydrolyzed from starches. They contribute one to four kcal per gram, are fully digestible, and have the texture and mouthfeel of fat upon gelling. Some examples of these are Maltrin M040, a corn starch maltodextrin produced by Grain Processing Corp.; N-Oil and Instant N-Oil I and II, tapioca dextrins and maltodextrins respectively produced by National Starch and Chemical Corp.; Paselli SA2, a potato starch maltodextrin produced by A.E. Staley Mfg. Co.; and Sta-Slim 143, a modified potato starch produced by Avebe American Inc., (Duxbury and Meinhold, 1991).

2.3.2.2.4 Soluble Bulking Agents

Bulking agents have similar body, creaminess, and smoothness as fats. When used with other hydrocolloids, they
can increase the viscosity of the product. These agents can be from sorbital, glycerol, or hydrogenated starch hydrolyzates (Glicksman, 1991). A typical bulking agent is polydextrose. According to Duxbury and Meinhold (1991), polydextrose is composed of a dextrose polymer in combination with sorbitol and citric acid. It is unabsorbable with 5 to 10% of it being digested and fermented in the colon and yields one kcal per gram. It is produced by Pfizer Inc., under the name of Litesse™ (Hundall et al., 1991).

2.3.2.2.5 Pectins

Pectins are hydrocolloids found in plants and are obtained from an aqueous extraction of citrus and/or apple peels (A.E. Staley, 1992). Pectin is located in water soluble dietary fiber. It is a "polymer of alpha-1-4, glycosidic-linked D-galacturonic acid units," (Kim and Atallah, 1993). The backbone acid units during the pectin extraction process are partly neutralized by ammonium, calcium, potassium, and sodium ions (Pszczola, 1991). Attached to the polygalacturonic backbone are sugar side chains consisting of galactose, arabinose, and possibly xylose and fucose (Sanderson, 1981). According to Sanderson (1981), a proportion of the galacturonic acid residues are methyl esterified. The degree of methyl-esterification depends on the pectin's source. Kim and Atallah (1992) state that the molecular weight and degree
of esterification contribute to the functional properties of: solubility, strength of mineral binding, and gel characteristics. As the degree of methylation decreases, the viscosity of the solution has been determined to increase (Glicksman, 1969). Pectin has also been used as a stabilizer in baked goods (Glicksman, 1969). According to Krehl (1976), citrus pectin’s most outstanding characteristic is its water binding ability.

An example of a pectin replacer is Slendid®, "a proprietary specialty pectin derived from citrus peel, standardized by the addition of sucrose," which is produced by Hercules Inc., (Hercules Incorporated Fragrance & Food Ingredients Group, 1993). According to specifications (Hercules Incorporated Fragrance & Food Ingredients Group, 1993), Slendid® is a low esterified pectin. Pectins with low methyl esters usually have a degree of esterification of 50% or less. This low esterification allows the pectin to form gels with calcium ions present (Sanderson, 1981). Slendid® is a powder which is able to form a 95% water-based gel which is heat stable, specifically retortable, microwavable, and bakeable (Duxbury, 1991). Usage level is suggested at less than 5% (Thayer, 1992) and has been used at a level of 1% in muffins without loss of flavor, volume, body, or mouthfeel (Hercules Incorporated, 1993).
2.3.2.3 Microparticulate Fat Replacers

Microparticulate fat replacers consist of spherical particles no bigger than 0.1-3.0 microns which are not perceived by the tongue (Glicksman, 1991). Some examples are Avicel®, a microcrystalline cellulose produced by FMC Corp.; Fibercel®, a microspherical yeast fiber produced by Alpha Beta Corp.; and Simplesse®, a microparticulated egg, milk, and whey protein produced by Nutrasweet Co. According to Stern and Hermann-Zaidins (1992), the protein particulates are digestible, absorbable, and produce only one to two kcal per gram due to the ability to entrap water. These particulates are known for their function of producing a creamy, flowing mouthfeel. Lubricity is due to the entrapment of water by the particulates. A disadvantage of the protein particulates is that they tend to denature and lose their creamy mouthfeel when used at very high temperatures (frying for example).

2.3.2.4 Composite Materials

2.3.2.4.1 Composite Blends

Composite blends are made from the co-drying, extruding, and agglomerating specific hydrocolloid blends (Glicksman, 1991). These blends are modified for increased functionality in fat replacement. Examples of these replacers are a blend of microcrystalline cellulose and carboxymethyl cellulose

2.3.2.4.2 Functional Blends

These blends are from simple blending of substitutes for a more functional replacer (Glicksman, 1991). They contain gums and starches as a "critical functional component of the blend." Examples of functional blends are N-Flate, a blend of nonfat milk solids, emulsifiers, modified food starch, and guar gum produced by National Starch and Ultra-Freeze 400, a blend of modified food starch, vegetable protein, and corn syrup solids produced by A.E. Staley Mfg., Inc.

2.3.2.5 Uses of Fat Replacers

Fat replacer systems are being incorporated into food products to reduce the amount of calories being obtained from fats and oils. Fat replacers have been used in baked goods, dressings, dairy products, meat products, frozen desserts, frostings, sauces and gravies. Upon incorporation, a reformulation of the product is needed in order to compensate for the functional characteristics of the replacers. "Fat mimetics impart sensory characteristics such as creaminess and
smoothness. Body, cling, and firmness are developed with addition of maltodextrins, corn syrup, and gums. Emulsifiers are incorporated to interact with carbohydrates and proteins and to modify tenderness, reduce set back, and provide lubrication. Water activity within a product determines its microbiological stability. When carbohydrate-based fat mimetics are applied in a food system, the water activity of these systems is altered, and steps must be taken to counter the effects of increased water activity," (Yackel and Cox, 1992). In a reformulation, one must keep in mind the eating quality, ease of use, shelf stability, cost, labeling, and availability of the ingredients.

2.3.2.6 Nutritional Aspects of Fat Replacer

2.3.2.6.1 Lipid-based replacers

These replacers are not fully digestible which can cause them to function as a solvent for fat-soluble materials. They have the advantage of absorbing cholesterol, but also the disadvantages of absorbing fat-soluble vitamins, reduce intestinal transit time, and cause diarrhea (Mela, 1992).

2.3.2.6.2 Carbohydrate-based replacers

Hydrocolloids assist in caloric reduction due to reducing the level of dietary fat in food products and by increasing
the amount of soluble and insoluble dietary fiber sources. Within the last 15 years, experimental studies have been conducted on hydrocolloids and their physiological functions. Upon ingestion, these agents have been observed to reduce serum cholesterol and low density lipoprotein levels and moderate blood glucose levels (Glicksman, 1991). These fiber sources have also been determined to assist in the prevention of heart disease, appendicitis, diverticulitis, gallstones, hiatus hernia, colon and rectal cancers (Glicksman, 1982). They also bind harmful substances and increase intestinal transit time. This aids in the prevention of dietary fat and cholesterol intestinal absorption (Beasely and Swift, 1989; Carroll, 1989).

Xanthan gum has been determined to be resistant to the digestive system thereby, not producing any caloric value to the product (Betz, 1979). According to Staub and Ali (1982), guar gum is difficult to digest. It often may gel in the intestine producing poor absorption of nutrients, diarrhea, and a sticky feces. Guar is partially digestible; however, it has not been determined to contribute caloric value to a product. Jonnalagadda et al., (1993) have determined that guar gum among other dietary fibers, pectin, produce hypocholesterolemic effects in animals due to the fibers' ability to form "viscous and gel-forming properties" within the digestive tract for faster elimination of plasma
cholesterol. This function is due to the fiber being able to increase the excretion of cholesterol-containing fecal bile acids and in turn lowering the plasma very low density lipoprotein and low density lipoprotein levels.

One food source rich in soluble fiber is oats. Carroll (1989) determined that adding oat bran to one's diet was able to reduce the total and LDL plasma cholesterol levels. Raloff (1991), reported that a component of oat bran, beta-glucans, has been investigated to contribute to the bran's cholesterol reducing effects. Oats have one of the largest amounts of B-glucans ranging from 2 to 6% (Duxbury, 1990). According to Seibert (1987), beta-glucans have been determined to inhibit the biosynthesis of cholesterol and enhance cholesterol catabolism. The mechanisms by which these B-glucans are thought to work are that they bind cholesterol and its metabolites in the digestive tract, thereby preventing reabsorption. The beta-glucans also absorb intestinal water therefore, becoming viscous and in turn decreasing the absorption of bile acids in the intestines (Malkki et al., 1992). Beta-glucans also undergo a fermentation by colonic bacteria producing short chain fatty acids that are being investigated for their ability to inhibit the formation of cholesterol and possible colon cancers.

Some studies on the effects of B-glucans on animals have been conducted. De Groot in 1963, observed rats on oat diets
were found to have decreased serum cholesterol levels (Klopfenstein, 1988). Newman (1991) reported chicks fed soluble oat fiber had reductions in total cholesterol and low-density lipoproteins with increases in high-density lipoproteins. Klopfenstein (1988) conducted a study where rats fed a white pan bread containing 7% and 13% oat B-glucans had reduced serum cholesterol, liver triglycerides and liver cholesterol levels. Very few human studies have been conducted on B-glucans and their affects on reducing serum cholesterol.

Pectins, sources of soluble dietary fiber, contribute: no caloric value; increase fecal bulk; increase intestinal time; bind bile acids; and prevent absorption of dietary fats and cholesterol (Carroll, 1989). Krehl (1976) reported that incorporating pectin, 50 grams per day in bakery products, results in a reduction in blood cholesterol levels. According to Thomas (1991), the dietary fiber in citrus fruits, including pectins, can reduce an individual’s susceptibility to cancer of the lung, stomach, and colon.

Carbohydrate-based fat replacers do offer some disadvantages. Due to their bulking properties, these agents in large amounts may "bulk up" in the digestive tract causing malabsorption of micronutrients such as calcium, zinc, and iron (Mela, 1992). They may produce laxative effects from the large amounts of dietary soluble fibers, particularly in the
gums and polydextroses. Dextrins and maltodextrins are void of this problem due to their high level of digestibility (Haumann, 1986). The fat replacers' function in increasing intestinal transit times can also result in reduced lipid absorption. This decreases the bioavailability of fat-soluble vitamins and minerals (Klopfenstein, 1988).

2.4 Physical Measurements of Food Properties

The physical properties of foods influence the overall quality of a product. These properties are measured objectively for precision and accuracy (Faridi and Faubion, 1990). The physical properties of food are geometrical, size and shape of particles, volume, density and surface area; optical, visual color and surface appearance; thermal; and mechanical, texture and compressibility (Szczesniak, 1983). Other properties of baked goods that determine overall quality are the amount of staling and moisture and caloric content.

2.5 Sensory Evaluation

According to Pangborn (1984), sensory evaluation is used to set standards of quality, quality control, and product development. It is used to correlate the perceived sensory attributes to the physical and chemical measurements of a product (Amerine et al., 1965). Objective tests respond in minutes and can only analyze one attribute at a time.
Subjective tests, however respond instantaneously and encompass more attributes. Brennen (1980) states that results of objective tests must be related both statistically and conceptually to sensory data. Objective tests are tools to supplement and help control product evaluation but, they should not replace subjective methods. The "final standard of quality is human evaluation," (Amerine et al., 1965). Pangborn's (1984) approach to sensory methodology is comprised of: informal bench top evaluation for familiarization of the product; descriptive tests for defining important attributes and their perceived intensities; establishing a degree of liking for the products with a pilot consumer panel; and establishing the acceptability of the product in a central location.

The Sensory Evaluation Division of the Institute of Food Technologists (1981) states that a descriptive method should be used when one wants to relate sensory results with physical and chemical measurements. Gormley (1989) has reported that the only way to obtain data on the consumer acceptability of a product was by conducting a "full scale consumer panel." The expert judges in a descriptive panel should not be used in preference tests due to the fact they are likely to be more sensitive to product defects and have more precise standards for quality than a consumer (Roberts and Vickers, 1994). Seaman et al., (1993) documented that consumer panel responses
would give a greater insight into market acceptability due to
the consumer not being overly concerned with subtle
differences between products. It is hoped however, that
descriptive test results can be somewhat indicative of
consumer acceptability (Harries, 1983).

2.5.1 Quantitative Descriptive Analysis (QDA)

QDA is a descriptive testing procedure in which product
attributes are defined by trained panelists. The attributes
are assigned certain perceived intensities by each panelist on
an unstructured line scale. Repeated judgements on the
attributes' intensities are collected from each panelist
(Pangborn, 1984).

2.5.1.1 Panelist Training

According to Amerine et al., (1965), training is
conducted to increase the panelists' effectiveness in rating
the attributes and to limit the differences in physical
measurements. It is also conducted to eliminate any panelist
preferences and to develop the panelists' abilities to
perceive small differences between products. The training is
also conducted to familiarize the panelists with testing
procedures (ASTM, 1981). For QDA tests, it is recommended
that a minimum of six panelists, preferably ten to twelve, be
recruited for training in order to provide replicate
judgements for attribute evaluation (ASTM, 1981). The panelists come together in an open session or focus group in order to generate terminology and definitions of attributes perceived in the category of the product to be studied. There should be reference samples depicting some or all of the attributes of the product, and especially those that will be experienced in the study (Pangborn, 1984). The training sessions are led by a panel leader who facilitates the terminology development and assists in training for testing procedures. However, they do not have any input into the development of terminology or the definitions of product attributes (Stone, 1992). It is suggested that the more training sessions involved in QDA, the more consistent the panelists' scoring will be on the attributes (ASTM, 1981).

During the training session, the panelists develop a scorecard which has the perceived attributes in the order in which they are encountered by the panelist upon testing (Stone, 1992). The scorecard consists of "name, date, appropriate designation for product code and serving order, and a list of the attributes that were developed in the language development sessions." The scale is an unstructured line scale, approximately 6-inches in length with two anchor points 0.5 inches from either extreme end of the scale. One can also use a 15-cm scale with the anchor points 2.5 cms from the ends. The panelists mark a vertical line anywhere on the
scale which is representative of the perceived intensity of the attribute (Stone et al., 1974). For statistical analysis, the mark is assigned a numerical value upon measuring its distance from the far left end of the scale (Stone, 1992).

2.5.2 Central Location Testing

Consumer acceptance tests relate perceived attribute ratings with the consumer's perceived degree of excellence (Cardello, 1993). As compared to trained panelists who agree or disagree in magnitude of an attribute, consumers agree or disagree in the direction of liking. For new product development to be profitable, there needs to be a reliable, efficient, and representative sampling of consumer opinion (Amerine et al., 1965). An acceptance test will discover whether or not the participant would buy or use the product. It is different from preference in that a consumer may be interested in a product but, would not necessarily purchase it (Seaman et al., 1993). The results of an acceptance test can then be used to infer the degree of preference for the product (Meilgaard et al., 1991). One consumer test is a CLT or central location test (The Sensory Evaluation Division of the Institute of Food Technologists, 1981).

2.5.2.1 Panelists

A large number of respondents is needed who are untrained
to be a representative sample of the targeted population for the consumption of the product (The Sensory Evaluation Division of the Institute of Food Technologists, 1981). The sampling is usually based on previous usage of the product, the number and age of family members, occupation, economic or social level, and geographic area. The selection of participants is also based on their willingness to participate in the study (Seaman et al., 1993). The minimum amount of participants should be somewhere between 50 and 100 per test location in order to obtain a preliminary idea to the consumer acceptability (Katz, 1994). However, no matter how large the sampling is, the participants are not going to accurately represent a "full cross-section" of any population. The data from the study should therefore, be interpreted statistically with caution (Seaman et al., 1993).

2.5.2.2 Rating Scale

A hedonic rating scale is used to measure the participants' degree of liking for a food. The participant is asked to identify the descriptor which most describes their reaction to a product (Seaman et al., 1993). The use of this scale is recommended due to the ease of its understanding by evaluators. A hedonic scale often used is one in which consecutive integral scores are assigned to increasing hedonic categories. Analysis of variance is used on the numerical
scores of the hedonic categories in order to determine any significant differences between products (Amerine et al., 1965). The scale is a 9-point scale with 1="dislike extremely" to 9="like extremely" or vice versa (Meilgaard et al., 1991).

2.5.2.3 Testing Procedures

The Sensory Evaluation Division of the Institute of Food Technologists (1981) states that the samples can be presented either singly or paired with the control for evaluation. The participants should only be instructed on the basic mechanisms of the test procedure (Brennan, 1980).

2.5.3 Sources of Error in Sensory Evaluation

According to Gacula et al. (1986), there may be problems with the questionnaire form or any wording; halo effects; positional biases; or psychological or physiological characteristics of the participants. There may also be problems with contrast effects; motivation and expectations of the evaluators (Larmond, 1977). When considering trained panelists, there might be perceptual differences that could cause incorrect results (Tragon Corporation, 1994).
Chapter 3
Materials and Methodology

3.1 Experimental Design

A 3x3x1 incomplete block design was used in this study. There were three types (3) of carbohydrate-based fat replacers times (x), three rates (3) of fat substitution times (x), and the control. The study was carried out over a seven and a half week period.

A baking powder biscuit formula derived from Hogbin and Fulton (1992) was used as the control formula (Appendix A). The levels chosen for fat substitution were 0% (control), 33%, 66%, and 100% fat replacement. These levels were chosen for equal intervals of fat replacement in the biscuit formula (Appendix A).

Four biscuit variations were produced during each block, and were repeated six times, during the course of the study (Appendix B).

3.2 Ingredients for Biscuit Formulation

A low protein soft wheat biscuit flour (Southern Biscuit All-Purpose Flour®) was sifted with salt (Morton Iodized Salt®), baking powder (Calumet Double-Acting Baking Powder®), and if applicable a fat replacer (TrimChoice-5®, Slendid®, or KEL-LITE BK®) and gums (TICAXAN® Xanthan gum and Guar gum). Vegetable shortening (Crisco All Vegetable Shortening) and
skim milk were added to the respective formula. All ingredients except for the fat replacers and gums were purchased locally (Appendix C).

3.3 Manipulation of Biscuit Dough

The biscuits were produced in a climate controlled laboratory of approximately 70 degrees F at Virginia Polytechnic and State University, Blacksburg, VA. All formulations were manipulated based on the AACC approved method for "Biscuit Baking Without Self-Rising Flour" (AACC, 1989). One level of fat substitution was used throughout the entire study. All dry ingredients were weighed using a top load balance (Fisher Scientific XL-500 Top Load Balance #13028824, Denver Instrument Company, Arvada, CO). The dry ingredients were weighed out twice in order to produce a double batch of biscuits. All dry ingredients, including fat replacers and gums were weighed out and sifted together one batch at a time into a stainless steel mixing bowl. The solid shortening (when applicable), was added to the dry ingredients and mixed using a KitchenAid Heavy Duty Mixer (K5SS, St. Joseph, MI) with a flat beater attachment for ten seconds (GraLab Universal Timer, #191 Dimco-Gray Company, Dayton, OH). All mixing was done at speed one. The blade and sides of the bowl were scraped with a rubber spatula (RubberMaid Inc., Wooster, OH) before proceeding. The mixture was mixed for
three minutes. The milk was added to the dry ingredients. The level of milk was increased in the fat substituted variations due to hydrocolloids competing with the starches and proteins in the gluten complex for the liquid present (Miller and Setser, 1982). The increased amount of milk was determined upon a trial basis. The mixture was mixed for fifteen seconds. The blade and bowl were scraped. All fat replaced variations were left in the mixing bowl to hydrate for ten minutes. The dough was placed onto a heavily floured surface, kneaded seven times and reformed into a ball. The dough was rolled to 0.5 inch thickness using square wooden dowels as guides. A metal biscuit cutter with a 6.9 cm diameter was used to form the biscuits. Remaining dough was gently reshaped and formed into biscuits. Raw biscuit samples were arranged on a metal cookie sheet (AirBake Insulated Cookie Sheet #805, The Mirro Company, Manitowoc, WI) which was placed on the middle rack of a preheated 450 degree F standard household oven (General Electric Conventional Oven, J245007WH10, Louisville, KY). After fourteen minutes bake time, the biscuits were removed from the oven and placed on a wire cooling rack.

3.4 Physical Properties

The physical properties which were measured in this study were degree of expansion upon baking; crust color; tenderness;
degree of softness; percentage moisture content; degree of staling at 24 and 48 hours after baking; and caloric content. All physical measurements were conducted after the biscuits had cooled for one hour (Matthews and Dawson, 1963).

3.4.1 Degree of Expansion

The degree of expansion of the biscuit was determined by the change in volume (Appendix D). A caliper (West Germany), was used to measure height and diameter of the biscuit before and after baking (Appendix D). The following formula was used to compute volume:

\[ \text{Volume} = \frac{22}{7} r^2 h \]

where \( r \) = radius and \( h \) = height (Minor and Denney, 1972).

3.4.2 Texture

A Stevens-LFRA Texture Analyzer TA-100 (Texture Technologies, Scarsdale, NY) was used to measure the external and internal texture of the biscuit (Appendix E). The analyzer was set at a normal cycle, a speed of 2.0 mm/second, and at a distance of 4mm and 5mm for the crust and crumb, respectively. These were determined during pilot work. A 0.5 inch in diameter probe was used for analysis. For crust analysis, the biscuit sample was placed top crust up on the load cell. The bottom half of the biscuit was used for determining the compressibility of the internal crumb.
3.4.3 Moisture

The Brabender Moisture Tester (C.W. Brabender Instruments Inc., South Hackensack, NJ); was used to determine moisture content of the biscuit samples (Appendix F). Ten grams were used for the analysis (Satorius Portable Top Load Balance PT1200, Bohemia, NY). Samples were dried for at least one and a half to two hours or until equilibrium was reached. The percent (%) of moisture in the biscuit was then determined.

3.4.4 Degree of Staling

An adapted procedure of Zeleznak and Hoseney (1986) was used to determine the degree of staling by exothermic reactions in the biscuits after 24 and 48 hours of storage (Appendix G). A Differential Scanning Calorimeter [(DSC), Perkin-Elmer, Norwalk, CT]; was used for determining the degree of staling in the biscuits. The DSC is connected to a Perkin-Elmer Thermal Analysis Data Station (Perkin-Elmer, Norwalk, CT) for data analysis. An indium standard was used as the reference. Approximately a thirty (30) milligram sample was taken from the biscuit crumb and enclosed in a sample pan. The enthalpies measuring the dissociation of the amylopectin bonds formed upon retrogradation were determined by the area of the first endotherm peak. This area is obtained by constructing a baseline, "a smooth line from beginning to end of the endotherm," and calculating the area
between the baseline to the endotherm's peak (Kugimiya and Donovan, 1981).

3.4.5 Color

A Hunter Lab L Optical Sensor 45/0, D-25 PC 2 (HunterLab, Reston, Virginia) which was connected to a Toshiba T1000 System Unit (Tokyo, Japan, #PA 7027U) was used to measure crust and crumb color of the biscuits (Appendix H). The instrument measures the L and b values of the product. "L" measures the degree of lightness (black, grey, and white) while "b" measures blue/yellow hues (Clydesdale, 1984).

3.4.6 Total Caloric Value

To determine the total caloric value of each biscuit variation, a Parr Adiabatic Calorimeter (Parr Instruments Co., Moline, IL), which was located in the Department of Fishery and Wildlife, Virginia Polytechnic Institute and State University, was used (Appendix I). Approximately one gram of the sample was formed into a pellet using a Parr Pellet Maker (Moline, IL). An oxygen bomb chamber was assembled using a Parr 45C 10 nickel-chromium fuse wire which was attached to the metal electrodes of the upper section of the bomb. The chamber was filled with oxygen to 30 atmospheres of pressure. The sample was ignited after an initial temperature reading and timed for eight minutes.
The determined kcal per 100 gram of sample was compared to the calculated kcal per 100 grams of an edible fast food plain biscuit sample (Dickey and Weihrauch, 1988). The caloric content of a refrigerated plain baked biscuit was 373 kcal or 1,563 kJoules per 100 grams.

3.5 Sensory Evaluation

3.5.1 Modified Quantitative Descriptive Analysis (QDA)

The Sensory Evaluation Division of the Institute of Food Technologists suggests (1981) using a descriptive method when correlating sensory results with physical and chemical measurements. Modified QDA is a test method that consists of a laboratory evaluation of product differences by identifying and quantifying sensory characteristics. Seven panelists from the faculty and student body of Virginia Polytechnic Institute and State University were recruited for the QDA panel.

3.5.1.1 Training

Training is needed to produce an efficient and reliable panel. Amerine et al. (1965) state that evaluations of a properly trained panel come very near to the limiting errors of objective measurements. The procedures used to train the seven panelists are located in Appendix J. According to the procedures suggested by Moskowitz (1985), the panelists were
introduced to the control biscuit and the variations from the actual study. The panel along with the supervision of a facilitator, developed terms to accurately and precisely describe the characteristics of the samples. The panelists then agreed upon the terms once they were defined and understood (Piggott, 1991).

3.5.1.2 Testing Procedures

The scale used for each attribute was an unstructured interval scale. The scale was six inches in length with anchors 0.5 inches from each end. The anchors were words or expressions which were determined by the panel as extremes of the attributes. An example of the scorecard which was developed and used is located in Appendix K. The testing procedures used at each test session are described in Appendix L.

3.5.2 Consumer Acceptance

For a representative sample of the inhabitants of the Appalachian region, the consumer acceptance test was conducted at a central location point (Wades Supermarket, South Main Street Blacksburg, VA). The supermarket was chosen due to its position away from the shopping area greatly influenced by the university faculty and students. The expectation then was that this store's consumers would be local residents who are
native Appalachians, and who are familiar with a Southern-style baking powder biscuit.

3.5.2.1 Testing procedures

The control biscuit formulation and the oat-based replacer at 33% and 66% fat replaced levels were chosen because they were the most representative of the ideal baking powder biscuit as determined by the QDA testing results (Tables 7-10). If the formulations were not acceptable to the consumer, then it would be useless for a restaurant or food company to continue to develop, improve upon, and promote these fat replaced biscuits. The testing procedures used for this study are described in Appendix M.

A 9-point hedonic rating scale was used for this study (Appendix N). This scale is a measure of the degree of liking for a product which infers acceptance and preference for a product (The Sensory Evaluation Division of the Institute of Food Technologists, 1981). The scorecard (Appendix N) contained an informed consent paragraph and the 9-point scale ranging from 9="like extremely" to 1="dislike extremely". Comments were also written on the scorecard. A questionnaire was developed to obtain demographic information on the evaluator (Appendix N): sex, age, ethnic background, educational background, yearly household income, native region most associated with, and their familiarity with Southern-
style cake-like biscuits. Participants were also asked their opinion on biscuits as a high source of fat; general attitude toward biscuits; frequency of biscuit consumption; familiarity with biscuits made with lard; concern with dietary fat; and would they choose a low fat biscuit with similar attributes of the one they sampled.

3.6 Statistical Analysis

Statistical analysis was conducted using the Statistical Analysis System (SAS Institute Incorporated, SAS Circle, Box 8000, Cary, NC) (Appendix 0). Objective test analysis included analysis of variance (ANOVA) and Fisher's Least Significant Difference (LSD) for the determination of significant interactions among overall means. QDA panel data analysis included ANOVA which was conducted on each attribute and LSD which was conducted on the overall means to determine any significant interactions. A p-value of 0.05 was used for determining significant levels. The means of the attributes were used to determine two of the most ideal fat replaced biscuit variations for the consumer acceptance test.

The consumer acceptance results were converted into numerical values with 1.0="dislike extremely" and 9.0="like extremely." ANOVA was conducted on the scores of the three formulations to determine any significant differences in acceptance. A p-value of 0.05 was used for significant
levels. These results indicated the most acceptable level of a fat replaced, oat-based, baking powder biscuit for use in the Appalachian diet.
Chapter 4

Results and Discussion

4.1 Degree of Expansion

Upon manipulation and the addition of moisture to the flour, gluten forms a network in the dough. Upon heating, a rigid structure forms which entraps gases produced from the leavening agents and water vapor (Bennion, 1985). The cell structure of the finished product is then formed. Baking powder has been observed to cause a spreading and flattening of biscuits upon baking (Sultan, 1977). Brennan (1980) indicates that the volume of a product can be used as a measure of openness in its structure. The degree of expansion can be measured by utilizing the formula for the volume of a cylinder (Appendix D).

4.1.1 Change in Volume upon Baking

Table 1 shows that only the pectin-based (Slendid\textsuperscript{®}) and oat-based (TrimChoice-5\textsuperscript{®}) 33% biscuit formulation exhibited a significant (p<0.05) increase in volume when compared to the full fat biscuit (control). The control may have not expanded due to the weakening/tenderizing of the gluten-protein structure by the fat (Orthoefer and McCaskill, 1992). The 66% and 100% biscuit formulations had gums incorporated into the formula which produced an increase in volume, but not to a significant degree.
Table 1: Volume Changes in Fat Substituted Baking Powder Biscuits Before and After Baking.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean Volume (cm³) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>59.5a ± 22.3</td>
</tr>
<tr>
<td>Pectin-based 33%*</td>
<td>79.5b ± 9.4</td>
</tr>
<tr>
<td>Pectin-based 66%</td>
<td>60.5a ± 20.9</td>
</tr>
<tr>
<td>Pectin-based 100%</td>
<td>67.7a ± 19.2</td>
</tr>
<tr>
<td>Gum-based 33%*</td>
<td>57.3a ± 18.2</td>
</tr>
<tr>
<td>Gum-based 66%</td>
<td>64.8a ± 10.6</td>
</tr>
<tr>
<td>Gum-based 100%</td>
<td>68.3a ± 9.3</td>
</tr>
<tr>
<td>Oat-based 33%*</td>
<td>89.5b ± 16.6</td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>71.1a ± 17.9</td>
</tr>
<tr>
<td>Oat-based 100%</td>
<td>72.6a ± 17.4</td>
</tr>
</tbody>
</table>

n=6

*Slendid®=citrus peel; Kel-Lite BK®=xanthan gum, guar gum, cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides; and TrimChoice®=beta-glucans and low dextrose equivalent maltodextrins.

+ Mean scores with the same letter denote no significant differences at p>0.05 as compared to the control.

#Value represents mean ± SD
The hydrocolloids contribute to the increase in dough viscosity because of their water-binding properties. The pectins and oat fibers can become hydrated by water and form a gel matrix with the entrapped water (Schneeman, 1986). As stated (Anonymous, 1992c), "Hydrocolloids play an essential role in an oil replacer system and in caloric reduction due to their viscosity, lubricity, and ability to bind about 100 times their weight in water." The pectin and oat fibers along with the increased amount of milk were significant enough in amount to produce a highly viscous solution which would retain the gases produced upon heating. Therefore, these substitution levels were able to increase the dough’s expansion.

The added xanthan and guar gums in the 66% and 100% formulations may have competed with the starch for the water which in turn, may have caused a slight expansion of the dough upon baking (Miller and Setser, 1982). The gums may have produced a synergistic effect on the ability of the hydrocolloids to cause expansion of the dough. Xanthan gum bound with gelatinized starches in the gluten-protein structure of bread was observed to form a complex-like lattice structured wall which retained produced gases upon heating (Miller and Setser, 1982). This retention of gases produces an increase in volume and a finer cell structure.

The gum-based replacer (Kel-Lite BK²) produced an
increase in volume to a lesser degree as compared to the pectin and oat-based substitutes. Some of the emulsifiers present in the gum-based substitute, such as lecithin and mono and diglycerides, are known to tenderize and weaken gluten structures (Orthoefer and McCaskill, 1992). This weakened structure may prevent full retention of the gases that were noted in the starch-xanthan gum and gluten-protein complexes.

4.2 Biscuit Crust and Crumb Tenderness

The degree of tenderness or texture is in part attributed to the gluten-protein structure which develops upon the hydration of the flour (Medved, 1986). When these two ingredients combine, the gluten forms a strong elastic film around gelatinized starch granules. Upon heating, the gluten is coagulated into its structure. The gluten provides elasticity and viscosity to the dough and the starch contributes plasticity. Chemical leaveners produce thick cell walls which can cause firmness of texture (Hoseney, 1988). Fat present in a biscuit forms a film around the flour so that it can not hydrate, preventing the gluten-protein interaction (Pyler, 1973). Yamazaki (1987) states that the lower protein content in a soft wheat flour will also contribute to a product’s tenderness.

Tenderness is an indication of the degree of firmness/softness upon the application of a force. Texture
measurement is based on the degree of sample deformation or resistance of the sample to such deformation (Brennan, 1980). When measuring texture, some factors may cause misinterpretation: a dull knife used to cut the sample; a misaligned probe or cell causing frictional resistance; or improper standardization of the equipment (Brennan, 1980).

Crust and crumb tenderness was measured on the biscuit variations (Table 2). All of the 33% substituted formulations had significantly (p<0.05) softer crusts than the control. Crusts for all treatments required less force per gram than the control with the exception of the gum-based 100% variation. The soluble fibers and low concentrations of gums in the substitutes retained some of the water within their viscous matrixes (Anonymous, 1992d). According to Bakshi and Yoon (1984) there is a rapid loss in moisture upon heating which is curtailed by the formation of a hard surface layer entrapping the remaining liquid. The water may have remained in this hydrocolloid network providing a softer crust. The pectin-based 66% substitution produced a biscuit with significantly (p<0.05) softer crust. The gum-based 100% variation produced a significantly (p<0.05) firmer crust. This firm crust could be partially due to a point at which the amounts of soluble fibers present require more liquid than is present for hydration. Miller and Setser (1982) observed that starch and xanthan gum in a cake batter will compete for
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crust Tenderness (force/gm)</th>
<th>Crumb Tenderness (force/gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>569.0a ± 103.9</td>
<td>406.8a ± 153.5</td>
</tr>
<tr>
<td>Pectin-based 33%*</td>
<td>379.8b ± 136.9</td>
<td>345.3a ± 82.3</td>
</tr>
<tr>
<td>Pectin-based 66%</td>
<td>377.9b ± 138.2</td>
<td>275.7b ± 101.6</td>
</tr>
<tr>
<td>Pectin-based 100%</td>
<td>553.2a ± 234.1</td>
<td>343.7a ± 136.5</td>
</tr>
<tr>
<td>Gum-based 33%*</td>
<td>277.6b ± 65.7</td>
<td>216.4b ± 79.6</td>
</tr>
<tr>
<td>Gum-based 66%</td>
<td>481.6a ± 107.1</td>
<td>305.9b ± 96.0</td>
</tr>
<tr>
<td>Gum-based 100%</td>
<td>873.5c ± 206.4</td>
<td>316.0b ± 58.1</td>
</tr>
<tr>
<td>Oat-based 33%*</td>
<td>318.5b ± 100.2</td>
<td>281.0b ± 88.8</td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>497.8a ± 131.2</td>
<td>350.9a ± 88.5</td>
</tr>
<tr>
<td>Oat-based 100%</td>
<td>493.9a ± 183.0</td>
<td>257.5b ± 85.9</td>
</tr>
</tbody>
</table>

n=6

*Slendid®=citrus peel; Kel-Lite BK®=xanthan gum, guar gum, cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides; and TrimChoice-5®=beta-glucans and low dextrose equivalent maltodextrins.

* Mean scores within the same column with the same letter denote no significant differences at p>0.05 as compared to the control.

#Value represents mean ± SD
water for hydration. If there is insufficient liquid, the gums may not be able to hydrate enough to provide needed textural components of a product (Igoe, 1982). There may have been a need in this biscuit for an increased amount of milk, greater than the 195 mls. A firm crust could also be due to the baking process. The water present in the surface of the gluten-protein network evaporates, decreasing surface moistness and producing a crust (Medved, 1986).

Generally, a softer crumb was the result when compared to the control (Table 2). All levels of the gum-based replacer produced a significantly (p<0.05) softer crumb than the control. The increase in crumb softness maybe due to three factors: the level of xanthan and guar gums present in the formulation; the emulsifiers, such as mono and diglycerides and lecithin; and the increased level of milk. The gums are able to retain moisture in the dough during dough manipulation and baking. The emulsifiers are known to function as crumb softeners. When used together for synergistic effects, an improved texture and tenderness in the product results (Anonymous, 1992d).

In the oat-based products, the 33% and 100% formulations were significantly (p<0.05) softer than the control. The 33% had some fat to contribute to softness, but with the 100% this was not the situation. Perhaps, the functional properties of the soluble oat fibers especially the beta-glucans, are able
to bind more water within its fibrous network increasing moisture retention and improve tenderness (Kapica, 1993).

The pectin-based formulation showed a significance (p<0.05) at the 66% level. This formulation also had gums added. This combination appeared to produce a softer product with the combination of the pectin, xanthan, and guar all interfacing and trapping the water within the dough. Pectin is one of the few hydrocolloids which produces a true gel matrix with the ability to entrap large amounts of water (Schneeman, 1986).

Generally, the substituted formulas all produced a crumb which was softer than the control. This is surprising due to the percentage and type of fat used in the control. The formula contained an emulsified shortening. One function of the fat is tenderizing and emulsifiers ensure an increased and uniform dispersion of the fat (Pyler, 1973). The results may not have been very reproducible due to the high level of standard deviations. These values may be the results of variability in the samples such as irregular crust contours, biscuit volume, and the degree of crumb height used for measuring the crumb tenderness.

4.3 Percentage Moisture Content

It has been established in the previous sections that the gluten-protein network is developed upon kneading and binding
of water within the gluten-protein structure. The liquid is also used for the gelatinization of starches (Bennion, 1980). Medved (1986) states this structure is able to absorb one fourth its weight in water. Soft wheat flour also has the attribute of being able to absorb and retain moisture upon baking (Sultan, 1986). However, as the dough is exposed to high heat, some of the moisture evaporates helping to form the cell structure of the biscuit (Pyler, 1973). Hydrocolloid fat substitutes increase moisture retention of the dough throughout the baking process (Glicksman, 1982b). The moisture is immobilized in a rigid gelation network.

Moisture content increased significantly (p<0.05) in all biscuits regardless of the type or the amount of the substitute (Table 3) as compared to the control. In the fat substituted variations, the added milk (195 mls) as compared to the control (160 mls) may have contributed to the increase in moistness. As the amount of added gums increased, more moisture was bound and prevented from evaporating during heating. The pectin and gum-based substitutes were more efficient in trapping and holding the water during the baking process. This could be in part due to pectin’s and xanthan’s great water holding capacities upon baking (Schneeman, 1986; Miller and Setser, 1982). In the gum-based substitutes, the emulsifiers may have attributed to some moisture retention. Sobczynska and Setser (1991) state that mono- and diglycerides
Table 3: The Effect of Fat Substitutes on the Percent Moisture Content in Baking Powder Biscuits

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Moisture (%)*#</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>33.8a ± 0.5</td>
</tr>
<tr>
<td>Pectin-based 33%*</td>
<td>38.8b ± 0.5</td>
</tr>
<tr>
<td>Pectin-based 66%</td>
<td>40.6b ± 0.7</td>
</tr>
<tr>
<td>Pectin-based 100%</td>
<td>42.2b ± 0.9</td>
</tr>
<tr>
<td>Gum-based 33%*</td>
<td>39.1b ± 0.6</td>
</tr>
<tr>
<td>Gum-based 66%</td>
<td>40.1b ± 0.8</td>
</tr>
<tr>
<td>Gum-based 100%</td>
<td>42.9b ± 0.7</td>
</tr>
<tr>
<td>Oat-based 33%*</td>
<td>38.7b ± 0.7</td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>40.0b ± 0.8</td>
</tr>
<tr>
<td>Oat-based 100%</td>
<td>42.4b ± 0.8</td>
</tr>
</tbody>
</table>

n=6

*Slendia®=citrus peel; Kel-Lite BK®=xanthan gum, guar gum, cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides; and TrimChoice-5®=beta-glucans and low dextrose equivalent maltodextrins.

*Mean scores with the same letter denote no significant differences at p>0.05 as compared to the control.

#Value represents mean ± SD
also assist in retaining moisture.

### 4.4 Differential Scanning Calorimetry

Staling or retrogradation is caused by the rigid realignment of amylose and amylopectin molecules (Bennion, 1980). Zhang and Jackson (1992) state most staling is due to amylopectin realignment. Labuza (1982) attributes a faster staling rate to a weak protein flour.

Staling is measured using a differential scanning calorimeter (DSC). According to Lund (1983), the DSC measures the difference between enthalpy changes in a sample and an inert reference material. As retrogradation increases, an endothermic peak can be observed as the temperature rises. This peak measures the degree of starch crystallinity (Labuza, 1982). The major endotherm peak is observed to be the melting of the retrograded amylopectin (Zeleznak and Hoseney, 1986). Zhang and Jackson (1992) reported the melting temperature for amylopectin crystallization is approximately 55 degrees C. Peak area is proportional to the heat enthalpy required for the melting of amylopectin crystallites.

Staling, particularly from amylopectin crystallinity, in all variations was examined at 24 and 48 hours intervals (Figure 1, 2, and 3). The control biscuit had the least amount of staling when compared to the other variations (Figure 1, 2, and 3). This was probably credited to the monoglycerides and
Figure 1. Amylopectin peak areas derived from the effects of fat substitutes at a 33% level on the staling rate (24-48 hours) in baking powder biscuits.
Figure 2. Amylopectin peak areas derived from the effects of fat substitutes at a 66\% level on the staling rate (24-48 hours) in baking powder biscuits.
Figure 3. Amylopectin peak areas derived from the effects of fat substitutes at a 100% level on the staling rate (24-48 hours) in baking powder biscuits.
### Table 4: The Effect of Fat Substitutes on the Staling Rates (24-48 hours) of Baking Powder Biscuits

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean Peak Area-24 hrs.</th>
<th>Mean Peak Area-48 hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.3a ± 1.5</td>
<td>4.4a ± 1.5</td>
</tr>
<tr>
<td>Pectin-based (SL)</td>
<td>3.3a ± 2.5</td>
<td>5.2a ± 0.7</td>
</tr>
<tr>
<td>33%*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pectin-based 66%</td>
<td>2.1a ± 0.4</td>
<td>5.4a ± 1.4</td>
</tr>
<tr>
<td>Pectin-based 100%</td>
<td>4.7b ± 0.9</td>
<td>7.1b ± 1.0</td>
</tr>
<tr>
<td>Gum-based (KL)</td>
<td>3.2a ± 0.7</td>
<td>4.5b ± 0.4</td>
</tr>
<tr>
<td>33%*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gum-based 66%</td>
<td>2.2a ± 1.7</td>
<td>5.0a ± 0.8</td>
</tr>
<tr>
<td>Gum-based 100%</td>
<td>5.9b ± 3.2</td>
<td>8.4b ± 1.3</td>
</tr>
<tr>
<td>Oat-based (OT)</td>
<td>3.5a ± 1.4</td>
<td>5.8a ± 1.9</td>
</tr>
<tr>
<td>33%*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>2.9a ± 0.8</td>
<td>5.1a ± 0.3</td>
</tr>
<tr>
<td>Oat-based 100%</td>
<td>6.5b ± 2.1</td>
<td>8.2b ± 1.5</td>
</tr>
</tbody>
</table>

n=3

*Sleendig™=citrus peel; Kel-Lite®=xanthan gum, guar gum, cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides; and TrimChoice®=beta-glucans and low dextrose equivalent maltodextrins.

*Mean scores with the same letter denote no significant differences at p>0.05 as compared to the control.

*Value represents mean ± SD
other lipid components of the shortening forming complexes with the amylose. This formation may prevent the amylose and amylopectin from forming crystal structures which forces the water out of the protein-starch matrix and leads to firming of the crumb (Blenford, 1994; Medved, 1986).

 Generally, the 33% and 66% substituted levels had a lower staling rate for all fat substituted varieties (Table 4). These variations may have had a reduction in staling due to the withheld moisture by the hydrocolloids and emulsifiers (Anonymous, 1992d). Zeleznak and Hoseney (1986) reported that some studies determined that water played a significant role in the control of staling. When much moisture was present during retrogradation, the degree of staling decreased to the point of disappearing. The 33% variations staled more than the 66% variations. This could be due to the added xanthan and guar gums in the 66% variations entrapping more moisture.

The 100% variations staled significantly (p<0.05) more than the control with the pectin-based variation staling to a lesser degree than the oat and gum-based variations (Figure 3). The pectin-based variation was probably able to entrap more water than the oat-based or gum-based varieties thereby, preventing the movement of the amylopectin molecules and retarding the staling process (Roberfoird, 1993). The gum-based variation staled the most after the 48 hour period. It is possible that the gum-based variation did not have the
needed emulsifiers or efficient water binding system to retard staling. The figures show that the fat replacers were able to retard some of the staling in the biscuits, but not to the full degree as observed with the control biscuit.

4.5 Biscuit Crust Color

According to Clydesdale (1993), color affects the aesthetics, safety, sensory attributes, and acceptability of foods. Color also affects other perceived sensory characteristics such as flavors, textures, and odors. The color of the crust is associated with the pH of the dough and the Maillard browning reaction (Bennion, 1980). An alkaline batter will produce a yellowish crust color. A brownish-yellow color is characteristic of the Maillard reaction which involves the lactose in the milk with the proteins in the flour and milk (Bennion, 1980). Dextrinization of the surface flour particles could also participate somewhat in crust browning (Medved, 1986).

The L and b values were used for evaluation of color. The L value measures the degree of lightness (100) to darkness (0) (HunterLab Instrumental Manual, 1990). The pectin and oat-based substitutes at 33% levels did not produce a significantly (p>0.05) lighter crust than the control (Table 5). This could be due to some fat still being present. The gum-based substitute did produce a significantly lighter
**Table 5:** The Effect of Fat Substitutes on the Crust Color of Baking Powder Biscuits

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean L*#</th>
<th>Mean b*#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>72.6a ± 4.3</td>
<td>37.9a ± 3.3</td>
</tr>
<tr>
<td>Pectin-based 33%*</td>
<td>74.5a ± 2.9</td>
<td>38.2a ± 3.6</td>
</tr>
<tr>
<td>Pectin-based 66%</td>
<td>78.9b ± 1.5</td>
<td>32.0b ± 3.1</td>
</tr>
<tr>
<td>Pectin-based 100%</td>
<td>82.6b ± 1.2</td>
<td>23.6b ± 1.2</td>
</tr>
<tr>
<td>Gum-based 33%*</td>
<td>77.2b ± 3.5</td>
<td>37.4a ± 4.1</td>
</tr>
<tr>
<td>Gum-based 66%</td>
<td>81.3b ± 1.1</td>
<td>29.5b ± 2.9</td>
</tr>
<tr>
<td>Gum-based 100%</td>
<td>82.6b ± 1.9</td>
<td>22.1b ± 3.3</td>
</tr>
<tr>
<td>Oat-based 33%*</td>
<td>74.3a ± 2.3</td>
<td>40.2a ± 4.8</td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>78.3b ± 2.4</td>
<td>32.7b ± 3.3</td>
</tr>
<tr>
<td>Oat-based 100%</td>
<td>82.2b ± 0.8</td>
<td>23.5b ± 2.4</td>
</tr>
</tbody>
</table>

n=6

*Slendid®=citrus peel; Kel-Lite BK®=xanthan gum, guar gum, cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides; and TrimChoice-5®=beta-glucans and low dextrose equivalent maltodextrins.

* Mean scores within the same column with the same letter denote no significant differences at p>0.50 as compared to the control.

L=lightness(100) and darkness (0) and b=yellow(+70) and blue(−80).

*Value represents mean ± SD
crust (p<0.05) at all levels. This replacer may cause a decrease in the alkaline pH of the dough. The lighter crust color could be attributed to the hydrocolloids affecting the alkalinity of the dough. The hydrocolloids and gums may have contributed proteins and sugars to the Maillard reaction. According to literature these fat replacers and gums are pH and temperature stable (Whistler, 1969 & 1985; Kelco, Division of Mereck & Co., Inc., 1992b; Duxbury, 1990). However, a tendency was observed whereby, the lightness of the crust was influenced by increased levels of the fat substitute.

The b value indicates the degree yellowness (+70=yellow and -80=blue) in the crust (HunterLab Instrumental Manual, 1990; Francis and Clydesdale, 1975). All 33% formulation levels were similar (p>0.05) in degree of yellowness to the control (Table 5), but the b values for the pectin and oat-based 33% levels were higher than the control. The gum-based variation was less yellow. All 66% and 100% substitute levels were significantly (p<0.05) less yellow than the control. This could be due to the hydrocolloids reducing the alkalinity of the dough which in turn will produce a lighter yellow crust.

4.6 Bomb Calorimetry

In bomb calorimetry, the heat of combustion (caloric content) is determined by the burning of a weighed sample in
an oxygen-bomb calorimeter under controlled conditions (ASTM, 1979). The amount of energy obtained from a fuel is calculated from the temperature observations before, during, and after combustion with allowances for thermochemical and heat transfer corrections. Energy given off is recorded in kcalories of Joules (1 calorie = 4.1868 Joules). According to Wunderlich (1990), an adiabatic calorimeter has the highest precision in determining caloric content due to the fact it heats the sample continuously.

An increase in fat substitution levels (Table 6) caused a significant decrease (p<0.05) in the caloric content of the variations when compared to the control. The 33% fat replacement produced a 12-15% caloric reduction as compared to the control. The 66% replacement produced a 18-23% caloric reduction, while the 100% produced a 30-33% caloric reduction. The fat replacers were able to reduce the caloric value of the biscuits by replacing the calories from the fat with a lower caloric contribution of approximately 1 to 4 cal/gram (Anonymous, 1993a; Hercules Incorporated Fragrance & Food Ingredients Group, 1993; and Anonymous, 1992b).

The caloric results of the fat substituted variations were actually an over-estimation of the calories that would be available for human use. The fat replacers contain soluble fibers which are non-digestible upon human consumption, but do provide calories upon combustion.
Table 6: The Effect of Fat Substitutes on the Caloric Content of Baking Powder Biscuits

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean Kcal/100 Gram of Sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>389.9a ± 0.6</td>
</tr>
<tr>
<td>Pectin-based 33%*</td>
<td>334.9b ± 8.2</td>
</tr>
<tr>
<td>Pectin-based 66%</td>
<td>298.2b ± 13.0</td>
</tr>
<tr>
<td>Pectin-based 100%</td>
<td>258.7b ± 0.0</td>
</tr>
<tr>
<td>Gum-based 33%*</td>
<td>331.3b ± 4.5</td>
</tr>
<tr>
<td>Gum-based 66%</td>
<td>321.1b ± 6.4</td>
</tr>
<tr>
<td>Gum-based 100%</td>
<td>269.5b ± 4.6</td>
</tr>
<tr>
<td>Oat-based 33%*</td>
<td>344.7b ± 10.8</td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>302.9b ± 5.7</td>
</tr>
<tr>
<td>Oat-based 100%</td>
<td>264.3b ± 0.2</td>
</tr>
</tbody>
</table>

n=6

*Slendidi* = citrus peel; Kel-Lite BK = xanthan gum, guar gum, cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides; and TrimChoice-5 = beta-glucans and low dextrose equivalent maltodextrins.

+ Mean scores with the same letter denote no significant differences at p>0.05 as compared to the control.

#Value represents mean ± SD
4.7 Perceived Degree of Browning

Color, an optical property, incorporates visual color and surface appearance. It is also one of the most important quality attribute which can affect a consumer's perception (Szczesniak, 1983). Color is important for its aesthetic value, sense of quality, and degree of acceptability of a food (Clydesdale, 1993). According to Brennan (1980), color can also affect a food's perceived flavor.

Panelists evaluated the degree of browning for all biscuit treatments. The panelists determined the control had the most intense degree of browning (Table 7). This could be due to the combination of the lactose reacting with the milk and flour proteins in the Maillard reaction; and possibly the dextrinization of the flour particles. The panelists perceived a decrease in browning as the percentage of fat replacement increased. The gum-based 33% level produced a lighter biscuit as compared to the other 33% substitutes. This could be due to gums and emulsifiers producing a more acidic dough. An acidic dough would produce less of a yellow color (Bennion, 1980). They may also have interfered in the Maillard browning reaction by producing a film around the proteins and sugars or prevented the dextrinization of the starches (Orthoefer & McCaskill, 1992). The fat replacers and gums may have contributed some sugars and proteins to the
Table 7: The Effect of Fat Substitutes on the Perceived Degree of Browning of Baking Powder Biscuits

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Perceived Browning†/**/#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>9.0a ± 1.2</td>
</tr>
<tr>
<td>Pectin-based 33%*</td>
<td>8.4a ± 1.7</td>
</tr>
<tr>
<td>Pectin-based 66%</td>
<td>6.7b ± 1.6</td>
</tr>
<tr>
<td>Pectin-based 100%</td>
<td>4.6b ± 1.4</td>
</tr>
<tr>
<td>Gum-based 33%*</td>
<td>8.0b ± 1.0</td>
</tr>
<tr>
<td>Gum-based 66%</td>
<td>6.9b ± 1.3</td>
</tr>
<tr>
<td>Gum-based 100%</td>
<td>4.9b ± 1.6</td>
</tr>
<tr>
<td>Oat-based 33%*</td>
<td>8.5a ± 1.1</td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>7.8b ± 1.6</td>
</tr>
<tr>
<td>Oat-based 100%</td>
<td>5.0b ± 1.4</td>
</tr>
</tbody>
</table>

n=6

*Slendid®=citrus peel; Kel-Lite BK®=xanthan gum, guar gum, cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides; and TrimChoice-5®=beta-glucans and low dextrose equivalent maltodextrins.

** Degree of Browning: the degree of browning of the top crust of the biscuit (0=not brown and 15=very brown).

† Mean scores with the same letter denote no significant differences at p>0.05 as compared to the control.

#Value represents mean ± SD
Maillard reaction. The 66% and 100% substitute levels produced significantly (p<0.05) lighter biscuits than the control. This could be due to the hydrocolloids and emulsifiers suspending proteins and sugars in the crumb so they were not able to participate in the browning reactions.

4.8 Perceived Cell Size

Changes in cell size influence changes in volume upon baking. The shape, size, and distribution of gas cells in the product also affects texture (Taranto, 1983). Cells are formed upon the fat melting and the release of carbon dioxide and water vapor into the protein-gluten structure (LeRoux et al., 1990). The porosity and lightness of a cell structure are also a result of chemical leavener reactions which produce steam and carbon dioxide (Medved, 1986). A fine texture desired in baked goods is composed of a multitude of small to medium sized cells which are close together (Matz, 1987). The control was perceived to have medium crumb cells (Table 8). All variations at the 66% and 100% substituted levels produced significantly (p<0.05) smaller cell sizes as compared to the control. This could be due to the increased levels of hydrocolloids and emulsifiers producing a finer dispersement of the fat-coated gas bubbles. Therefore, there was an increase in the number of air cells and a decrease in their size. According to Birnbaum (1978), this allows for more
Table 8: The Effect of Fat Substitutes on the Perceived Cell Size of Baking Powder Biscuits

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Perceived Cell Size*/<em>/</em>/#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>7.2a ± 1.9</td>
</tr>
<tr>
<td>Pectin-based 33%*</td>
<td>7.4a ± 1.6</td>
</tr>
<tr>
<td>Pectin-based 66%</td>
<td>5.9b ± 2.0</td>
</tr>
<tr>
<td>Pectin-based 100%</td>
<td>4.6b ± 1.7</td>
</tr>
<tr>
<td>Gum-based 33%*</td>
<td>7.2a ± 1.1</td>
</tr>
<tr>
<td>Gum-based 66%</td>
<td>5.7b ± 1.8</td>
</tr>
<tr>
<td>Gum-based 100%</td>
<td>4.1b ± 1.5</td>
</tr>
<tr>
<td>Oat-based 33%*</td>
<td>7.8a ± 1.1</td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>5.8b ± 1.9</td>
</tr>
<tr>
<td>Oat-based 100%</td>
<td>4.6b ± 1.5</td>
</tr>
</tbody>
</table>

n=6

*Slendid®=citrus peel; Kel-Lite BK®=xanthan gum, guar gum, cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides; and TrimChoice-5®=beta-glucans and low dextrose equivalent maltodextrins.

** Cell Size: the size of the cells located in the crumb of the biscuit (0=small cell size and 15=large cell size)

* Mean scores with the same letter denote no significant differences at p>0.05 as compared to the control.

#Value represents mean ± SD
gases to stay dispersed in the product, and thereby producing an increase in volume and a finer grain.

Pectin and oat-based variations at 33% produced similar and significant increases \((p<0.05)\) in volume changes when measured objectively (Table 1). This could be due to the hydrocolloids and emulsifiers of the shortening producing a greater emulsification of air cells in the dough. However, xanthan gum in complex with the starch can form a framework to retain the gases during baking, which then produces coarse cell walls (Miller and Setser, 1982).

4.9 Perceived Cohesiveness, Dryness and Tenderness

These three attributes are linked together by how the product is perceived in the mouth upon mastication. The intensity of one attribute may increase or decrease the intensity of the other attributes. However, in this study, cohesiveness was only defined by one’s sight not by mouthfeel. This may have caused difficulties in differentiating the three attributes in one’s mouth.

Cohesiveness is an attribute describing the mechanical characteristics of a product (Szczesniak, 1983). Brennan (1980) describes cohesiveness as the extent to which a sample can be deformed before it ruptures. A more moist and less tender product can be characterized as being cohesive. Fat contributes to tenderness which in turn produces a less
cohesive crumb (Anonymous, 1992a). Dryness is attributed to the degree of moistness present. It is possible that dryness can be attributed to the absence of the creamy, coated mouthfeel associated with fats (Drewnowski, 1992). Tenderness of a product is also related to the fat and moisture present. Tenderness is related to the degree in which the fat is able to shorten the gluten strands thereby, producing a softer product (Pyler, 1973).

The control was judged by the panelists to be significantly (p<0.05) the least cohesive, the most dry, and the most tender (Table 9). The low cohesiveness and high tenderness can be attributed to the high percentage of fat which weakened the protein-starch structure (Orthoefer & McCaskill, 1992). When fat substitutes were incorporated, there was an overall increase in cohesiveness along with a decrease in both dryness and tenderness.

A significant increase (p<0.05) in cohesiveness is due in part to the hydrocolloids binding the water present and forming a complex with the starch and protein. Kapica (1993) indicates that oat fiber for example, strengthens the dough due to the configuration of unbound cellulose fibers retaining moisture in its network. Gums also contribute to cohesiveness due to their ability to thicken by producing highly viscous solutions (Glicksman, 1982). For instance, guar gum due to its effect on increased moisture retention contributed to a
Table 9: The Effect of Fat Substitutes on the Perceived Cohesiveness, Dryness, and Tenderness of Baking Powder Biscuits

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Perceived Cohesiveness</th>
<th>Perceived Dryness</th>
<th>Perceived Tenderness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+/**/#</td>
<td>+/**/#</td>
<td>+/**/#</td>
</tr>
<tr>
<td>Control</td>
<td>6.6a ± 2.6</td>
<td>10.0a ± 2.0</td>
<td>9.5a ± 2.0</td>
</tr>
<tr>
<td>Pectin-based 33%*</td>
<td>8.0b ± 2.2</td>
<td>8.7b ± 2.2</td>
<td>8.0b ± 2.2</td>
</tr>
<tr>
<td>Pectin-based 66%</td>
<td>9.2b ± 2.1</td>
<td>9.1b ± 1.8</td>
<td>6.6b ± 2.1</td>
</tr>
<tr>
<td>Pectin-based 100%</td>
<td>10.9b ± 2.4</td>
<td>9.3b ± 1.9</td>
<td>4.3b ± 2.4</td>
</tr>
<tr>
<td>Gum-based 33%*</td>
<td>7.3a ± 1.9</td>
<td>9.1b ± 1.8</td>
<td>8.3b ± 1.6</td>
</tr>
<tr>
<td>Gum-based 66%</td>
<td>9.2b ± 1.4</td>
<td>8.8b ± 1.7</td>
<td>6.8b ± 2.0</td>
</tr>
<tr>
<td>Gum-based 100%</td>
<td>11.1b ± 1.7</td>
<td>9.2b ± 2.2</td>
<td>4.4b ± 2.0</td>
</tr>
<tr>
<td>Oat-based 33%*</td>
<td>7.5b ± 1.7</td>
<td>8.7b ± 1.9</td>
<td>7.8b ± 1.7</td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>8.9b ± 2.1</td>
<td>9.1b ± 2.0</td>
<td>6.6b ± 2.3</td>
</tr>
<tr>
<td>Oat-based 100%</td>
<td>11.8b ± 1.3</td>
<td>9.2b ± 1.9</td>
<td>4.1b ± 1.9</td>
</tr>
</tbody>
</table>

n=6

*Slendid®=citrus peel; Kel-Lite BK®=xanthan gum, guar gum, cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides; and TrimChoice-5®=beta-glucans and low dextrose equivalent maltodextrins.

** Cohesiveness: the ability of the biscuit to stay together (no crumbling) as it is broken in half on the plate (0=not cohesive and 15=very cohesive).

** Tenderness: the ease with which the biscuit is penetrated with ones teeth upon chewing (0=not tender and 15=very tender)

** Dryness: the amount of dryness perceived within the mouth (0=not dry and 15=very dry).

+ Mean scores with the same letter denote no significant differences at p>0.05 as compared to the control.

#Values represent mean ± SD
firm crumb that does not crumble upon slicing (Glicksman, 1969).

The ability of these hydrocolloids to retain moisture also affected the panelists’ perception of the biscuits’ dryness. Actually the objective results indicated that the percentage moisture content increased as the amount of hydrocolloids present increased and fat decreased (Table 3). Table 9 shows fat replacement caused panel members to detect moister biscuits. The combination of hydrocolloid and fat at the 33% and 66% levels was found to produce a slightly moister biscuit (p<0.05) than the 100% variations when compared to the control. The gum-based 66% level especially produced a moister biscuit possibly due to the synergistic combination of hydrocolloids, emulsifiers and fat. Emulsifiers such as mono- and diglycerides also have water binding abilities (Sobzynska and Setser, 1991). Within each substitute however, there was an increase in perceived dryness. It is possible that the additional milk (195 mls) was not sufficient at the 66% and 100% levels. The control biscuit would have been perceived to be less dry if the milk level was 195 mls instead of 160 mls.

Tenderness in the biscuits (Table 9) decreased significantly from the control (p<0.05) due to the decrease in fat content and increase in hydrocolloids. Fats and emulsifiers contribute to tenderness and weaken the gluten structure of a product (Orthoefer & McCaskill, 1992). Without
the fat present, the higher fat replaced levels were able to maintain a firm gluten structure. The hydrocolloids also affect the firmness of the starch-protein structure due to their water binding abilities. Glicksman (1982) states that hydrocolloids form three-dimensional continuous networks which entrap and immobilize the water thereby, forming a rigid structure. It is possible that the panelists interrelated the cohesiveness and tenderness of the product, since the results indicate a trend that as the perceived cohesiveness increased, the perceived tenderness decreased.

4.10 Perceived Bitterness

Undesirable flavor in a baking powder biscuit can be partially attributed to the large amount of baking powder (Glissen, 1989). Table 10 indicates that there was an increase in bitterness as compared to the control for some levels of fat substituted biscuits. In the pectin-based variations, the bitterness increased as the fat level decreased with the 100% substituted biscuit being significantly more bitter (p<0.05). This could be due to the fact that fat appears to dissolve certain flavor components, possibly masking some of bitterness (Medved, 1986). It is also possible that the addition of xanthan gum could have contributed to some bitterness (Sanderson, 1981). The gum-based biscuits also increased in perceived bitterness with the
Table 10: The Effect of Fat Substitutes on the Perceived Bitterness of Baking Powder Biscuits

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Perceived Bitterness(^*/**/#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>7.3a ± 2.3</td>
</tr>
<tr>
<td>Pectin-based 33%*</td>
<td>7.6a ± 2.0</td>
</tr>
<tr>
<td>Pectin-based 66%</td>
<td>7.9a ± 2.4</td>
</tr>
<tr>
<td>Pectin-based 100%</td>
<td>8.4b ± 2.6</td>
</tr>
<tr>
<td>Gum-based 33%*</td>
<td>8.0a ± 2.3</td>
</tr>
<tr>
<td>Gum-based 66%</td>
<td>8.5b ± 2.2</td>
</tr>
<tr>
<td>Gum-based 100%</td>
<td>8.5b ± 2.2</td>
</tr>
<tr>
<td>Oat-based 33%*</td>
<td>7.5a ± 1.7</td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>8.5b ± 2.1</td>
</tr>
<tr>
<td>Oat-based 100%</td>
<td>8.0a ± 1.8</td>
</tr>
</tbody>
</table>

\(n=6\)

*Slendid\(^a\)=citrus peel; Kel-Lite BK\(^a\)=xanthan gum, guar gum, cellulose gel, sodium stearoyl lactylate, gum arabic, dextrin, lecithin, and mono and diglycerides; and TrimChoice-S\(^a\)=beta-glucans and low dextrose equivalent maltodextrins.

** Bitterness: the degree of which the bitter taste is perceived after ten chews (0=not bitter and 15=very bitter).

* Mean scores with the same letter denote no significant differences at \(p>0.05\) as compared to the control.

# Values represent mean ± SD
66% and 100% levels being significantly more bitter (p<0.05) than the control. Again, the large amounts of xanthan gum may have been the contributing factor. The oat-based variation was only significantly (p<0.05) more bitter than the control biscuit at the 66% level. It is possible that the oat fiber imparted some bitterness at this level in combination with the xanthan gum. This inconsistency may also be in part due to the panelists having difficulty perceiving and defining bitterness. Tragon Corporation (1994) states that "Even among 'expert panelists,' there are perceptual differences."

4.11 The Determination of the Consumer Acceptance of the Baking Powder Biscuit Formulations

The scores of the QDA attributes for an "ideal" baking powder biscuit were determined as: degree of browning=10, cell size=7.5, cohesiveness=7.5, dryness=0, tenderness=15, and bitterness=0. These "ideal" scores were compared to the given QDA mean scores of all six attributes. It was determined that the oat-based 33% and 66% substitution levels had the attribute mean scores nearest to those of the "ideal" biscuit. The control was included since throughout the entire study all variations were statistically compared to the control.

4.12 Central Location Test

A central location test at a local supermarket in
Blacksburg, VA, was used to determine the acceptance level of the control and the oat-based 33% and 66% biscuit formulations. The acceptance of these formulations among a general population with an Appalachian influence was tested.

4.12.1 The Acceptance Levels of Local Consumers

The mean hedonic rating scores of the three biscuit formulations indicated that the control was accepted as "liked moderately" (Table 11). The consumers who sampled the oat-based 33% and 66% formulations accepted the biscuits as "liked moderately." There was no significant differences (p<0.05) in degree of liking observed between the three formulas.

4.12.2 The Effect of Demographical Information on Hedonic Ratings

Of the 55 participants questioned, 87.27% were females and 12.73% were males. Slightly over 50% (56.4%) were between the ages of 18-44 years old. Seventy (70) percent of these participants sampled the control formulation, while 63.2% and 36.8% sampled the oat-based 33% and 66%, respectively. These percentages varied due to the consumer handling of the samples. Of the 55 participants, 87.27% were of white/Caucasian race. There was 9.09% participants who were of Afro-American origin. The other participants were of other ethnic backgrounds.
Table 11: The Effect of Fat Substitutes on the Acceptance of Baking Powder Biscuits by Appalachian Consumers

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean Scores of Hedonic Rating*#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>7.1a ± 0.9</td>
</tr>
<tr>
<td>Oat-based 33%*</td>
<td>7.2a ± 1.4</td>
</tr>
<tr>
<td>Oat-based 66%</td>
<td>7.4a ± 1.0</td>
</tr>
</tbody>
</table>

n=1

*TrimChoice-5* = beta-glucans and low dextrose equivalent maltodextrins.

'Means for hedonic rating scales are not significantly different between groups (p<0.05)

Numerical scores were given to the acceptance levels according to Larmond (1973), with 1="dislike extremely" and 9="like extremely."

*Value represents mean ± SD
There were 25.93% of the participants with either an educational level of six grade or less or a high school education. Seventy four (74) percent held a college or advanced degree. Since the majority of the consumers held an advanced degree, they might be more health conscious. If they did consume biscuits, they might choose fast food style biscuits instead of the homemade ones due to the tendency of today's society to eat meals out more often than in the past (Beasely and Swift, 1989).

Approximately half of the consumers (54.00%) had income levels of $31,000 or more. However, only 14.00% of the consumers had incomes of $10,000 or less.

Of the consumers in the study, 62.75% were from the Appalachian region. There were 25.49% of the consumers who were from an urban/suburban region. Since over half of the participants considered themselves from the Appalachian region, this general population could be considered to have an Appalachian influence.

4.12.3 General Knowledge About Biscuits and Nutrition

Eighty-eight (88) percent of the participants were familiar with the characteristics of a Southern-style biscuit. This percentage indicates that the consumers were familiar with the attributes of a Southern-style baking powder biscuit, and that the participants evaluated the biscuits on the
characteristic attributes of a Southern-style baking powder biscuit.

The questionnaire established that 62.50% of the participants associated biscuits as a high source of fat. This high percentage indicated that participants were somewhat knowledgeable on nutritional information. The questionnaire also indicated that 71.43% of the participants were "extremely" to "very much concerned" with fat levels in food. This information was in agreement with the fact that only 11.63% of the participants consumed biscuits several times a day to several times a week.

Of the consumers questioned, 26.53% indicated they liked biscuits "extremely"; 40.82% indicated they liked biscuits "very much"; and 20.41% indicated they liked biscuits "moderately". These percentages indicated that the participants liked biscuits, however, it was not specified the type of biscuit in question. Therefore, the ratings may not have applied to Southern-style baking powder biscuits.

4.12.4 Frequency of Consumption of Lard-Produced Baking Powder Biscuits

When asked at what frequency the participants consume biscuits, only 2.33% consumed biscuits every day. There were 9.30% of participants who consumed biscuits several times a week. The majority of the participants only consumed biscuits
from several times a month to never (25.58%-several times a month, 32.56%-several times a year, and 30.23%-never). These results indicated that this population was not a historically accurate representation of the Appalachian culture in which it was known that people consumed biscuits at least once a day. (Egerton, 1987).

4.12.5 Desire to Choose a Similar Low-Fat Biscuit

The study indicated that 83.67% of the participants would choose a low-fat biscuit with similar attributes of the experimental biscuits. It is possible therefore, these fat replaced biscuits would be acceptable to the general population with an Appalachian influence. According to Gormley (1989), higher socio-economic consumers are more discerning than lower socio-economic consumers. Therefore, since most participants were of the higher socio-economic class and accepted the biscuits then it could be expected that the lower socio-economic consumer should also accept these fat-reduced biscuits. These biscuits also may have been desired due to the fact that the purchasers of low fat products are primarily females (Anonymous, 1992c).

4.12.6 Sources of Error

This study indicated that the present biscuit formulation with up to a 66% fat reduction using an oat-based replacement
could produce an acceptable low-fat biscuit. This is an improvement because some companies have only been able to replace up to 50% of the fat in baking-powder biscuits (Kelco, Merck & Co., Inc., 1992). The results of this study should be interpreted with caution since it is not entirely representative of an Appalachian population (Seaman et al., 1993). There should have been a larger population surveyed and the population should have been drawn from a more rural/mountainous region. Even though Wades Supermarket was away from the nucleus of the university, there is still a possibility that university professors, staff, and students would infiltrate the shopping population.

Other possibilities affecting the representation of the general population could be age and the time factor. Some of the participants did not have time to fill out the entire questionnaire, while the older consumers were not willing or were not able to participate due to physical incapacities (no glasses, trouble writing). Seaman et al. (1993) states that co-operation in consumer tests by older participants and single person households is poor resulting in insufficient representative sampling. It has also been noted that consumers of higher economic status have been observed to be more discriminating of product attributes and acceptance than those of lower economic status (Gormley, 1989). The confinement of the testing station within the store also did
not allow for a big sampling. The table was behind products which hindered consumers' view of the table, and another aisle allowed for consumers to enter the store without even passing the table.
Chapter 5

Summary, Conclusions, and Future Research

With the push towards reducing the fat intake in the American diet, manufacturers and food service operators are developing products which incorporate fat replacers. Fat replacers are designed in many such as from lipid-based, protein-based and carbohydrate-based substitutes. The Appalachian diet is one that is thought to be high in dietary fat, especially saturated fats. One such food in the Appalachian diet that contributes to saturated fat is baking powder biscuits. If the fat content of the foods present in this diet can be reduced, this could lead to a reduced risk of health related diseases, such as, cardiovascular heart disease, cancer, and obesity.

The main objective of this study was to develop a Southern-style baking powder biscuit that was partially and totally fat replaced using three carbohydrate-based fat replacers. Xanthan and guar gums were added to the respective formulas to produce a synergistic water binding effect with the fat replacers.

Changes in volume were determined upon baking. Only the pectin-based replacer at a 33% level was able to produce a significant increase as compared to the control. The other types and levels did produce an increase in volume upon baking, but not to a significant degree. The degree of
expansion is in part due to the hydrocolloids ability to entrap water and gases during baking.

Tenderness was determined for both the biscuit crust and crumb. Tenderness can be influenced by the strength of the gluten structure and the moisture content within the hydrocolloid matrixes. At all 33% substitute levels, crusts were significantly (p<0.05) softer than the control. The only variation that was firmer than the control was the gum-based 100% level. Most variations produced a significantly softer crumb than the control except the oat-based 66% and the pectin-based 33% and 100% levels. The softness of the crumb could be most attributed to the hydrocolloids and emulsifiers binding the water and retaining it throughout baking. Crumb softness could also depend on a sufficient amount of milk for hydrocolloid hydration.

In relation to tenderness of the biscuit, the percentage moisture content was also determined after baking. All variations at each level were able to retain significantly (p<0.05) more moisture than the control upon baking.

The moisture content of the biscuits also influenced the degree of staling, however, it appeared that staling was more affected by the fat content. The fat produced lipid-amylose complexes which could prevent and/or retard staling. The control staled the least. The 66% variations staled less than the 33% and 100% levels. It seems there was some synergistic
effect between the added gums and the fat in retarding the staling process. At the 33% and 66% levels, the gum-based replacers staled the least in part due to the added emulsifiers forming lipid-amylose complexes. At the 100% level however, the pectin-based replacer staled the least possibly due to its high water binding abilities. It is possible that the pectin wraps or inter-locks with the starch granules thereby, preventing retrogradation.

The biscuits’ crust color was determined on the basis of L-lightness to darkness and b-the degree of yellowness. The brownish-yellow color of the control can be attributed to the dough’s pH, Maillard browning, and possibly some dextrinization of the starches. The gum-based substitute and the oat and pectin-based substitutes at the 66% and 100% levels produced significantly (p<0.05) lighter crusts. This could be due to the hydrocolloids decreasing the alkalinity of the dough or contributing proteins and sugars to the Maillard reaction. The emulsifiers present may have also retained the fat from the heating process. In looking at the degree of yellowness, the 66% and 100% substitutes produced significantly less yellow crusts as compared to the control. The high percentages of hydrocolloids may have influenced a less alkaline dough which produced a lighter yellow crust.

Bomb calorimetry was also performed on the biscuit variations. There was a significant reduction of 12-15%, 18-
23%, and 30-33% in the 33%, 66%, and 100% replacement levels, respectively. This however, is an over-estimation of the calories which would be utilized by the human digestive system.

Sensory tests (QDA and consumer tests) were conducted on the biscuit variations, and served as a complement to the objective measurements. The QDA panelists determined that the control had the darkest crust. The degree of browning then decreased as the amount of fat replacement increased. The 66% and 100% levels were observed to be significantly lighter than the control. The lighter color is in part due to the increased amount of hydrocolloids affecting the alkalinity of the dough thereby, producing a lighter yellow crust.

The panelists observed the 66% and 100% variations to have significantly smaller cell sizes than the control. This was possibly due to the ability of hydrocolloids and emulsifiers to produce a finer dispersion of air cells. This allowed for a greater retention of gases and increase in volume upon baking.

Panelists also evaluated the perceived cohesiveness, dryness, and tenderness of the biscuit variations. All three attributes appeared to be interrelated. They were all influenced by the moisture and fat content. The more moisture present, the more cohesive, the less tender, and the less dry the biscuit was perceived, by the judges. The more fat present, the less cohesive and more tender the biscuit. The
present, the less cohesive and more tender the biscuit. The control was significantly the least cohesive, most dry, and most tender of all the variations. The control however, could have been less dry if the milk added had been equal to that incorporated into the fat replaced variations. As the fat was replaced, there was a significant increase in cohesiveness, decrease in dryness, and decrease in tenderness. The hydrocolloids and emulsifiers with the addition of the gums were able to retain a large portion of water as compared to the control upon baking.

Bitterness was also evaluated by the QDA panel. Bitterness increased as the fat level decreased with the gum-based 66% and the pectin and gum-based 100% variations being significantly more bitter than the control. The fat in the control may have masked some of the bitterness while the addition of gums in 66% and 100% variations may have contributed to the perceived bitterness.

A consumer central location test was then conducted in order to determine the acceptance level of three biscuit variations: the control and the oat-based 33% and 66% levels. These variations were chosen based on QDA results. It was observed that among a representative population with an Appalachian influence, that all three variations were "moderately liked." This study therefore, was able to produce a fat replaced Southern-style biscuit, greater than 50%
reduced, which was acceptable to the general consumer. However, it is possible that these biscuits would rarely be consumed by this population due to their dietary behaviors. These biscuits may be more acceptable and marketable in an urban and/or suburban area where consumers may be more health conscious and adventuresome to consume innovative products.

Results indicated that the pectin and oat-based fat replacers produced a baking powder biscuit similar and in some instances more improved than the control. The 33% fat substitution level produced a biscuit most like the control with some characteristic improvements. The 66% fat substitution levels also produced somewhat of a similar biscuit. The 100% fat substitution levels did not produce a baking powder biscuit with attributes similar to an "ideal" biscuit or to the control.

In the future, manufacturers and food service operators may want to investigate the addition of other gums, such as locust bean gum; emulsifiers; flavorings; and enzymes, such as amylases or proteases; to improve the fat replacer's ability to function as a fat thereby, increasing the overall quality of the biscuit. Investigators could study fat replacement in biscuits, using lipid or protein-based replacers. Studies could be conducted to produce a 100% fat replaced biscuit which would be acceptable to the Appalachian population. Investigators could observe the effects of carbohydrate-fat
replacers on water activity and consequential microbial growth in the biscuits. The effect of the fat replacers on the dough pH and the color of the crumb could be investigated. One could also measure the moisture content of the biscuit dough to investigate the extent to which moisture is retained upon baking. Total lipid, protein, and crude fiber content may also be determined. Subjective results of this study may have been validated further by increased training of the modified QDA panel and a selection of QDA panelists from outside the university's population. A larger consumer sampling and/or a sampling from a more rural Appalachian area may have produced more reliable acceptance results. In the future, one may also want to conduct a clinical study to determine if the consumption of fat substituted biscuits would reduce dietary fat intake and health related diseases in a general population, specifically one with Appalachian influence. All of the fat replacers did produce a caloric reduction in all variations. However, when consumed, these biscuits may not actually contribute to an overall reduction in dietary caloric intake. For instance, biscuits are often served with butter, jelly, cheese, eggs, bacon, sausage, and ham. Often biscuits are consumed three to five at a time. Under these consumption conditions, the investigator believes that the fat replaced biscuit would not lead to a large caloric reduction in one's diet.
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Appendix A

Biscuit Formulations
Formulations for Carbohydrate-based Fat Substituted Southern-style Baking Powder Biscuits

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Control</th>
<th>TrimChoice® 33%</th>
<th>TrimChoice® 66%</th>
<th>TrimChoice® 100%</th>
<th>Slenlid 33%</th>
<th>Slenlid 66%</th>
<th>Slenlid 100%</th>
<th>Kel-Lite® BK 33%</th>
<th>Kel-Lite® BK 66%</th>
<th>Kel-Lite® BK 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour (gms)</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
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<td>240</td>
</tr>
<tr>
<td>Baking Powder (gms)</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
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<td>13</td>
</tr>
<tr>
<td>Salt (gms)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Crisco (gms)</td>
<td>63</td>
<td>49.5</td>
<td>24</td>
<td>0</td>
<td>43.5</td>
<td>24</td>
<td>0</td>
<td>43.5</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Skim Milk (mls)</td>
<td>180</td>
<td>185</td>
<td>185</td>
<td>185</td>
<td>185</td>
<td>185</td>
<td>185</td>
<td>185</td>
<td>185</td>
<td>185</td>
</tr>
<tr>
<td>Fat Replacer (gms)</td>
<td>4.81</td>
<td>4.81</td>
<td>4.81</td>
<td>4.81</td>
<td>4.81</td>
<td>4.81</td>
<td>4.81</td>
<td>4.81</td>
<td>4.81</td>
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</tr>
<tr>
<td>Xanthan Gum (gms)</td>
<td>n/a</td>
<td>n/a</td>
<td>1.2</td>
<td>1.2</td>
<td>n/a</td>
<td>1.2</td>
<td>n/a</td>
<td>1.2</td>
<td>n/a</td>
<td>1.2</td>
</tr>
<tr>
<td>Guar Gum (gms)</td>
<td>n/a</td>
<td>n/a</td>
<td>1.2</td>
<td>1.2</td>
<td>n/a</td>
<td>1.2</td>
<td>n/a</td>
<td>1.2</td>
<td>n/a</td>
<td>1.2</td>
</tr>
</tbody>
</table>

*n/a = not applicable
Appendix B

Experimental Design
For the purpose of randomly assigning the biscuit formulations to specific days, numbers were assigned to each variation:
1=Slendid® 33%; 2=Kel-Lite BK® 100%; 3=TrimChoice-5® 66%; 4=Control; 5=Slendid® 100%; 6=Kel-Lite BK® 66%; 7=TrimChoice-5® 33%; 8=TrimChoice-5® 100%; 9=Slendid® 66%; and 10=Kel-Lite BK® 33%.
Appendix C

Ingredients
1. Southern Biscuit All-Purpose Flour, Midstate Mills, Inc., Newton, North Carolina


4. Skim Milk (less than 0.5% fat, homogenized and pasteurized)

5. Crisco All Vegetable Shortening, Procter & Gamble Co., Cincinnati, Ohio


7. KEL-LITE BK® (K1B357), Merck and Co., Inc., Kelco Division, U.S.A., Rahway, New Jersey

8. Slendid Fat Replacer® (Slendid Pectin Low Esterfied), Hercules Incorporated, Hercules Plaza, Wilmington, Delaware

Appendix D

Degree of Expansion
Sample Analysis

1. The initial biscuit cut from the first rolling of the dough was used to determine the expansion.
2. Measurements were taken on the cookie sheet both before and after baking.
3. A caliper was used to measure the height and diameter of the biscuit.
4. For the height measurement before baking, two random measurements near the center of the biscuit were taken.
5. These two measurements were averaged for analysis.
6. Prior to baking, two random measurements of the diameter of the biscuit were taken.
7. These measurements were averaged for analysis.
8. After baking, two random height measurements were taken.
9. One height measurement was taken at the perceived highest part of the biscuit.
10. The other measurement was taken at the lowest perceived part of the biscuit.
11. These two measurements were then averaged for analysis.
12. Two random diameter measurements were taken and averaged for analysis.
13. All the measurements were taken in centimeters.

Formulas for Computing Volume:

1. The measurements were then computed in the following formula:
Volume = \( \frac{22}{7}r^2h \)

where \( h \)=height of the biscuit and \( r \)=radius of the biscuit
Appendix E
Texture Analysis
Texture Analyzer Preparation

1. The Stevens-LFRA Texture Analyzer TA-1000 (Texture Technologies, Scarsdale, New York) was turned on by the supply button and was set at normal cycle and a speed of 2.0 mm/second.

2. A TA-10 standard probe (0.5" in diameter, 35 mm long) was used for the measurements.

3. For the crust analysis, the distance was set at 4mm.

4. For the crumb analysis, the distance was set at 5mm.

Sample Analysis

1. For crust analysis, the biscuit sample was placed top crust up on the load cell mounting block.

2. The start button was pressed and the probe applied force, giving a reading in force/gram.

3. For crumb analysis, the bottom half of the biscuit was placed on the load cell mounting block.

4. The reset button was pressed and the distance readjusted.

5. The start button was pressed and the probe applied force, giving a reading in force/gram.
Appendix F

Moisture Content
Sample Preparation

1. A biscuit was cooled at room temperature for one hour.
2. The crumb was then torn into small pieces, placed in a teflon-lined metal pan and weighed to 10 grams (Sartorius portable top load balance, PT 1200-OUR, Bohemia, NY).

Brabender Moisture Tester Preparation

1. A Brabender Moisture Tester (C.W. Brabender Instruments, Inc., South Hackensack, New Jersey) SAS 692 was switched on one hour prior to testing.
2. Once heated, the sample pans were placed into the Brabender and the door was latched.

Sample Analysis

1. The samples were dried for one and a half to two hours until the moisture content readings reached an equilibrium.
2. After drying, each sample was reweighed in the Brabender using a two gram weight which indicated the percentage moisture lost upon drying.
Appendix G

Differential Scanning Calorimeter
Sample Preparation

1. A sample of the crumb was then removed, approximately 29.0 to 31.0 mgs.
2. A Perkin AD-6 Autobalance (Perkin-Elmer, Norwalk, CT) was calibrated and the sample was weighed in an aluminum pan.
3. The sample was encapsulated in the pan and a lid with an O-ring was crimped into place (Perkin-Elmer, Norwalk, Ct.).

Differential Scanning Calorimeter Calibration

1. The systems TADS, DSC program disk was put into drive 0.
2. The DSC start-up data disk was put into drive 1.
3. TADS was typed and Go to Set Up was pressed.
4. ‘Standard’ and the operator was entered.
5. The parameters were modified for the indium standard.
6. Set Up was pressed on the microprocessor controller and parameters of temperature minimum, temperature maximum, heat rate, cool rate, and temperature span were entered.
7. The load temperature was modified to that of the temperature minimum.
8. Enter was pressed and the Go to Load and Reset buttons were pressed at the same time.
9. An indium standard weighing 2.94 mgs, and a reference pan were placed in the sample compartment head and the lever was pushed down to close the compartment head.
10. The compartment head temperature was equilibrated to the appropriate minimum temperature.
### Parameters for Indium Standard and Biscuit Samples

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Indium Standard</th>
<th>Biscuit Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Temperature (degree C)</td>
<td>175</td>
<td>140</td>
</tr>
<tr>
<td>Minimum Temperature (degree C)</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>Temperature Increase (degree C)</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Initial Temperature (degree C)</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>Y Range</td>
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<td>5</td>
</tr>
<tr>
<td>Heating Rate (degree C/minute)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Cool Rate (degree C/minute)</td>
<td>320</td>
<td>320</td>
</tr>
<tr>
<td>Sample Weight (mgs)</td>
<td>2.94</td>
<td>29.0-31.0</td>
</tr>
<tr>
<td>Temperature Span (degree C)</td>
<td>400</td>
<td>400</td>
</tr>
</tbody>
</table>
11. **Zero** was pressed and the Y range was stabilized between 0.5 and 1.00 mcal/second.

12. **Ready** and **Start** were then pressed.

13. Once the run was finished, **Go to Load**, **Reset**, and **Go to Analysis** were pressed.

14. The temperature scale was rescaled to 50 to 175 degrees.

15. If needed the slope was adjusted to a Slope=0 position and the Y scale was rescaled.

16. The **Peak** was then set between 155 and 165 degrees.

17. For calibration, the indium standard had to have a melting point of 156.6 +/- 0.2 degrees.

**Sample Analysis**

1. Ice was placed in the sample compartment in front of the sample compartment head.

2. The sample pan and a reference pan were placed in the sample compartment head once it reached minimum temperature.

3. The compartment head was sealed and equilibrated to the minimum temperature.

4. The sample I.D. and operator were entered.

5. The parameters of the system controller and the microprocessor controller were modified.

6. The Y scale was zeroed and the **Ready** and **Start** buttons were pressed.

7. Once the run was finished, the **Go to Load** and **Reset** buttons
were pressed together to reset the load temperature.

8. The temperature scale was rescaled to 30 to 140 degrees centigrade and if needed the slope and Y scale were adjusted.

9. The peak was determined and the thermogram was saved and plotted.

Sample Analysis

1. The peak area (height*length of peak) divided by the sample weight in mgs was calculated and displayed graphically for correlations.
Appendix H

Colorimeter
Sample Preparation

1. Excess flour was removed from the surface of the biscuits with a pastry brush prior to measurement.
2. The sample was cooled to room temperature for one hour prior to testing.

Colorimeter Preparation and Standardization

1. The Hunter Lab L Optical Sensor 45/0 D25-PC2 (HunterLab, Reston, VA) was placed on stand-by along with a laptop PC for at least a half an hour prior to testing.
2. The machine was then switched to "operate" and the white uncalibrated white tile was removed from the specimen port.
3. A black standard glass tile was placed on the specimen port, shiny side toward the port.
4. <F1> was pressed and the bottom of the scale was standardized/ 'zeroed'.
5. The black tile was then removed and a white glass standardized tile was placed on the specimen port.
6. <F1> was pressed and the top of the scale was standardized or 'zeroed'.
7. <F1> was again pressed to place the measurement mode into delta E values of L, a, and b.
8. <F8>, #1, and <F2> were pressed in order to place the standard values into L, a, and b values.

Sample Analysis
1. The biscuit sample was placed top crust up on the sample port and positioned so no light was able to come through.
2. <F1> was pressed and the L, a, b, and delta E values were calculated.
Appendix I

Bomb Calorimetry
Sample Preparation

1. Two biscuits were cooled to room temperature for one hour and then sealed in a zip loc bag.
2. A sample was torn from each biscuit, minced, and placed in a tin.
3. The sample was weighed to the nearest ten thousandth of a gram and dried at 100 degree C for approximately 24 hours.
4. The sample was then reweighed to the nearest ten thousandth of a gram.
5. The dried samples were then powdered using a mortar and pestle.
6. Approximately one gram of sample was formed into a pellet using a Parr Pellet Maker (Moline, Illinois).
7. The crucible was weighed and pellets reweighed using a Mettler H2OT (Scientific Products, Evanston, Illinois) balance before combustion occurred.

Bomb Calorimeter Preparation and Standardization

1. A Parr Adiabatic Calorimeter (Parr Instrument Company, Moline, IL) was used to determine the energy content.
2. An oxygen bomb chamber was assembled using a Parr 45C 10 nickel-chromium fuse wire which was attached to the metal electrodes of the upper section of the bomb.
3. The crucible and sample was placed in the holder so the fuse wire was in contact with only the sample.
4. The upper section of the bomb was placed into the lower section of the chamber, with the collar securely tightened and the release valve closed.
5. The chamber was filled with oxygen to 30 atmospheres of pressure.
6. The chamber was placed into the water bucket with the attachment of the electrodes.
7. Two liters of tepid water were added to the water bucket.
8. The cover was put into place and the thermometer was carefully lowered into the water.
9. The bomb calorimeter was turned on and the water equilibrated for three minutes.
10. The temperature recorded was the initial temperature reading.

Sample Analysis
1. The sample was ignited after initial temperature reading and timed for eight minutes.
2. After eight minutes, the instrument was turned off and the final temperature was recorded.
3. The chamber was removed from the calorimeter and disassembled.
4. Unburned fuse wire was removed, measured in length for the determination of the wire correction value.
5. The upper and lower sections of the chamber and the crucible were rinsed off with deionized water into a
6. A methyl-red indicator was added and titrated using 0.0709N sodium carbonate solution for the determination of the acid correction value.

Formulations for Caloric Determination

1. Final temperature-initial temperature=net temperature rise
2. Net temperature rise x water equivalent=total heat liberated
3. Acid correction + wire correction=total correction
4. Total heat liberated-total correction=net heat liberated
5. Net heat liberated-sample weight=amount calories/gram
6. For corrections, the amount of wire burned was subtracted from the total amount of calories.
Appendix J

Modified Quantitative Descriptive Analysis Panel Training
1. Due to time restrictions, the recruited panelists participated in five one hour training sessions.

2. The investigator of this study acted as facilitator for the training sessions.

3. Sessions were conducted as focus groups.

**First Training Session**

1. This session was used for the panelists to develop terminology and definitions of a wide variety of biscuit references.

2. Panelists were asked to sign informed consent forms.

3. The biscuit references used were the control formulation, the 100% oat-based formulation, Hardee's Buttermilk Biscuits, Hungry Jack Flaky Biscuits, and Arnold Old Fashioned Biscuits with Buttermilk.

4. Each panelist wrote down every perceived attribute of each biscuit.

5. The investigator condensed the list of attributes into seven attributes: degree of browning, tenderness, cell size, cohesiveness, crumbliness, dryness, and bitterness.

**Second Training Session**

1. Three biscuits were compared based on the list of predetermined attributes.

2. The references used were the control formulation, the oat-based 100% formulation and Hungry Jack Flaky Buttermilk Biscuits.
3. The panelists sampled each biscuit and commented on the attributes provided.

4. The panelists then decided on six attributes: degree of browning, cell size, tenderness, dryness, bitterness and cohesiveness.

5. The panelists defined each attribute and ordered them in the way in which they were perceived by the panelists senses during evaluation.

Third, Fourth and Fifth Training Sessions

1. The panelists evaluated two biscuits per session to demonstrate their ability to evaluate reference standards and extremes of the defined attributes.

2. For the third training session, the control formulation and same control formulation with added 15 grams of baking powder were used to evaluate the attribute of bitterness.

3. For the fourth training session, the control formulation and the oat-based 100% formulation were used to evaluate the attribute of dryness.

4. In the fifth training session, the control formulation with 130 mls of milk and the control formulation with 180 mls of milk were used to evaluate the attributes of cohesiveness and tenderness.

Training Location

1. The training was conducted in 336 Wallace Hall and the sensory booths in 339 Wallace Hall, VPI & SU, Blacksburg,
2. The panelists were in partitioned booths in a laboratory.
3. The lighting was white fluorescent lights.
4. The environment was at room temperature, approximately 72 degrees F and relative humidity.
5. Panelists received training material through booth doors.

Sample Preparation
1. The biscuits were cooled to room temperature and cut into four pieces and then placed on a plate and wrapped in plastic wrap.
2. The samples were randomly coded with three-digit numbers.

Testing Procedures
1. Panelists received a tray with the scorecard, definitions, a pencil, a cup of room temperature tap water, a napkin, an expectorate cup, and a plate with the sample.
2. The panelist received the samples successively.
3. Each panelist received the samples in a randomly assigned order.
4. The panelist placed a vertical mark on the line scale at the point at which they believed best represented the perceived intensity of the attributes.
5. Panelists were asked if they understood the scorecard, attributes and definitions at each session.
6. The scorecard was adjusted according to their suggestions and concerns.
QDA Attribute Definitions:

1. **Degree of Browning**: the degree of browning of the top crust of the biscuit

2. **Cell Size**: the size of the cells located in the crumb of the biscuit

3. **Cohesiveness**: the ability of the biscuit to stay together (no crumbling) as it is broken in half on the plate

4. **Dryness**: the amount of dryness perceived within the mouth

5. **Bitterness**: the degree of which the bitter taste is perceived after ten chews

6. **Tenderness**: the ease with which the biscuit is penetrated with one’s teeth upon chewing
Appendix K

Modified Quantitative Descriptive Analysis Scorecard
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panelist</strong></td>
<td><strong>Sample No.</strong></td>
</tr>
<tr>
<td>Degree of Browning</td>
<td></td>
</tr>
<tr>
<td>Not</td>
<td>Very</td>
</tr>
<tr>
<td>Cell Size</td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td></td>
</tr>
<tr>
<td>Not</td>
<td>Very</td>
</tr>
<tr>
<td>Dryness</td>
<td></td>
</tr>
<tr>
<td>Not</td>
<td>Very</td>
</tr>
<tr>
<td>Bitterness</td>
<td></td>
</tr>
<tr>
<td>Not</td>
<td>Very</td>
</tr>
<tr>
<td>Tenderness</td>
<td></td>
</tr>
<tr>
<td>Not</td>
<td>Very</td>
</tr>
</tbody>
</table>
Appendix L

Modified Quantitative Descriptive Analysis Testing

Procedures
Panelists

1. The panelists who were trained were recruited faculty, staff, and students from Department of Human Nutrition and Food, VPI & SU, Blacksburg, VA.

Testing Location

2. Each panelist was seated in a partitioned booth located in 339 Wallace Hall, VPI & SU, Blacksburg, VA.

3. The booths had fluorescent white lighting and were at room temperature, approximately 72 degrees F and at relative humidity.

Sample Preparation

1. The biscuits were cooled to room temperature for one hour.

2. The top crust of the biscuits were brushed with a pastry brush to remove any excess flour.

3. The biscuits were then cut into four pieces, placed on a paper plate and wrapped in plastic wrap.

4. Each sample was assigned a randomly selected three-digit code.

Testing Procedures

1. Each panelist received a tray with a scorecard, definitions of attributes if needed, a pencil, a cup of room temperature tap, an expectorate cup, and a plate with a coded sample.

2. Each panelist received four samples each testing session.

3. The samples were given to the panelists in a randomly
assigned order in a successive manner.

4. Between each sample, the panelists took a sip of water and waited 30 seconds before testing the next sample.

5. Panelists evaluated the samples according to the order and definitions of the attributes.

6. The panelists placed a vertical mark on the line scale at the point at which best represented their perceived intensities of the attributes.

**Statistical Analysis**

1. For analysis, the location of the mark was measured from the extreme left end of the line scale in centimeters.

2. Analysis of variance and Fisher’s LSD test were used to determine where significant differences existed among the overall means at a P-value of 0.050.
Appendix M

Central Location Testing
Testing Location
1. A table was set up after the entrance of Wades Supermarket, South Main Street, Blacksburg, VA, on Friday May 13, 1994, from 8:30 AM to 1:00 PM.
2. The table was under fluorescent white lighting and the environment was at room temperature with a relative humidity.

Panelists
1. Fifty untrained panelists who were shoppers at the supermarket participated.

Sample Preparation
1. The control, oat-based 33%, and oat-based 66% formulations were chosen as the samples to be used according to preliminary statistical analysis of the QDA panel results.
2. The biscuits were prepared approximately two hours before testing in 339 Wallace Hall, VPI & SU, Blacksburg, VA, and transported by car to the testing location.
3. The biscuits were cooled to room temperature, placed on a paper plate, and wrapped in plastic wrap.
4. The biscuits were cut into four pieces.
5. The biscuits were randomly assigned a three-digit code.

Testing Procedures
1. Each shopper received a scorecard with an informed consent paragraph.
2. Each shopper who participated was given a piece of biscuit with a napkin and a pencil.

3. The samples were given to the shoppers by alternating the samples.

4. The shopper tasted the biscuit and rated their degree of liking on the 9-point hedonic scale.

5. The shopper filled out as much of the questionnaire as possible.
Appendix N

Central Location Testing Scorecard
Panelist No._____ Date_____

**Biscuit Evaluation**

These samples are regular or fat-reduced biscuits which I developed in my thesis research for my Master of Science degree in Foods. The fat-reduced biscuits contain starch-based fat replacers. All the ingredients used in the biscuits are FDA approved. You may decline participation if you wish. I thank you for your time and participation in my thesis research.

Please taste this biscuit sample and indicate on the scale below how well you like it.

Product Code:_____

_____Like extremely
_____Like very much
_____Like moderately
_____Like slightly
_____Neither like nor dislike
_____Dislike slightly
_____Dislike moderately
_____Dislike very much
_____Dislike extremely

Thank you for your response. Please complete the questionnaire.
Panelist No._____ Date____

**Biscuit Evaluation**

Thank you for tasting my biscuit sample. Your input is a very valuable part of my research. To assist in the analysis of the data, I need to acquire some additional information from you. Please answer the following questions.

1. Female___ Male___

2. Age
   ___less than 18
   ___18-24
   ___25-34
   ___35-44
   ___45-54
   ___55-64
   ___65 or over

3. Ethnic Background
   ___White/Caucasian
   ___Black
   ___Hispanic
   ___Asian/Pacific Islander
   ___American Indian/Alaskan Native

4. Educational Background
   ___Sixth grade or less
   ___High School
   ___College
   ___Advanced degree
5. Yearly Income (Household)
   ____ 10,000 or less
   ____ 11,000 to 20,000
   ____ 21,000 to 30,000
   ____ 31,000 or more

6. Native region you are most associated with:
   ____ Appalachian mountains
   ____ Coastal region
   ____ Urban/Suburban

7. Are you familiar with what is considered a Southern-style biscuit with cake-like characteristics (ex. Hardee’s biscuits)?
   ____ Yes  ____ No

8. Do you think biscuits are a high source of fat?
   ____ Yes  ____ No

9. Please rate how well you like biscuits in general.
   ____ Like extremely
   ____ Like very much
   ____ Like moderately
   ____ Like slightly
   ____ Neither like nor dislike
   ____ Dislike slightly
   ____ Dislike moderately
   ____ Dislike very much
10. How often do you eat biscuits made with lard?
   ___ Several times a day
   ___ Several times a week
   ___ Several times a month
   ___ Several times a year

11. How concerned are you about fat level in food?
   ___ Extremely concerned
   ___ Very much concerned
   ___ Moderately concerned
   ___ Slightly concerned
   ___ Not concerned

12. Would you choose a low fat biscuit that has similar attributes of the biscuit you tasted?
    ___ Yes              ___ No

Thank you for participating in this study. For your information, the low fat biscuits were 284 and 730.
Appendix O

SAS Program
Factor Structure

<table>
<thead>
<tr>
<th></th>
<th>33%</th>
<th>66%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slendid</td>
<td>T1R1(1)</td>
<td>T1R2(9)</td>
<td>T1R3(5)</td>
</tr>
<tr>
<td>Kel-Lite BK</td>
<td>T2R1(10)</td>
<td>T2R2(6)</td>
<td>T2R3(2)</td>
</tr>
<tr>
<td>TrimChoice-5</td>
<td>T3R1(7)</td>
<td>T3R2(3)</td>
<td>T3R3(8)</td>
</tr>
</tbody>
</table>

DATA OBJECT;
INPUT DAY TRT VB VA AB AA L A B DELTA E TCRUST TCRUMB MOISTURE;
D VOLAB=VB-VA; DARE=AA-AB;
IF TRT=4 THEN FACTOR='CONTROL';
IF TRT=1 THEN FACTOR='T1R1';
IF TRT=2 THEN FACTOR='T2R3';
IF TRT=3 THEN FACTOR='T3R2';
IF TRT=5 THEN FACTOR='T1R3';
IF TRT=6 THEN FACTOR='T2R2';
IF TRT=7 THEN FACTOR='T3R1';
IF TRT=8 THEN FACTOR='T3R3';
IF TRT=9 THEN FACTOR='T1R2';
IF TRT=10 THEN FACTOR='T2R1';
IF TRT=1 THEN RATE='33%';
IF TRT=2 THEN RATE='100%';
IF TRT=3 THEN RATE='66%';
IF TRT=4 THEN RATE='0-RATE';
IF TRT=5 THEN RATE='100%';
IF TRT=6 THEN RATE='66%';
IF TRT=7 THEN RATE='33%';
IF TRT=8 THEN RATE='100%';
IF TRT=9 THEN RATE='66%';
IF TRT=10 THEN RATE='33%';
IF TRT=1 THEN TYPE = 'SLENDID';
IF TRT=2 THEN TYPE = 'KEL-LITE';
IF TRT=3 THEN TYPE = 'OATRIM';
IF TRT=4 THEN TYPE = 'NO-TYPE';
IF TRT=5 THEN TYPE = 'SLENDID';
IF TRT=6 THEN TYPE = 'KEL-LITE';
IF TRT=7 THEN TYPE = 'OATRIM';
IF TRT=8 THEN TYPE = 'OATRIM';
IF TRT=9 THEN TYPE = 'SLENDID';
IF TRT=10 THEN TYPE = 'KEL-LITE';
PROC MEANS N MEAN STD STDERR;
TITLE 'MEANS BY TYPE';
CLASS TYPE;
VAR DVOLAB VB VA DAREAAB AB AA L A B DELTAE TCRUST TCRUMB MOISTURE;

PROC MEANS N MEAN STD STDERR;
TITLE 'MEANS BY RATE';
CLASS RATE;
VAR DVOLAB VB VA DAREAAB AB AA L A B DELTAE TCRUST TCRUMB MOISTURE;

PROC MEANS N MEAN STD STDERR;
TITLE 'MEANS BY FACTOR';
CLASS FACTOR;
VAR DVOLAB VB VA DAREAAB AB AA L A B DELTAE TCRUST TCRUMB MOISTURE;

PROC CORR;
TITLE 'CORRELATION AMONG RESPONSES';
VAR DVOLAB VB VA DAREAAB AB AA L A B DELTAE TCRUST TCRUMB MOISTURE;

PROC GLM;
TITLE 'MODEL1 DVOLAB=DAY FACTOR';
CLASS DAY FACTOR;
MODEL DVOLAB=DAY FACTOR;
LSMEANS FACTOR/TDIFF;
CONTRAST 'TYPE';
CONTRAST 'RATE';
CONTRAST 'TYPE*RATE';
CONTRAST 'CONTROL*REST'

FACTOR 0 1 1 1 -1 -1 0 0 0,
FACTOR 0 1 1 1 1 1 2 -2 -2,
FACTOR 0 1 1 0 0 1 -1 0,
FACTOR 0 1 1 -1 -1 -2 1 1 -2,
FACTOR 0 1 -1 1 1 0 0 0 0,
FACTOR 0 1 1 -2 -1 -1 2 0 0,
FACTOR 0 1 1 0 1 -1 0 -2 2 0,
FACTOR 0 1 1 -2 1 1 -2 -2 -2 4,
FACTOR -9 1 1 1 1 1 1 1 1 1 1,
REPLICATED FOR REST

DATA SENSORY;
INPUT DAY PANELIST TRT DOFBROWN CELLSIZE COHESIVE DRYNESS BITTER TENDER;
IF TRT=4 THEN FACTOR='CONTROL';
IF TRT=1 THEN FACTOR='TR1';
IF TRT=2 THEN FACTOR='T2R3';
IF TRT=3 THEN FACTOR='T3R2';
IF TRT=5 THEN FACTOR='T1R3';
IF TRT=6 THEN FACTOR='T2R2';
IF TRT=7 THEN FACTOR='T3R1';
IF TRT=8 THEN FACTOR='T3R3';
IF TRT=9 THEN FACTOR='T1R2';
IF TRT=10 THEN FACTOR='T2R1';
IF TRT=1 THEN RATE='33%';
IF TRT=2 THEN RATE='100%';
IF TRT=3 THEN RATE='66%';
IF TRT=4 THEN RATE='0-RATE';
IF TRT=5 THEN RATE='100%';
IF TRT=6 THEN RATE='66%';
IF TRT=7 THEN RATE='33%';
IF TRT=8 THEN RATE='100%';
IF TRT=9 THEN RATE='66%';
IF TRT=10 THEN RATE='33%';
IF TRT=1 THEN TYPE='SLENDID';
IF TRT=2 THEN TYPE='KEL-LITE';
IF TRT=3 THEN TYPE='OATRIM';
IF TRT=4 THEN TYPE='NO-TYPE';
IF TRT=5 THEN TYPE='SLENDID';
IF TRT=6 THEN TYPE='KEL-LITE';
IF TRT=7 THEN TYPE='OATRIM';
IF TRT=8 THEN TYPE='OATRIM';
IF TRT=9 THEN TYPE='SLENDID';
IF TRT=10 THEN TYPE='KEL-LITE';
CARDS;

PROC MEANS N MEAN STD STDERR;
TITLE 'MEANS BY TYPE';
CLASS TYPE;
VAR DOFBROWN CELLSIZE COHESIVE DRYNESS BITTER TENDER;
PROC MEANS N MEAN STD STDERR;
TITLE 'MEANS BY RATE';
CLASS RATE;
VAR DOFBROWN CELLSIZE COHESIVE DRYNESS BITTER TENDER;
PROC MEANS N MEAN STD STDERR;
TITLE 'MEANS BY FACTOR';
CLASS FACTOR;
VAR DOFBROWN CELLSIZE COHESIVE DRYNESS BITTER TENDER;
PROC CORR;
TITLE 'CORRELATION AMONG RESPONSES';
CLASS FACTOR;
VAR DOFBROWN CELLSIZE COHESIVE DRYNESS BITTER TENDER;
PROC MEANS NWAY MEAN;
CLASS DAY FACTOR;
VAR DOFBROWN CELLSIZE COHESIVE DRYNESS BITTER TENDER;
OUTPUT OUT=COLLAP MEAN=MDB MCELL MCOHES MDRY MBITTER MTENDER;

PROC PRINT;
TITLE 'DATA SET COLLAPSED OVER PANELIST';

PROC GLM;
TITLE 'MODEL MDB=DAY FACTOR';
CLASS DAY FACTOR;
MODEL MDB=DAY FACTOR;
CONTRAST 'TYPE'
CONTRAST 'RATE'
CONTRAST 'TYPE*RATE'
CONTRAST 'CONTROL*REST'

FACTOR 0 1 1 1 -1 -1 -1 0 0 0 ,
FACTOR 0 1 1 1 1 1 -2 -2 -2 ,
FACTOR 0 1 -1 0 1 -1 0 1 -1 0 ,
FACTOR 0 1 1 -2 1 1 -2 1 1 -2 ,
FACTOR 0 1 -1 0 -1 1 0 0 0 0 ,
FACTOR 0 1 1 -2 -1 -1 2 0 0 0 ,
FACTOR 0 1 -1 0 1 -1 0 -2 2 0 ,
FACTOR 0 1 1 -2 1 1 -2 -2 -2 4 ,
FACTOR -9 1 1 1 1 1 1 1 1 1 1 ,

Replicated for the rest.
VITA

Stacey Charles was born in Granville, OH, on April 5, 1970. She attended Eastern Kentucky University in Richmond, KY, and received a Bachelor of Science Degree in Dietetics in 1992. There she was the President of the Alpha Chi Omega Sorority; Lambda Sigma, a sophomore national honor society; and Phi Upsilon Omicron, a home economic honor society. She also participated in the Honors Program.

She then attended Virginia Polytechnic Institute and State University in Blacksburg, VA, and received a Master of Science Degree in Foods. She was a member of The Institute of Food Technologists. She held a summer internship with RJ Reynolds Tobacco Company in which she worked in the Sensory Evaluation Division. She also held several teaching assistantships throughout her two years at VPI & SU. She completed the requirements for this degree in July 18, 1994.

Stacey A. Charles