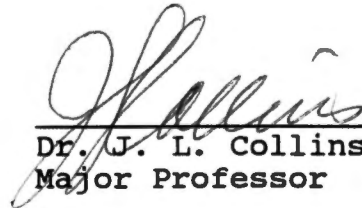


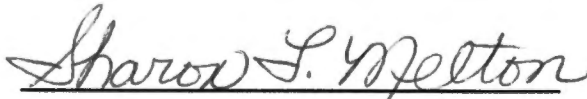
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I am submitting herewith a dissertation written by Lori Lynn Huskey entitled "Battered/breaded apple and mushroom prepared and baked to resemble their deep-fried counterparts." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Food Science and Technology.

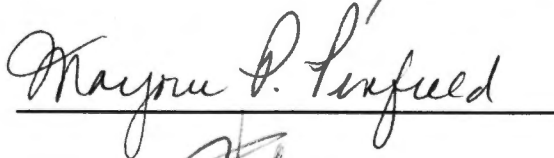


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BATTERED/BREADED APPLE AND MUSHROOM
PREPARED AND BAKED TO RESEMBLE
THEIR DEEP-FRIED COUNTERPARTS

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Lori Lynn Huskey

May, 1993

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DEDICATION

This dissertation is dedicated to my parents,
Raymond and Elaine Huskey, who have always
believed in me and given me their best.

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ABSTRACT

There is much interest in the development of food products which are compatible with the changing lifestyles of American consumers. The objectives of this research were: to develop acceptable snack foods using apple and mushroom; to develop an acceptable baked, low-fat coating system; to determine the effect of pretreatment on product characteristics; and to determine the effect of reheating method on product characteristics.

Stayman Winesap apple pieces and Snow White mushrooms were predusted or predried in an air impingement oven, then coated with a batter containing 3, 20 or 40% vegetable oil. Products coated with the 3% oil batter were deep-fried; the remainder were baked in an air impingement oven. Products were frozen and later reheated in conventional or microwave ovens.

Coating pickup increased and coating loss decreased as batter viscosity increased or with use of a predust. Percentage of coating retained on the product after reheating tended to be higher for products which had been coated with a higher viscosity batter, predusted, or reheated in microwave oven. Moisture of reheated products was lowest for fried products with variable effects of pretreatment and reheating oven. Fried products had lower Hunter L and higher

hue angle values than baked products. Conventional oven reheating produced a greater total color difference (Delta E value) than did microwave reheating. Sensory panelists agreed that fried products were darker in color, however, they rated microwave reheated products as being darker than products reheated in a conventional oven. Fried products were rated by sensory evaluation as glossier, lower in coating adherence, crisper, less moisture absorbing and stronger in deep-fried flavor. There was no difference in acceptability of baked and fried apple products; fried mushroom products were more acceptable than baked mushroom. Apple and mushroom reheated in a conventional oven were crisper, absorbed less moisture from the mouth during chewing and were more acceptable than products reheated in a microwave oven.

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CHAPTER I

INTRODUCTION

Nutritional concerns of American consumers have prompted them to make food purchases more carefully (Farr, 1987; Lachance, 1989; van Osnabrugge, 1988). Regardless of nutritive value, consumers still expect foods to possess excellent taste and provide eating enjoyment (Kinsey, 1987; Stillings, 1985). A wide variety of foods is eaten as snacks, many contributing to the image of containing empty calories (Ekvall and Vallo, 1983; Morgan, 1983). However, fruits, vegetables and other "healthy" products are reported also as favorite snacks (Anonymous, 1988a; Farr, 1987). Snack sales, particularly those classified in the hot snacks category, have increased dramatically since 1986 (Anonymous, 1987a; 1988b).

Convenience also has become a major factor in the purchase of foods for home preparation and will most likely be a major force in shaping the food products of the future. Many factors such as increased number of women in the workforce, aging of the "baby boomer" generation and proliferation of single- and two-person households contribute to the increased demand for products with easy preparation (Henneberry and Charlet, 1992; Kinsey, 1987; Sills-Levy, 1989).

Battered and breaded foods have long been popular with consumers because of their convenience and unique attributes (Hurni and Loewe, 1990; Suderman, 1990a). Many factors such as color, density and porosity of breading, batter and breading ingredients and batter viscosity influence quality and final characteristics of batters and breadings (Burge, 1990; Davis, 1983; Dyson, 1983; Loewe, 1990; Suderman, 1983, 1990a, 1990b). Combinations of these factors are so extensive that the practice of battering and breading foods has long been considered more an art than a science.

Use of the microwave oven is an extremely popular cooking method with over 75% of American households owning at least one oven (Shapiro, 1990). Due to cooking characteristics of the microwave oven, product formulations typically must be modified to achieve a product with the desired texture or browned flavor (Anonymous, 1987b; Best, 1987; Przybyla, 1989; Schiffman, 1990).

There are several cooking methods available to food processors for use in the initial cooking step. Deep-fat frying contributes to the color, flavor and texture of a product but also to the caloric and fat content (Birch et al., 1986; May et al., 1978). Impingement baking uses hot air forced onto the food product to accelerate heat and moisture transfer (Walker and Sparman, 1989).

Characteristics of foods cooked in the impingement oven are highly dependent upon the food itself and upon baking conditions (Sato et al., 1987; Skjoldebrand, 1980; Walker and Sparman, 1989).

The development of food products which are more compatible with the changing consumer lifestyles than are existing products has become an important research area for the food industry. The objectives of the present study were: to develop acceptable snack foods using apple and mushroom; to develop an acceptable baked, low-fat coating system; to determine the effect of pretreatment on product characteristics; and to determine the effect of reheating method on product characteristics.

CHAPTER II

REVIEW OF LITERATURE

A. SNACKS

1. Definition

Snacks were defined by Pao and Mickle (1980) as "...foods eaten between the three main meals." Many foods fall into this category as over 60% of the United States' population consumes food or beverages between meals. According to Ekvall and Vallo (1983), satiety was the primary consideration when choosing a snack; other considerations included personal preferences, product availability, and product promotion. However, van Osnabrugge (1988) suggested that snacks were chosen primarily for flavor. Farr (1987) agreed that taste was the major consideration but reported that health value, economy and convenience were important factors also.

2. Sales and Consumption

From 1980 to 1987, snack sales leaped from \$15.2 billion to \$25.2 billion with hot snacks, popcorn and dried fruit the largest gainers (Anonymous, 1988b). Hot snacks are considered hors d'oeuvre-type products and do not include foods such as frozen pizza, microwave popcorn, toaster pastries and others (Anonymous, 1987a). Sales of hot snacks increased from \$60 million to \$480 million during

1980 - 1987. While hot snacks have shown impressive sales growth, this group still accounts for only 1.9% of the total snack food market (Anonymous, 1988b).

Purchase and consumption of snack foods are largely functions of age. Pao and Mickle (1980) estimated that 59 - 70% of children and teenagers in the United States consumed one or more snacks each day; this figure decreased to 40 - 64% of adults. Consumers 18-24 years of age snacked the least, while children aged 2-5 years snacked about 30% more than the average consumer. Snack preference also varied with age. Among children aged 2-18, sweets were the favorite. Salty snacks were also popular choices for older children and teenagers (Anonymous, 1988b).

Reported snack favorites differed among researchers. Farr (1987), reporting on a survey of shoppers age 18 or over conducted by Lou Harris and Associates, stated that 73% of those surveyed frequently consumed vegetables or fruits as snacks. One-half indicated no favorite snack but of those who expressed a preference, the most popular snack items were nuts, grains, popcorn, pretzels, chips, ice cream, fruits and vegetables. Another report (Anonymous, 1988a) contended that adults aged 35 to 54 favored beverages as snacks, while consumers age 55 and older expressed a preference for "healthy snacks."

3. Nutritional Aspects of Snacking

Snack foods commonly are viewed by consumers as being high in calories and low in bulk and nutrient density (Ekvall and Vallo, 1983). While this is true for some snack foods, certainly, it is not true for all. Morgan (1983) reported that snack foods were not responsible necessarily for obesity, and some were, in fact, excellent sources of valuable nutrients. Estimates indicated that persons who consumed at least one snack per day received, on average, the following percentages of their daily intake: 20%, food energy; 12%, protein; 16%, fat; 25%, carbohydrate; 14%, iron; 18%, phosphorus; 25%, magnesium and calcium; 13-14%, vitamins A, B6, B12, thiamin and preformed niacin; and 16-17%, vitamin C and riboflavin. Snacking actually increased magnesium and zinc in the diets of most children, while contributing vitamin B6, calcium, iron, magnesium, and zinc to diets of adolescents (Pao and Mickle, 1980). Snacks have become more nutritious and many now are regarded more as meal substitutes, not just treats. Also, research aimed at decreasing fat content of snacks, and thus solving an important consumer dilemma, continues (Morris, 1988). Overall, snack foods should not be condemned as "empty calorie" foods. Instead, they should be evaluated as components of the total diet and not judged in isolation (Morgan, 1983).

B. CONSUMER DEMOGRAPHICS AND FOOD CONCERNS

Regardless of type of food and the needs it satisfies, consumers want foods with similar basic attributes. Products should be fresh, safe, natural and healthy, without sacrificing taste or eating enjoyment (Kinsey, 1987; Stillings, 1985). Also, convenience in handling and preparation are desirable features (Labuza, 1985). As lifestyles and demographics of consumers change, the food industry must keep pace with the changes. Two important areas of concern to both consumers and food processors are health and convenience.

1. Health Concerns

In 1978, 70% of consumers surveyed realized that dietary changes could lead to improved health but were reluctant to make changes because alternative healthy and tasty foods did not exist. Since then, the "healthy" food segment of the market has increased to \$30 billion/yr with business growing at about 6%/yr as compared to 1% for the remainder of the food industry (van Osnabrugge, 1988).

Recently, nutrition awareness increased to a point such that 93% of Americans now profess not only an interest in the nutritional content of the foods they eat, but also an interest in nutrition as an important consideration of their shopping pattern. Reports have indicated concerns about nutrition that included vitamin and mineral content, fat

content and calorie content of foods (Farr, 1987). At any one time, there are about 45 million people dieting to either lose or maintain weight. Almost 80 million consumers regularly use low calorie products (Lachance, 1989).

2. Convenience Products

Convenience is also an important attribute of food products. Recently, convenience products have experienced rapid growth and will most likely become the dominant trend in the future (Sills-Levy, 1989). Changing consumer lifestyles and demographics are primary factors contributing to the increased demand for convenience foods. Among these factors are the increased number of women in the workforce, the buying power of "baby boomers," the rise in number of small households and the popularity of "grazing" or eating small meals throughout the day.

In 1986, 72% of American women aged 25-44 had careers outside the home, a percentage that should increase to 76% in the 1990's (Hess, 1987). By AD 2000, 84% of women aged 35-44 are expected to join the workforce (Sills-Levy, 1989). In 1984, both spouses in over 41% of married couples worked outside of the home, leading to increased demand for convenience items because of higher incomes and declining leisure time. Typically, with each 1% increase in income, food expenditures increased 0.32%, except for food products such as frozen fruits and vegetables and food prepared away

from home; these latter categories experienced a larger increase (Kinsey, 1987). As incomes increased, type and form of foods purchased changed; additional processing, packaging and servicing were expected (Henneberry and Charlet, 1992; Kinsey, 1987).

The "baby boom" generation has been considered by marketers as innovators, being more likely to adopt new products. Consumers aged 35 to 44 spent more for food (about 14% of their income) than any other group and accounted for 20.9% of all households (Anonymous, 1989). By AD 2000, a majority of the 74 million baby boomers will reach their prime spending years (Sills-Levy, 1989). The boomers' willingness to experiment and their high spending rate will make them a very attractive market segment for convenience foods.

In 1987, single-person households accounted for 25% of all households; by AD 2000, this number likely will increase to 33% (Sills-Levy, 1989). About 55% of households have only one or two persons. As this percentage is expected to increase, so will the demand for convenience-type products, particularly those in single-serve or reclosable containers and those which require minimum cooking. This market segment will be particularly attractive because of the amount this group will spend on food. In smaller households, economies of scale cannot be attained in food

purchases; thus, these residents spend 44% or more per person than larger households (Kinsey, 1987; Henneberry and Charlet, 1992).

C. COATING USAGE

A food coating was defined by Suderman (1983) as the "...batter and/or breading adhering to a food product after cooking." Coatings perform several functions such as improving appearance, taste and nutritional value, increasing eating pleasure and functioning as a moisture barrier. Unfortunately, coatings can contribute also to the microbial load of products (Suderman, 1983).

In the United States, the use of breaded coatings began in 1937; about a decade later, the food processing industry began to use these coatings (Johnson and Hutchison, 1983). Since that time, coated foods have become popular as evidenced by an increase in breading and batter usage of almost 51,000 metric tons from 1978 to 1988 (Hurni and Loewe, 1990). Coated products are prepared and consumed easily, provide excellent taste and crispness and can be formulated to meet portion control guidelines (Suderman, 1990a).

Presently, there are many foods on the market that are coated with batter and breading systems. Coated animal products such as chicken and fish are quite common; however,

coated vegetables are marketed also. In the United States, some of the most commonly breaded and/or battered vegetable products include cauliflower, mushrooms, okra, egg plant, zucchini and onion, the most popular coated vegetable (Suderman, 1990b). In some cases, coating of a vegetable can increase its consumer acceptability by modifying acidity. Processors profit from coated vegetables by increasing their price per pound and by creating a use for wholesome products which do not meet visual grading standards (Martin, 1977). Shape and texture of the raw product are drawbacks to using vegetables as coating substrates, but the primary limiting factor is moisture content. The high moisture content of vegetables contributes to batter pillowing during frying and leads to a decrease in the time that the product can be held under a heat lamp without becoming soggy (Suderman, 1990b).

Moisture loss and oxidation can be inhibited, crispness can be retained and bacterial penetration can be decreased by using edible films as coatings, either alone or in combination with batters and breadings. Also, films can increase shelf life, control weight loss, reinforce structure of the product and serve as barriers to absorption of oil and grease (Suderman, 1983).

Most coatings are formulated for cooking and/or reheating by frying. It is possible, however, to produce a

coating system for baked products to provide the product with fried characteristics. Obviously, this type of product would have a lower fat content than a fried product. The processor also could eliminate variation in the product which results from the frying process and changes in the fat during storage and the expense associated with purchasing and using frying equipment (Andres, 1987). This type of coating does, however, contain some fat. Efforts to make this coating system fat-free have met with limited success when used on meat products but have not been successful with vegetables (Spencer, 1990).

D. BATTERS

1. Definition

Suderman (1983) defined a batter as "...a liquid mixture comprised of water, flour and seasonings into which food products are dipped prior to cooking." Typically, a dry batter mix contains 80-90% starch and flour and is added to water at a ratio of 1.5-2.0 parts mix to 1 part water. The dry mix is composed of 3-5% seasoning; some of the spices used as seasoning include black and white pepper, dried celery, thyme, marjoram, savory and capsicum oleoresin (Donahoo, 1970). Batter mixes for vegetables usually contain 3-8% salt (Yost, 1983).

2. Ingredients

Many ingredients are useful for modifying characteristics of the batter mixture. Suderman (1983) classified these ingredients as seasonings, fats and oils, proteins, water and polysaccharides with each category contributing a pronounced influence on the acceptability of the final coated product.

a). **Seasonings** - Primarily, seasonings are comprised of spices and their derivatives, sugar, salt and pepper. Typically, spices are present at 0.5%-1.0% in the finished product; however, some spices exhibit little flavoring strength at these levels. Spices also require time to achieve flavor equilibrium in the product and may exhibit flavor variation due to growing, processing and storage conditions. Some spices also may impart color or contribute the appearance of specks in the product. Spices may be eliminated by use of essential oils or oleoresins of a particular spice which are 100 and 5-20 times stronger than the parent spice, respectively. The primary disadvantage to the use of derivatives is that the flavor is not as full as with the use of pure spices (Suderman, 1990a).

Salt and pepper are used in batters primarily for flavor with pepper level up to 3.0-5.0% (Davis, 1983). Sugar is used to some extent for taste but also for its plasticizing effect and ability to enter into Maillard

browning (Suderman, 1983). Salt and sugar both can compete for water, thus slowing protein hydration and delaying viscosity development; but typically, this is not an important problem in batter systems (Davis, 1983).

Many factors must be considered when choosing a flavoring system for a coating. First, flavorant and desired flavor intensity must be determined. Secondly, flavor migration and flavor and color leaching must be examined. Mixing characteristics, ease of dispersion, bulk density and hydration rate of the flavorant are important factors to ensure that the flavorant becomes suspended and remains in suspension. Heat release and resistance value of flavorants are important to the final characteristics of the products as is ability of the flavorant to withstand frozen storage. Addition of some flavorants also may lead to eventual formation of off-flavors, rendering the product undesirable. Lastly, preparation method used by the consumer is of great importance in determining a flavorant for use in a food product (Suderman, 1990a).

b). Fats and Oils - In addition to improving flavor and adding fat-soluble vitamins, fats and oils contribute to mouthfeel. Also, texture is affected; the coating is made more tender by lubrication and interaction of fats and oils with other ingredients (Loewe, 1990).

c). **Protein** - Wheat flour used in most batters is the primary contributor of protein to the batter system; however, protein can be added to the batter by optional ingredients such as soy and corn flours, milk and eggs. Protein components are important for batter adhesion. Visually, egg albumen produces the most effective adhesion results, followed closely by wheat gluten and soy concentrate (Suderman, 1983).

Commonly, wheat flour is used in batters and breadings because of the ability of wheat proteins to form gluten as a result of mixing (Loewe, 1990). Gluten, composed of gliadin and glutenin, exhibits elasticity due to presence of glutenin, and extensibility due to presence of gliadin (Pyler, 1988).

Quality of batter gluten is influenced greatly by the amount of water present in the batter system. Sufficient water must be available to hydrate fully the flour proteins. Thus, a batter made of hard wheat flour, as opposed to soft wheat flour, requires a greater proportion of water due to a higher protein content. Typically, an all-purpose flour with a 9-10% protein is used for batters and breadings because higher protein flours (11-13%) produce thick, hard coatings; low-protein flours (7-9%) produce batters with poor adhesive properties (Davis, 1983). Olewnik and Kulp (1990) reported that the influence of protein content on

batter quality can be minimized by attaining a viscosity of 1050-2000 cPs.

Presence of gluten is extremely important to the final characteristics of leavened batters. Leavening gas is trapped within the gluten matrix during cooking, resulting in an aerated batter. This is particularly true in tempura batters which require aeration to produce a crispy crust (Loewe, 1990).

Formation of gluten also aids in development of batter viscosity. The starch fraction of a batter tends to precipitate, but a relatively viscous batter reduces precipitation and maintains uniform starch distribution within the batter. Batter viscosity also is important in determining adherence of the batter to itself and to the product (Loewe, 1990).

In fried coatings, an increase in protein typically leads to darker color, rougher texture and increased brittleness. Milling of high-protein wheat flours results in a greater amount of damaged starch than milling of lower protein wheat (Pyler, 1988). Damaged starch absorbs less water, thus batters made with high-protein wheat flour tend to absorb greater amounts of fat during frying and retain less water (Olewnik and Kulp, 1990).

Soy flour does not contain gluten-forming proteins, but it is still an important batter ingredient because of its

high protein content (53% in defatted flour). Soy flour can act as a binder to decrease dough expansion, possesses a high water absorption capacity and can be used to dilute the gluten proteins of wheat. In fried bakery products, substituting defatted soy flour for 3-5% of total flour weight decreased the amount of oil absorbed by the product while improving crust color (Pyler, 1988). Addition of soy flour also may increase coating adhesion (Davis, 1983).

Corn flours are devoid of gluten-forming proteins, but like soy flour, can dilute wheat gluten proteins, resulting in a crisper coating. A 2:1 ratio of corn flour to wheat flour results in a brittle cooked coating; a 100% corn flour batter is very hard after cooking. Due to lack of a gluten matrix, 100% corn flour batters cannot retain leavening gas and the product tends to shrink from the batter during cooking (Burge, 1990). With corn, as with other non-gluten forming flours, cohesive doughs can be obtained. Such doughs do not exhibit elasticity but are cohesive due to flour particles being compacted by the surface of the water. Maximum cohesiveness may be achieved by using a fine flour and the optimum amount of water to just fill the voids between flour particles (Hoseney, 1986).

Corn flour contributes favorably to the appearance of the cooked coating. In combination with reducing sugar, corn proteins produce a golden brown surface. As an

ingredient in batters, corn flour increases coating adhesion possibly due to reduction of leavening gas retained and steam venting. In products containing fat (e.g. chicken), the corn flour proteins might complex with the fat, resulting in greater coating adhesion. Corn flour and meal are used commonly in homestyle breading to provide texture and visual appeal (Burge, 1990).

Although milk is not a large contributor of protein, its proteins and lactose contribute to the non-enzymatic browning of coatings developed during the cooking process (Davis, 1983). Loewe (1990) suggested that milk and whey products may be important ingredients in baked coatings due to their ability to participate in non-enzymatic browning.

Milk and whey products can be used in the liquid form; however, typically, they are added as powders due to their increased shelf stability and ease of handling. In addition to participating in non-enzymatic browning, milk and whey proteins also can provide structure and, in liquid form, modify viscosity of the batter (Loewe, 1990). Non-fat dry milk increases the water absorption capacity of the flour, improves baking quality of soft wheat flours, decreases moisture loss and contributes to flavor (Suderman, 1983).

Egg contains several ingredients important to successful batter formulation. Generally, egg albumen is thought to aid in binding the coating to the product and to

itself by forming an adhesive network when denatured or coagulated (Davis, 1983; Mountney, 1983). However, Hanson and Fletcher (1963) found that use of whole egg or egg yolk at 0, 5 and 10% of batter weight had no significant effect on batter adhesion, but the coating did become tougher with increased amounts of egg. Egg yolk lecithin acts as an emulsifier and contributes to the stability of the batter by suspending the ingredients until cooking sets the ingredient matrix (Davis, 1983; Mountney, 1983). Incorporation of egg gives the finished product a darker color. Egg, in combination with milk, is used as a predip ingredient because of the ability of egg to form a glaze which prevents dehydration and contributes to sheen (Mountney, 1983; Suderman, 1990a).

d). Starch - Starch is an important and commonly used ingredient in batters and breadings. Type and amount of starch used in a coating can influence viscosity of the batter and texture and color of the final product. Starch may be used to solve problems concerning adhesion of the breading to the product. In foods of very high moisture such as vegetables, starch at 65-85% is used in the batter or predip to absorb surface moisture that may interfere with adhesion (Yost, 1983). The amylose component of starch, a primarily linear chain, is capable of forming flexible films of great strength and is easily applied to food products

(Pyler, 1988; Whistler, 1965). However, amylose has limited dispersability in water until the temperature reaches 65°C (Foster, 1965; BeMiller, 1973). Amylose, which can absorb up to 4 times its weight of water, forms an opaque, irreversible gel, with a gel strength proportional to concentration and age. Films formed by amylose are oil resistant, largely oxygen impermeable and do not contribute flavor to the product (BeMiller, 1973). Amylopectin, the highly branched component of starch, forms stable aqueous solutions that are clear, viscous and do not gel on cooling and aging (Foster, 1965; Powell, 1973; Pyler, 1988).

Starch granules, insoluble in cold water, undergo gelatinization at about 60°C. Gelatinization is characterized by uptake of water, loss of birefringency and clearing of the starch solution (Pyler, 1988). Solubilization of starch components is a function only of temperature; time is not a factor (Hoseney, 1986). During gelatinization, short chains of amylose and amylopectin leach out of starch granules into the surrounding aqueous medium. Presence of free short chains and uptake of available water by the granules cause the suspension to become viscous. Starches classified as "waxy" contain little or no amylose and undergo a greater degree of granular swelling during gelatinization (Pyler, 1988). Ungelatinized starch settles out of the batter suspension

rapidly but forms a gel after undergoing gelatinization and cooking (Loewe, 1990).

Wheat flour is a common source of starch in coatings (Davis, 1983). Characteristics of the wheat flour starch depend upon type of wheat from which the flour is milled. As a result of increased milling of hard wheats, the starch components sustain much more damage than starch of soft wheats. Increased damage results in increased water absorption capacity. Starch damage increases peak mixing time also, possibly due to the competition between gluten proteins and starch for water (Olewnik and Kulp, 1990).

A change in absorptive capacity can affect batter viscosity and, in turn, influence batter pickup and characteristics of the cooked and uncooked coating (Olewnik and Kulp, 1990). These effects are minimized by adjusting viscosity of the batter to the optimum 1050-1200 cP. Increase in the amount of damaged starch in a batter influences color and texture of the fried coating, but not adhesion of the coating to itself or the product when batter viscosity is optimum. An increase in damaged starch causes the coating to become brittle and dark. Darker color is thought to be the result of dextrins and proteins present in the wheat flour, contributing to Maillard browning and caramelization.

Wheat flour starch typically undergoes gelatinization between 52 and 63°C, but gelatinizes at higher temperatures in a low moisture system (Davis, 1983). In the presence of excess water, starch granules become more swollen and distorted than in limited water systems (Hoseney, 1986).

Corn flour is the second most commonly used source of starch in coatings and is a highly versatile ingredient (Davis, 1983). Yellow corn contains carotenoids which, in combination with reducing sugar, yield golden brown crust color and improve color of the interior portion of the coating (Burge, 1990). However, use of corn flour can result in some undesirable coating appearances. Yellow corn flour alone can contribute a greenish-yellow appearance to coatings, while a combination of waxy and non-waxy corn starch may result in a light-colored coating. Use of waxy rice starch in combination with waxy corn starch results in glossy brown coatings (Suderman, 1983).

During gelatinization at about 70°C, corn starch has a high water holding capacity. Consequently, absorption of oil by the coating during frying tends to decrease as level of corn starch is increased. This property also makes corn flour an important factor in determining viscosity of the batter with more water being required in batter formulation as corn flour content increases (Burge, 1990).

Corn flour at low levels has little flavor, but at higher levels can function as a flavor enhancer and is used commonly as a flavorant carrier. Coatings containing large amounts of wheat flour or starch can exhibit a starchy flavor which can be diluted partially by the addition of corn flour (Burge, 1990).

Specialty starches are used commonly in batters at 5-15% (weight basis), with their primary function being viscosity control. Specialty starches also can increase coating adhesion either alone or by interaction with other batter ingredients such as gums and proteins to form films (Meyers, 1990). Addition of specialty starches will affect other batter components. For example, isolated starch serves to mimic the effects of reduced protein content and starch damage, while pre-gelatinized starches give characteristics similar to using flour with damaged starch (Davis, 1983). Specialty starches result from modifying native starch, typically corn or tapioca. Unmodified starch tends to break down when subjected to physical and/or chemical abuses. Modified starch is more resistant to processing and possesses desirable gelation properties.

e). Gums - Gums were defined by Meyers (1990) as "...non-digestible polysaccharides that have a profound effect on the available free water and the rheology of liquid batter systems." They are more expensive than

specialty starches but are used at lower levels of 0.5-3% on a dry weight basis (Meyers, 1990). Such low levels avoid dilution of the protein fraction (Davis, 1983).

The primary function of gums is to provide batter viscosity (Davis, 1983). Viscosity control is important in cold and low-solids batters. Gums contribute to viscosity in 2 ways: by thickening the medium and by providing interfacial tension which prevents separation of immiscible components (Meyers, 1990).

Gums can act also as water holding agents. This property enables gums to provide freeze-thaw stability to products by absorbing moisture as it is released. However, when using gum with high water holding capacity, Maillard browning is limited because dehydration is hindered. This can be compensated for by the addition of proteins and reducing sugars in the batter (Meyers, 1990).

Gums also are used for their film-forming properties which prevent batter "blow-off" and "pillowing" (Meyers, 1990). The film can serve also as a barrier to oil uptake and moisture loss (Duxbury, 1989; Hale and Goodwin, 1968).

Gum effectiveness in batters is based upon several factors, including gel strength, concentration, molecular weight and viscosity. Adhesion increases with an increase in gel strength, molecular weight or viscosity. Adhesion also increases to a point with an increase in concentration;

however, after the optimum concentration level is exceeded, coating is lost due to "blow-off." Gum effectiveness is influenced also by the interaction of the gum with other components of the batter (Meyers, 1990).

There are many types of gums available, with each having unique functional characteristics. The particular gum to be used is highly dependent upon processing and desired end characteristics of the product.

Gums are incorporated into coating systems in several ways. The most common industrial method involves blending the gum with the dry batter ingredients before the water is added. However, gums also can be hydrated prior to addition, particularly when added to a high-solids batter. Another method is the suspension of gums in non-aqueous ingredients such as oil. The method of addition depends upon the characteristics of the gum and the processing steps the batter undergoes (Meyers, 1990).

3. Viscosity

To retain viscosity of the batter, it should be prepared at a temperature lower than room temperature (Donahoo, 1970). It is vital that the batter be sufficiently viscous so that the starch is distributed evenly over the product being dipped, while at the same time, the batter system provides sufficient water to allow starch gelatinization. An increase in water level results

in decreased batter viscosity, thus gums are added typically to control viscosity (Davis, 1983).

Batter viscosity is the controlling factor in determining the amount of breading picked up by the product. Cunningham and Tiede (1981) found that for batters with a 1:2 ratio of water to solids, cooking losses were at a minimum while breading adhesion was maximized. Coating pickup was calculated by the following formula (Hutchison et al., 1990):

$$\% \text{ Pickup} = \frac{\text{weight after coating} - \text{raw weight}}{\text{raw weight}} \times 100$$

By law, pickup must be 30% or less for meat products (Meyers, 1990), while vegetables are not regulated and typically have around a 50% pickup (Brown, 1992).

E. BREADING

1. Definition

Breading was defined by Suderman (1983) as "...a dry mixture of flour, starch and seasonings, coarse in nature, and applied to moistened or battered food products prior to cooking." The content of breading is similar to that of batter, except that the breading typically contains 70-80% starch and hard wheat flour, in addition to specialty starches (Donahoo, 1970). The primary difference in breadings and batters, however, is that breadings are thermally processed (Dyson, 1983).

In breading production, dry ingredients are blended, then mixed with water to form a dough. The dough is forced through a series of rollers, forming thin sheets which are baked to a moisture content of about 35% and crumbled, using a granulating mill or grinder. The particles are dried to a moisture content of 8%, then bagged (Dyson, 1983).

2. Types of breading

There are many different breadings available, differing in particle size, color, texture, porosity, browning rate and flavor. These factors and the manner in which they interact create a wide variety of possible breading characteristics.

Particle size ranges from No. 5 U.S. sieve to No. 80 U.S. sieve and influences the ultimate appearance of the product. Coarseness also influences the rate at which moisture is absorbed from the batter and given off in the cooking process (Dyson, 1990). Smaller particles absorb (and release) moisture much more quickly than larger particles and increase the viscosity of the coating so that it appears dry and can be handled without surface marking. However, larger particles provide texture as well as visual appeal. For satisfactory coverage, the fractions from U.S. No. 20 sieve to U.S. No. 60 sieve are the most important (Dyson, 1983). Smaller particle sizes are used when a smooth appearance is desirable, with larger particles

contributing to a rough appearance. Particle size should remain in a narrow range to prevent the coated product from possessing an uneven appearance (Davis, 1983).

Porosity is important also in determining moisture absorption from the batter or food surface, final texture and ultimate color. Very porous breading granules absorb frying oil more readily and heat more rapidly than do granules of greater density. Thus, in particles of the same composition, the porous granules will exhibit a more rapid color change (Dyson, 1983). Dense, coarse particles are used typically when coating a product which will be reheated in the oven. The use of this type of breading would provide the coating a non-oily appearance (Dyson, 1990).

Browning rate of a coating is important in determining the processing the coated product will undergo. Breadings which brown quickly are said to have "low fry tolerances." For this reason, fryer line speeds are increased or lower frying temperatures are used for products coated with this type of breading. A rapid browning rate is due primarily to the use of reducing sugars in the breading. In addition to reducing sugars, annatto, paprika, caramel and other colorants are added to the breading ingredients to achieve a more balanced color. The processor is responsible for determining the color of prefried foods which will be reheated in the oven; little or no color development occurs

during reheating (Dyson, 1990). In addition to breadings ingredients, cooking method is also a very important factor in determining the color of the coating, as is the cooking medium and temperature (Suderman, 1983; Waimaleongroa-Ek and Chen, 1983).

Flavorants may be incorporated into the breading either before or after the dough is baked. However, if flavorant is incorporated prior to baking, it must withstand baking without losing flavoring strength. Many of the same considerations for choosing a batter flavorant also apply in selecting a flavorant for breadings (Suderman, 1990a).

F. PREDUSTS AND PREDIPS

Predusts and predips are typically used to prepare the food surface so that the coating adheres satisfactorily to the product (Hutchison et al., 1990). Predusts, in particular, act as an interfacial layer between the product and the coating (Suderman, 1990a). This is particularly important in products such as onions which have a very smooth surface; otherwise, batter would not adhere to the product (Burge, 1983).

Predusts are fine, dry mixes which are dusted onto the surface of a food (Dyson, 1990). They are composed primarily of starch, but corn flour and meal are used commonly because of their coarseness. Other ingredients may

be added also to enhance the flavor and appearance of the product (Burge, 1990). Gums can be used also as ingredients in either predusts or predips, primarily for their film-forming ability (Meyers, 1990).

Suderman (1990b) reported that use of milk as a predip increased breading adhesion compared to the use of water or no predip. Also, evaporated milk was more effective than whole milk. Milk and egg are standard predip ingredients; flavor emulsions may be used also (Suderman, 1990a). Use of phosphate predips for breaded fish, however, did not lead to an increase in coating adhesion (Corey et al., 1987).

G. COATING ADHESION

Suderman (1983) defined coating adhesion as "...the chemical and physical binding of a coating, both with itself and with the food it coats..." Adhesion is of major concern because the loss of breading materials is uneconomical and renders a product unacceptable in appearance (Loewe, 1990).

Most research on coating adhesion has been conducted on poultry, particularly to overcome the adverse effect poultry skin has on coating adhesion. Hale and Goodwin (1968) found that precooking of chicken prior to coating increased adhesion. Hanson and Fletcher (1963) experimented with the use of different flours, particularly corn flours and

starches, the effect of varying the amount of egg in the batter and precooking prior to the coating process.

Suderman et al. (1981) investigated the use of a variety of gums and protein sources to improve adhesion and concluded that protein was more effective than gums in binding the coating to the substrate, with protein source being a significant factor. Of the gums, carboxy methyl cellulose was most effective. Suderman and Cunningham (1981) also found that poultry pieces which were frozen then thawed before coating tended to have increased adhesion.

Suderman and Cunningham (1979) devised a rapid and accurate method for determining coating adhesion. The product was placed on a No. 4 U.S. wire sieve in a sieve shaker which was shaken for 1 min. The loose crumbs were weighed and breading loss determined as follows:

$$\% \text{ loss} = \frac{\text{loose crumb weight}}{\text{coated product weight} - \text{initial product weight}} \times 100$$

They suggested that breading loss of 15% or less indicated satisfactory adhesion.

H. COOKING METHODS

1. Microwave Ovens

When the microwave oven was introduced, it was considered a luxury item, but in today's society, it has become a standard kitchen appliance (Anonymous, 1987b). By 1980, microwaves were in only 20% of American households, as

compared to 75% of households today (Messenger, 1987; Shapiro, 1990). Stanton and McNutt (1990) predicted that by AD 2001, 95% of American households will have 1 microwave oven and 50% will own 2 or more.

Microwave ovens have had a significant effect on the lifestyles of consumers. They offered convenience of food preparation, and thus, were instrumental in advancing the "grazing" trend of eating small meals or snacks throughout the day instead of 3 main meals (Messenger, 1987). Children are frequent users of microwave ovens due to ease of use and the perception of safety (Schiffman, 1990). Older Americans are highly dependent upon microwaves since they were among the first purchasers of the appliance (Thoms, 1988). As consumers' education and income increase, so does the likelihood of microwave usage (Messenger, 1987). Microwave ovens are used 3 or more times per day by 47% of microwave owners and as the main cooking appliance by 33% of owners (Anonymous, 1987b). Over 50 million servings of foods and beverages are microwaved every day. Snacks are prepared in the microwave oven by about 44% of consumers, accounting for about 23% of the total usage time for microwave ovens (Messenger, 1987).

Although the microwave oven has made food preparation convenient, consumers also want foods with quality, variety and flavor (Messenger, 1987). Perhaps the most serious

drawback of the microwave oven use is the lack of browning, and thus, reduced production of flavor compounds such as buttery, roasted, caramelized and burnt which are typically formed in thermal reactions (Przybyla, 1989). The lack of browning occurs because the air inside a microwave oven is relatively cool and the surface of the food is cooled as moisture evaporates from it (Mudgett, 1989). The addition of flavors or flavoring compounds is employed typically to compensate for the lack of a "cooked" flavor. Also, product formulation may be modified to include ingredients such as lecithins, milk proteins or sugars that contribute to "runaway" browning. These would be added typically on the surface or in the coating of the product (Best, 1987). Flavor precursors such as a cheese powder in microwave popcorn can be used successfully (Anonymous, 1988c). An alternative method involves pre-baking the product by conventional means to allow browned flavors to form; the product is then reheated via the microwave (Best, 1987).

Texture of microwaveable foods suffers also, particularly those foods that achieve a crispy texture during conventional preparation. The amount of moisture present in these products is a very important factor. A microwave oven heats the inside and outside of a product simultaneously. In some instances, the internal temperature might be higher than the external temperature, causing

moisture to proceed to the surface more rapidly than the rate of evaporation (Schiffman, 1990). Migration of steam from within the product and its subsequent condensation on the surface tends to make surfaces soggy (Anonymous, 1987b). Any surface evaporation that does occur also results in a cooling effect, thereby, reducing potential for dehydration. Conversely, in conventional oven preparation, moisture migration from the interior to the surface occurs by capillary movement and is controlled by the diffusion rate (Schiffman, 1990). Slower rates of migration allow for increased surface drying.

Undesirable textural effects may be minimized by formulation changes. Crispness of breaded products may be maintained by use of crumb-type breading which remains crisp during microwaving and retains stability during shelf life (Anonymous, 1987b). Research has been conducted on use of starches and hydrocolloids as moisture absorbers and inhibitors of steam migration to the surface, both contributing to crispness and minimizing formation of dry spots (Anonymous, 1986; Best, 1987; Hegenbart, 1989; Schiffman, 1990). Also, the use of predusts and multiple stage coatings has been investigated (Schiffman, 1990).

Processing changes such as cooking products in a vented package or container and using metallized films as susceptors can contribute to maintenance of texture.

Susceptors collect microwave energy, convert it to latent heat and transfer it to food surfaces (Anonymous, 1987b). The Food and Drug Administration recently became concerned about the use of susceptors. During heating, many of the metals used in susceptors do not have temperature limits and, thus, may attain temperatures of 232°C or higher. At such high temperatures, metallic breakdown may occur, leading to the possibility that food may become contaminated with degradation products from the susceptors (Schiffman, 1990).

Consumer enthusiasm has not been damped by textural and flavor problems associated with microwaveable foods (Anonymous, 1987b). In 1988, sales of microwaveable foods totalled about \$1 billion; by 1989, this figure had more than doubled, with pizza, popcorn and other hot snacks accounting for about 66% of sales (Shapiro, 1990). Over 25% of all frozen foods which require some heating before consumption are prepared in a microwave. These products may be designed for heating in a microwave oven only, or in a microwave or conventional oven. Because the microwave is quite different from a conventional oven, quality of a product which may be heated in either oven may not be as satisfactory as if the product were designed for only one cooking method.

2. Deep fat frying

Frying is one of the most popular methods for the preparation of many foods, particularly snacks. Fats and oils can reach very high temperatures (150°C and above) when heated. This heating capacity gives products cooked in the medium many desirable characteristics. However, the uptake of fat during cooking also increases caloric content of the fried food (Birch et al., 1986).

Frying is essentially a dehydration process. The high temperatures quickly vaporize water at the surface, resulting in water migration from the interior of the product. Thus, the temperature at the surface of the product remains at approximately 100°C and the food does not burn as long as water continues to vaporize (Blumenthal, 1991). Crispness of the external surface of the fried product is a result of dehydration as is some of the brown color of the crust (Birch et al., 1986).

Frying also contributes to the flavor of the product. May et al. (1978) found that frying moist cotton balls led to the development of a pleasant deep-fat fried flavor in the oil. They then isolated several lactones from the fat and found that those primarily responsible for the desirable flavor were gamma lactones with unsaturation at the 2- or 3-position. Other isolated lactones had either an adverse effect or no effect at all. In addition, other compounds

responsible for flavor may be produced by an interaction between the food and the oil (Chang et al., 1978).

In addition to the desirable texture and flavors as a result of deep-fat frying, this method is used because of the speed with which processors can produce products. For example, many coated foods are fried only for 30-60 sec to set the coating, and in the case of vegetables, to inactivate enzymes. For these types of products, the consumer is responsible for cooking the product (Brown, 1992). In contrast, blanching and setting the coating by baking would require a much longer period of time and would decrease processing line speed.

3. Convection Baking

Baking in forced air convection ovens is similar to frying in that there is a rapid exchange of heat and water at the product surface. Several studies were conducted to determine heat transfer characteristics of "convection oven frying." Skjoldebrand (1980) found that "convection oven frying" had a lower heat transfer coefficient than other frying methods. This meant that a high resistance against heat transport existed and that the kind and size of product was a factor in "convection oven frying." He suggested that moisture loss could be minimized by using a high humidity, low-temperature air. Crust formation could be achieved by using dry air in the final stages of oven frying.

Skjoldebrand and Hallstrom (1980) reported that the final moisture content of a product during convection oven frying was largely a function of the water sorption isotherm for that product. They also suggested that once the crust of a product had reached 100°C the heat transfer in the product could be calculated as conduction instead of convection.

Sato et al. (1987) investigated the use of a forced air convection oven for baking cakes. They found that the final cake shape was highly dependent upon air velocity and temperature. High temperature and low air velocity resulted in cakes with a non-uniform appearance, but satisfactory texture; low temperature and high air velocity produced flatter, more uniform cakes.

An impingement oven is a type of convection oven in which the hot air is forced through impingement jets and onto the product to remove still air around the product and increase heat and moisture transfer. Over 40,000 impingement ovens currently are in use, mainly in the pizza industry. Impingement ovens are capable of baking many different products, usually at times and temperatures 25-50% lower than needed for conventional ovens, particularly for foods high in moisture and small in size (Walker and Sparman, 1989).

Presently, the food industry uses "convection oven frying" on a limited basis for some types of meat products, particularly reduced-fat, coated fish portions (Spencer, 1992). Although these baked products met with enthusiastic consumer response, deep-fat frying will continue to be the cooking method of choice for the food industry. At this point, the faster processing line speeds attainable with deep-fat frying give it a significant advantage over "convection oven frying" (Brown, 1990).

CHAPTER III

METHODS AND MATERIALS

A. STATISTICAL DESIGN

Two experiments were conducted to determine acceptability of apple and mushroom snacks produced with reduced-fat batter and heated in an air impingement oven. The experiments were identical except for different seasonings used in the batter and predust formulations.

In accordance with the experimental design (Appendix A), the analysis of coating pickup, coating loss and cooked color was conducted as a randomized complete block design with 6 replications. Because multiple measures were taken for each treatment, the subsampling error was identified in the ANOVA table (Lentner and Bishop, 1986). For responses measured after reheating (coating percentage, moisture percentage, reheated color and sensory characteristics), the interaction pretreatment*reheating method was confounded with blocks. Therefore, the error term used to test the significance of this interaction was obtained by subtracting its sum of squares (with 1 df) from the sum of squares for blocks (with 5 df).

B. STORAGE AND PRETREATMENT

Stayman Winesap apples (*Malus sylvestris*) (U.S. No. 1 and utility; Old Home Orchards, Winchester, VA) were stored at 7°C, then peeled, cored and cut into approximately 2-cm cubes using a Hobart food processor with a dicer attachment (Model 84142; Hobart Manufacturing Co., Troy, OH). The cubes were either predusted (Table III.1) or predried in an air impingement oven (model 1132; Lincoln Foodservice Products Inc., Fort Wayne, IN) at 66°C for 10 min.

Snow White mushrooms (*Agaricus bisporus*) of about 2 cm diameter (Monterey Mushrooms, Loudon, TN) were stored at 7°C, then washed and trimmed. Mushrooms were predusted (Table III.1) or predried for 10 min at 66°C in an air impingement oven.

C. BATTER PREPARATION

Batter ingredients and sources are listed in Tables III.2 and III.3 for use on apple or mushroom, respectively. Prior to addition of liquid ingredients, dry batter ingredients were mixed with a 3-speed, hand-held mixer (model 433; Rival Manufacturing Co., Sedalia, MO) to eliminate lumps. Appropriate amounts of vegetable oil and chilled water were added to the dry ingredients and the batter was mixed 1.5 min at low speed. After mixing, temperature of the batter was measured. Temperature ranged

Table III.1--Formulation^a of predusts used for apple and mushroom pieces

Ingredient	Substrate	
	Apple	Mushroom
	% of total predust weight	
Amylose	70	70
Hydroxypropyl methyl cellulose	5	5
Methyl cellulose	1	1
Non-fat dry milk ^b	20	20
Seasoning salt ^b	-	2
Creole seasoning ^b	-	2
Cinnamon, ground ^b	4	-

^aFormulations determined by laboratory trial and error.

^bSource: Kroger Co., Cincinnati, OH.

Table III.2--Formulations^a of batters applied to apple pieces

Ingredient	Batter		
	A	B	C
	% of total weight of non-water ingredients		
Wheat flour ^b (All-purpose)	35	30	40
Corn flour (masa)	15	10	22
Non-fat dry milk ^b	10	5	10
Rice maltodextrin ^c	10	5	15
Oil, soybean ^d	20	40	3
Hydroxypropyl methyl cellulose	2	2	2
Sugar, granulated ^b	3	3	3
Cinnamon, ground ^b	5	5	5

^aFormulations determined by laboratory trial and error.

^bKroger Co., Cincinnati, OH.

^cRiceTrinTM Complete (DE 12), Zumbro Co., Hayfield, MN.

^dWessonTM Vegetable Oil, Hunt-Wesson, Inc., Fullerton, CA.

Note: To hydrate batters, 250 mL, 220 mL and 260 mL of water were added to batters A, B and C, respectively.

Table III.3--Formulations^a of batters applied to mushroom

Ingredient	Batter		
	A	B	C
	% of total weight of non-water ingredients		
Wheat flour ^b (all purpose)	35	30	40
Corn flour (masa)	15	10	22
Non-fat dry milk ^b	10	5	10
Rice maltodextrin ^c	10	5	15
Oil, soybean ^d	20	40	3
Hydroxypropyl methyl cellulose	2	2	2
Salt ^b	1	1	1
Pepper ^b	2	2	2
Seasoning salt ^b	3	3	3
Creole seasoning ^b	2	2	2

^aFormulations determined by laboratory trial and error.

^bKroger Co., Cincinnati, OH.

^cRiceTrinTM Complete (DE 12), Zumbro Co., Hayfield, MN.

^dWessonTM Vegetable Oil, Hunt-Wesson, Inc., Fullerton, CA.

Note: To hydrate batters, 270 mL, 250 mL and 325 mL of water were added to batters A, B and C, respectively.

from 13 to 16°C. Batter consistency was determined using a Brookfield Syncro-Lectric Viscometer (model LVF; Brookfield Co., Stoughton, MA) at speed 30 with spindle 4. The spindle was allowed to rotate about 30 sec before the reading was taken. If necessary, batter viscosity was reduced by adding chilled water to the batter.

D. COATING PICKUP

To determine percentage of coating picked up in the batter and breading process, 15 pieces of product were selected randomly and weighed prior to application of batter and breading. A total of 90 observations was made for each batter*pretreatment combination. Predusted products were weighed prior to the application of predust; predried products were weighed after the predrying procedure. The dusted or dried product was dipped in the appropriate batter, then allowed to drain for 15 sec. Battered pieces were rolled in cornflake crumbs of 20-30 mesh size (Kellogg Co., Battle Creek, MI). The product was reweighed and percentage pickup was calculated (Hutchison et al., 1990).

E. INITIAL APPLE OR MUSHROOM PRODUCT COOKING

In each of the 6 experimental blocks, 120 pieces of apple or mushroom product were prepared for each batter*pretreatment combination. Products coated with

batters A or B were baked in an air impingement oven at 191°C for 9 min. Batter C products were fried 2 min at 191°C in an FW-12 Shallow Fryer (Model 8050; Gold Meadow Products Co., Cincinnati, OH). Products at this stage are referred to as "cooked" product.

F. PRODUCT STORAGE

After removal from the impingement oven or fryer, apple or mushroom products were placed on a wire rack and frozen in an air-blast freezer at -26°C. The frozen products were placed in freezer bags (Ziploc Brand; Dow Inc., Indianapolis, IN) and stored in a -23°C still air freezer.

G. BREADING LOSS

After 5 da of frozen storage, percentage of breading loss was determined for samples of all combinations of the pretreatment and batter conditions, using a modification of the method developed by Suderman and Cunningham (1979). About 115 g (approximately 30 pieces) of frozen product were placed on a U.S. No. 4 sieve with an exposed area of 120 cm². The product was shaken 1 min at speed 4, using a sieve shaker (50/60 Hz, catalog No. 18480; CSC Scientific Co. Inc., Fairfax, VA). Loose crumb was collected and weighed. Coating that adhered to the product was removed and weighed. Loss was expressed as percentage of total product weight and

of total coating weight by the following formulas:

$$\% \text{ loss (total product)} = \frac{\text{loose crumb wt.}}{\text{coated product wt.}} \times 100$$

$$\% \text{ loss (total coating)} = \frac{\text{loose crumb wt.}}{\text{loose crumb wt.} + \text{removed crumb wt.}} \times 100$$

H. PROXIMATE ANALYSIS OF APPLE AND MUSHROOM PRODUCTS

Treatments for proximate analysis were selected on the basis of sensory evaluation overall acceptability ratings. For each type of product, the most acceptable pretreatment within each of the 2 most acceptable batters was chosen. Loose crumb and product from the breading loss determination were recombined and chopped in a Hobart food processor with a chopper attachment (Model 84142; Hobart Manufacturing Co., Troy, OH). Moisture, fat, protein and ash were determined by AOAC (1990) methods. Dietary fiber was measured using an AOAC method adapted by Prosky et al. (1988).

I. REHEATING METHODS FOR APPLE AND MUSHROOM PRODUCTS

Frozen apple or mushroom products were reheated in a preheated conventional oven for 9 min at 191°C or in a microwave oven. For microwave reheating, 3 pieces were heated 1 min at medium high power (about 415 watts/hr) in a Quasar 800 watt oven (model MQS11082; Elk Grove Village, IL) using a Nordic Ware Compact Micro-Go-Round food rotator

(model 62301; Minneapolis, MN). After reheating, products were referred to as "reheated" product.

The wattage output of the oven was determined for each product heating session by measuring the increase in temperature (°F) as a result of heating 2 cups (475 mL) of deionized water for 1 min and multiplying the temperature difference by 17.5 (Van Zante, 1973). Water temperatures were measured with an Electro-therm digital thermometer (model SH66A; Cooper Instrument Co., Middlefield, CT). There were 4 wattage readings for each of the 6 experimental blocks; wattage data was analyzed using Analysis of Variance.

J. FINAL COATING PERCENTAGE OF REHEATED APPLE AND MUSHROOM

Fifteen pieces of previously heated and cooled product were weighed individually before and after the coating was removed by hand. The final coating percentage was determined for 45 pieces per treatment of apple or mushroom.

K. MOISTURE CONTENT OF REHEATED APPLE OR MUSHROOM

Reheated, cooled apple and mushroom products were chopped in a Hobart food processor with a chopper attachment as stated above. Percentage of moisture was determined for reheated products according to AOAC (1990) methods.

L. COLOR MEASUREMENT OF COOKED AND REHEATED APPLE OR MUSHROOM PRODUCTS

Surface color (Hunter L, 'a' and 'b' values) of cooked products (approximately 15 cubes) was measured with a Hunter Color Meter (model D25D2M; HunterLab, Reston, VA) which was standardized with a white tile (L=91.03, 'a'=-1.3, 'b'=1.6). Samples were held in a cuvette with an optical glass bottom for measurement. Four values were obtained for L, 'a' and 'b' by rotating the cuvette one-quarter turn after each set of readings. Hunter 'a' and 'b' values were converted to hue angle values for purposes of this research (Francis and Clydesdale, 1975).

Products on which color was measured were placed in freezer bags (Ziploc Brand; Dow Inc., Indianapolis, IN), frozen and stored with the remainder of the samples. After reheating and cooling, Hunter L, 'a' and 'b' values were measured. The degree of coating color change due to reheating was expressed as a "Delta E" value (Francis and Clydesdale, 1975).

M. SENSORY EVALUATION OF APPLE AND MUSHROOM PRODUCTS

After storage at -23°C for 6 da, products were reheated and held under a 500 watt Merco Food Warmer (model B-2; Merco Products Inc., Eugene, OR) until served. The 10-member sensory panel consisted of 6 females and 4 males. The panel was held Mondays, Wednesdays and Fridays from

8:00-10:30 AM with each panelist assigned an evaluation time so that the samples for each panelist could be reheated independently of the other samples (Walker, 1992).

Panelists were seated in individual evaluation booths, and samples were evaluated under cool, white fluorescent light. There were 6 panel sessions each for apple and mushroom samples. Panelists were oriented to the descriptive terms used on the scorecard during a preliminary session in which the reference samples (Table III.4) were presented and discussed along with a descriptor sheet (Appendix B). Panelists reviewed the references prior to the first panel of each week. A descriptor sheet was available also to panelists during individual evaluation. A trial panel was conducted prior to beginning actual sensory panels.

Samples were scored on a 154-mm line scale anchored at each end by opposing descriptive terms (Appendix C) (Penfield, 1992). The samples were evaluated for color, glossiness, crispness of initial bite, dryness, coating adhesion, deep-fried flavor and overall acceptability. Samples were coded with a 3-digit random code and presented to each panelist in a predetermined random order. Panelists received 3 pieces of product on 15-cm white paper plates; a stainless steel fork was provided. Panelists were asked to rinse their mouth between samples with room temperature

Table III.4--Reference samples for training of apple and mushroom sensory panelists

Product	Characteristic
Kellogg's TM Cornflake Crumbs	Dark brown ^a Light brown ^b
Glossy ceramic tile	Very glossy
Matte ceramic tile	Not glossy at all
Farm Rich TM Mixed Vegetable Sticks ^c	Adheres very well
Ore-Ida TM Coated Mushrooms ^d	Does not adhere well
Nabisco Premium TM Unsalted Tops crackers	Very crisp ^e Not crisp at all ^f Much moisture absorbed ^e No deep fried flavor
Brock TM Gummy Bears	No moisture absorbed
Michael Season's TM unsalted potato chips	Intense deep fried flavor ^e

^aBaked at 190°C for 15 min; L=22.0, a=7.8, b=8.1.

^bL=51.0, 'a'=10.1, 'b'=25.8.

^cPrepared according to manufacturer's instructions.

^dMicrowaved 12 pieces for 2 min at medium high power (ca 415 watts).

^eMeilgaard et al., 1991.

^fSteamed for about 5 min then stored over water in a closed container during evaluation.

spring water (Diamond Spring Water; Diamond Water Inc., Hot Springs, AR).

N. STATISTICAL ANALYSIS

Data analysis was performed with Proc GLM of the Statistical Analysis System (SAS) (SAS Institute, Inc., 1985) program of The University of Tennessee Computing Center. Analysis of Variance was used to determine significance of the main effects and their interactions on coating pickup (%), breaching loss (%), final coating (%), color (cooked and reheated) and sensory attributes. Interactions were considered significant at $P < 0.15$; main effects were considered significant at $P < 0.05$. Analysis of Variance models were simplified by deleting non-significant interactions. Significance among means, including those of proximate analysis values, was determined by the Duncan test for mean separation (SAS Institute, Inc., 1985).

Panelists were considered a random effect for analysis of sensory characteristics. Classification of panelists as a random effect reflects the high degree of variation among panelists and requires a larger treatment difference to attain significance (Lundahl and McDaniel, 1988). Sensory characteristic ratings for individual panelists were analyzed by ANOVA to determine if panelists could distinguish between treatments; panelists who could

not distinguish between treatments were dropped from the analysis for the particular characteristic.

CHAPTER IV
RESULTS, DISCUSSION AND CONCLUSIONS
FOR APPLE PRODUCTS

The effects of pretreatment, batter type and any significant interactions on the coating pickup (%), coating loss (%), proximate analysis values and cooked color of apple products are presented in Sections A, B, C and F, respectively. The effects of pretreatment, batter type, reheating method and any significant interactions on coating percentage, moisture, color change due to reheating and sensory evaluation are presented in Sections D, E, F and G, respectively.

A. COATING PICKUP (%)

Coating pickup was affected by batter type and pretreatment, but not by their interaction (Table IV.1). Among the batter types, batter C had the greatest percentage of pickup and batter B had the least (Table IV.2). Predusted products had a greater percentage of pickup than did predried products (Table IV.3).

The term viscosity was used throughout this manuscript to describe resistance of batters to flow. Actually, the terms consistency or apparent viscosity correctly describe this property, but the term viscosity is consistently used

Table IV.1--F-values from analysis of variance for characteristics of apple products

Source	Df	F-ratio	P-value
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COATING PICKUP (%)

Block	5	1.21	0.40
Batter	2	136.32	0.01
Pretreatment	1	110.91	0.01
Error mean square = 50.48 with 25 degrees of freedom.			

COATING LOSS (% OF TOTAL PRODUCT WEIGHT)

Block	5	3.28	0.02
Batter (B)	2	97.96	0.01
Pretreatment (P)	1	5.00	0.04
B*P	2	2.16	0.14
Error mean square = 0.06 with 25 degrees of freedom.			

COATING LOSS (% OF TOTAL COATING WEIGHT)

Block	5	1.25	0.30
Batter (B)	2	67.20	0.01
Pretreatment (P)	1	108.93	0.01
B*P	2	40.68	0.01
Error mean square = 3.71 with 25 degrees of freedom.			

COATING PERCENTAGE OF REHEATED APPLE

Block	5	2.00	0.14
Batter (B)	2	1291.13	0.01
Pretreatment (P)	1	9660.28	0.01
Reheat (R)	1	126.37	0.01
B*P	2	1106.73	0.01
B*R	2	3.13	0.10
B*P*R	2	3.49	0.05
Error mean square = 4.84 with 20 degrees of freedom.			

Table IV.1 Continued

Source	Df	F-ratio	P-value
MOISTURE CONTENT OF REHEATED APPLE			
Block	5	0.17	0.89
Batter (B)	2	54.49	0.01
Pretreatment (P)	1	0.91	0.35
Reheat (R)	1	6.08	0.02
B*R	2	10.62	0.01
B*P*R	4	1.85	0.07
Error mean square = 0.34 with 20 degrees of freedom.			
HUNTER L VALUE OF COOKED PRODUCT			
Block	5	0.53	0.57
Batter (B)	2	306.03	0.01
Pretreatment (P)	1	0.06	0.81
B*P	2	2.35	0.12
Error mean square = 1.09 with 25 degrees of freedom.			
HUE ANGLE OF COOKED PRODUCT			
Block	5	1.03	0.43
Batter	2	286.51	0.01
Pretreatment	1	0.34	0.52
Error mean square = 4.76 with 27 degrees of freedom.			
DELTA E VALUES			
Block	5	1.23	0.38
Batter	2	1.57	0.22
Pretreatment	1	0.72	0.46
Reheat	1	5.49	0.03
Error mean square = 0.18 with 26 degrees of freedom.			

Table IV.2--Mean values for characteristics of apple dipped in different batter types

Characteristic	Batter ^{a,b}		
	A	B	C
Coating pickup (%) ^c	42.52y ±5.82	39.73z ±5.82	51.56x ±6.63
Coating loss (%) ^{de}	3.14z ±0.28	4.33y ±0.40	3.03z ±0.22
Coating loss (%) ^{ef}	8.53y ±2.16	15.04x ±8.32	6.26z ±0.95
Final coating (%) ^c	47.93y ±10.09	44.52z ±15.57	56.00x ±6.69
Moisture (%) ^e	60.38y ±0.52	60.43y ±0.42	58.34z ±1.15
Hunter L (Cooked) ^e	36.31y ±1.06	35.43y ±1.06	26.78z ±1.03
Hue Angle (Cooked) ^e	20.78z ±1.32	19.65z ±1.21	27.61y ±1.53
Delta E ^e	0.91z ±0.52	0.86z ±0.44	0.94z ±0.55

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

Means represent batter values across pretreatments and reheating methods.

^bBatter formulations are shown in Table III.2.

^c180 observations were made for each batter type.

^dExpressed as a percentage of total product weight.

^e12 observations were made for each batter type.

^fExpressed as a percentage of total coating weight.

Table IV.3--Mean values for characteristics of pretreated apple products

Characteristic	Pretreatment ^a	
	Predry	Predust
Coating pickup (%) ^b	41.38z ±7.13	47.82y ±7.34
Coating loss (%) ^{cd}	3.59y ±0.74	3.41z ±0.59
Coating loss (%) ^{de}	13.29y ±7.26	6.59z ±1.07
Final coating (%) ^b	40.18z ±10.41	58.79y ±4.80
Moisture (%) ^d	59.87z ±1.24	59.68z ±1.33
Hunter L (Cooked) ^d	32.80z ±4.86	32.88z ±4.20
Hue angle (Cooked) ^d	23.71z ±5.78	22.84z ±6.03
Delta E ^d	0.98z ±0.41	1.03z ±0.54

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

Means represent pretreatment values across batter types and reheating methods.

^b270 observations were made for each pretreatment type.

^cExpressed as a percentage of total product weight.

^d18 observations were made for each pretreatment type.

^eExpressed as a percentage of total coating weight.

in the literature for this purpose. Batter viscosity is a factor in controlling pickup of coating, with more viscous batters resulting in greater coating pickup (Johnson and Hutchison, 1983; Loewe, 1990; Suderman, 1990b). The results of this study support that theory; mean pickup of coating by apple pieces increased ($P < 0.05$) as batter viscosity (A, 1300 cPs; B, 700 cPs; C, 1500 cPs) was increased (Table IV.2).

For industry use, low viscosity batters are sometimes more desirable. To achieve the desired coating pickup with a low viscosity batter, it is necessary to use a "double pass" system in which the product is battered, breaded, battered and breaded before cooking (Brown, 1992).

Use of predip or predust pretreatments may influence coating pickup. Predusted apple had greater coating pickup than predried apple (Table IV.3). Predusts may increase coating pickup by providing a more suitable surface for batter adherence than that of the underlying substrate (Burge, 1990; Hutchison et al., 1990;). This property is important particularly with substrates such as onions and other vegetables which possess a smooth, non-adhering surface (Burge, 1983).

Predusts also increase coating adhesion by modifying batter viscosity. Starches, a major predust ingredient, absorb water from the batter, thus increasing batter viscosity at the batter-substrate interface (Spencer, 1990).

Even when batter viscosity is controlled and predust application is uniform, coating pickup is highly variable. Johnson and Hutchison (1983) reported that hand-breading resulted in a considerable variation in amount of coating picked up. Variation reported within products produced by an individual within a given time period was almost as great as that reported between products produced by different individuals.

B. COATING LOSS (%)

When coating loss from cooked apple was expressed as percentage of total product weight, blocks, batter type, pretreatment and batter*pretreatment interaction significantly affected loss (Table IV.1). Batter, pretreatment and batter*pretreatment affected coating loss from apple expressed as percentage of coating weight. Apple coated with batter B lost the largest amount of coating as did predried products when expressed as a percentage of product weight and of coating weight (Tables IV.2 and IV.3).

There was no difference in coating loss as percentage of product weight between predried and predusted products when coated with batters A or C (Figure IV.1). Predried apple had greater ($P < 0.05$) coating loss than predusted when coated with batter B; both predried and predusted batter B

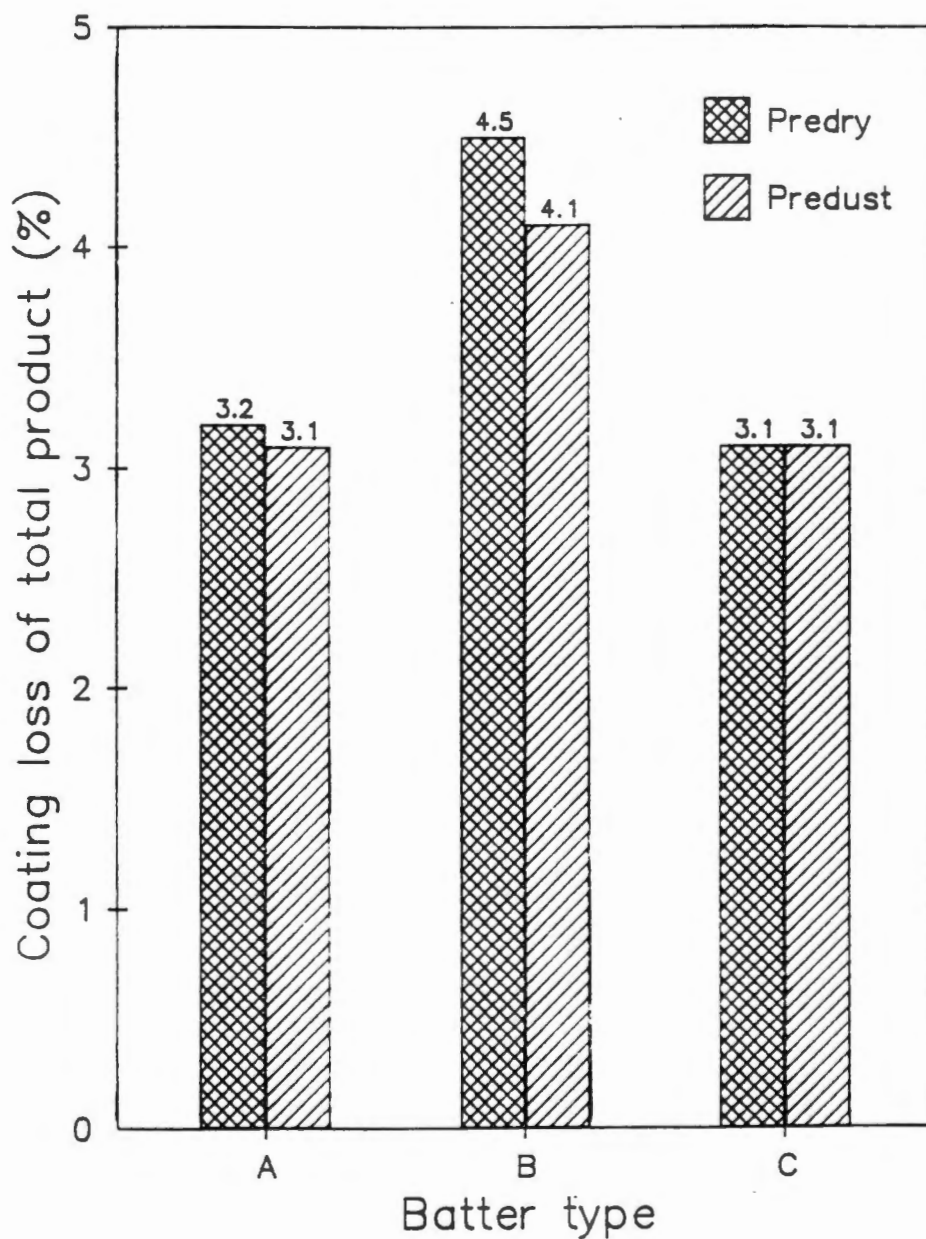


Figure IV.1--Coating loss of cooked apple products (expressed as a percentage of total product weight) as a function of pretreatment and batter type.

coated products had greater ($P < 0.05$) loss than products coated with batters A or C.

Coating loss expressed as percentage of coating weight was greater ($P < 0.05$) for predried products, regardless of batter type (Figure IV.2). The coating loss of predried products was almost 3 times that of predusted products when both were coated with batter B; differences between predusted and predried products coated with either batter A or C were not as large, but nonetheless, were significant.

Coating losses of predried products are a function primarily of batter viscosity and coating pickup. Cunningham and Tiede (1981) reported that batters of greater viscosity and coating pickup lowered coating loss; this trend was shown in Figures IV.1 and IV.2. Lower viscosity batters tend to break off during processing, handling or storage (Suderman, 1990b). The use of a predust, however, not only increases initial coating pickup due to modification of batter viscosity and the substrate surface, but can result in the formation of strong films or gels in the interfacial layer between substrate and coating (Meyers, 1990; Suderman, 1990a). The films increase coating adhesion and thus, the use of a predust in combination with a low viscosity batter can substantially reduce the amount of coating loss.

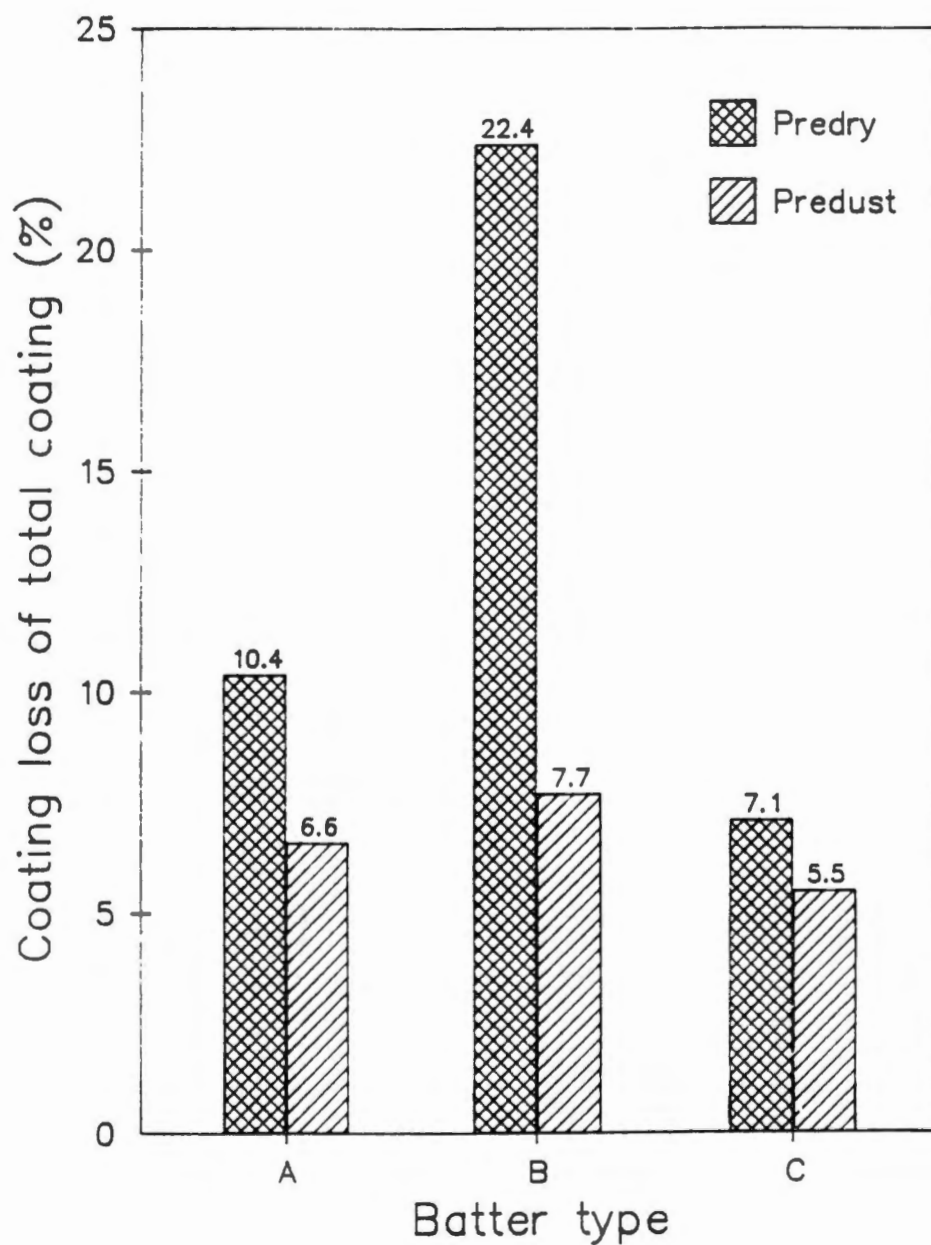


Figure IV.2--Coating loss of cooked apple products (expressed as a percentage of total coating weight) as a function of pretreatment and batter type.

Suderman and Cunningham (1979) developed a method to measure coating adhesion on chicken pieces and determined that loss of 15% or less indicated satisfactory coating adhesion. Their method did not involve a cooking process, and thus, was comparable to coating loss expressed as a percentage of total coating weight. By this criterion, all products except predried apple coated with batter B exhibited satisfactory adhesion (Figure IV.2).

C. PROXIMATE ANALYSIS

The apple products selected for proximate analysis were predried apple coated with batter A and predusted apple coated with batter B. Both products were baked in an air impingement oven. There was no difference in moisture and fat contents of cooked, predried apple coated with batter A and predusted apple coated with batter B (Table IV.4). Predusted apple products coated with batter B contained more protein and less fiber, ash and carbohydrate than predried products coated with batter A.

Apples contain approximately 2.5% protein, 2.5% fat, 15% fiber, 2% ash and 78% carbohydrate on a dry weight basis (Scherz and Senser, 1989). Wheat and corn flours and non-fat dry milk contained and contributed important amounts of protein to the batter. The non-fat dry milk predust ingredient may have been responsible for the difference in

Table IV.4--Mean proximate analysis values of cooked apple products

Component	Treatment ^{ab}	
	Batter A Predried	Batter B Predusted
Moisture (%)	45.57z ±0.70	46.42z ±1.10
Protein (%) ^c	17.38z ±0.32	19.57y ±0.48
Fat (%) ^c	6.81z ±0.16	7.14z ±0.12
Fiber (%) ^{cd}	8.35y ±0.16	7.68z ±0.36
Ash (%) ^c	4.29y ±0.11	4.04z ±0.16
Carbohydrate (%) ^{ce}	63.17y ±0.23	61.57z ±0.66

^aBatter formulation is shown in Table III.2.

^bMeans ± standard deviation within the same row are different at p<0.05. Analyses were performed in triplicate.

^cExpressed on a dry weight basis.

^dExpressed as total dietary fiber.

^e%Carbohydrate=100 - (% protein + % fat + % fiber + % ash).

protein values between the 2 treatments (Table IV.4). The predusted apple product coated with batter B had 14.87% greater coating pickup than the predried apple coated with batter A (data not presented); therefore, differences in protein content may be the result also of a difference in coating pickup.

An important function of protein is the binding of the coating to itself and to the substrate (Loewe, 1990). Olewnik and Kulp (1990) reported that adhesion of coating to poultry skin increased as the amount of protein in the coating increased. Differences in protein content between the 2 products could have caused the predusted product with batter B to possess greater coating adhesion (lower coating loss as % of total coating weight) than the predried product coated with batter A (Figure IV.2).

Batter B contained twice the amount of oil as batter A. The higher oil content, coupled with higher coating pickup, should have resulted in a greater fat content for predusted apple with batter B. This was not the case, however (Table IV.4). This author has no explanation for this occurrence. Although fat content of a product coated with batter C and fried was not determined, this author believes that it would be similar to the 39% fat content of the fried mushroom product (Table V.4).

There was a difference in fiber and ash contents of the 2 treatments (Table IV.4). The fiber content was due largely to the fiber component of apple itself, with small amounts of fiber contributed by the flours and the cornflake crumbs (Scherz and Senser, 1989). As expected, product coated with batter B had a higher coating pickup and thus, contained less fiber than apple with batter A.

Ash content of batter B-coated apple was lower than ash of apple coated with batter A although coating was responsible for much of the ash content of the product (Table IV.4). Non-fat dry milk and cornflake components of the coating contained 8% and 3% ash, respectively, on a dry weight basis (Scherz and Senser, 1989).

D. FINAL COATING PERCENTAGE

Coating percentage of reheated apple products was affected by batter type, pretreatment, reheating method, their interaction, the batter type*pretreatment interaction and the batter type*reheating method interaction (Table IV.1). Reheated apple coated with batter B had the lowest final coating percentage, while those coated with batter C had the greatest (Table IV.2). Predusted products had a greater percentage of coating after reheating than did predried apple (Table IV.3). Apple products which were reheated in the microwave oven had a greater coating

percentage than the counterparts reheated in the conventional oven (Table IV.5).

Predusted apple products had a greater ($P<0.05$) coating percentage than did predried products regardless of batter type (Figure IV.3). There was a difference ($P<0.05$), however, among the predried products, with batters B and C having the lowest and highest coating percentages, respectively. Final coating percentage followed the data trends found for coating pickup and coating loss and was most likely a function of those two characteristics.

Products coated with batter C had a greater coating percentage than products coated with either batter A or B, regardless of reheating method (Figure IV.4). The batter C-coated products were fried; oil absorbed during the frying process increased coating weight, and thus, coating percentage (Brown, 1990). Predried products tended to have a lower coating percentage than the predusted counterparts, most likely due to differences in coating pickup and loss. The predusted apple coated with batter A had a greater ($P<0.05$) percentage of coating than did predried or predusted products coated with batter B; there was no difference between batter B-coated products and the predried, batter A coated product.

Within batters, there was no difference in the final coating percentage of predried products due to reheating

Table IV.5--Means for characteristics of apple products after reheating in conventional or microwave ovens

Characteristic	Reheating Oven ^a	
	Conventional	Microwave
Final Coating (%) ^b	48.42z ±12.32	50.55y ±12.30
Moisture(%) ^c	60.02y ±0.69	59.54z ±1.65
Hunter L (Cooked) ^c	32.90z ±4.41	32.72z ±4.70
Hue angle (Cooked) ^c	25.78z ±7.63	27.01z ±6.94
Delta E ^c	1.42y ±0.23	0.80z ±0.27

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

Means represent reheated values across batter types and pretreatments.

^b270 observations were made for each reheating method.

^c18 observations were made for each reheating method.

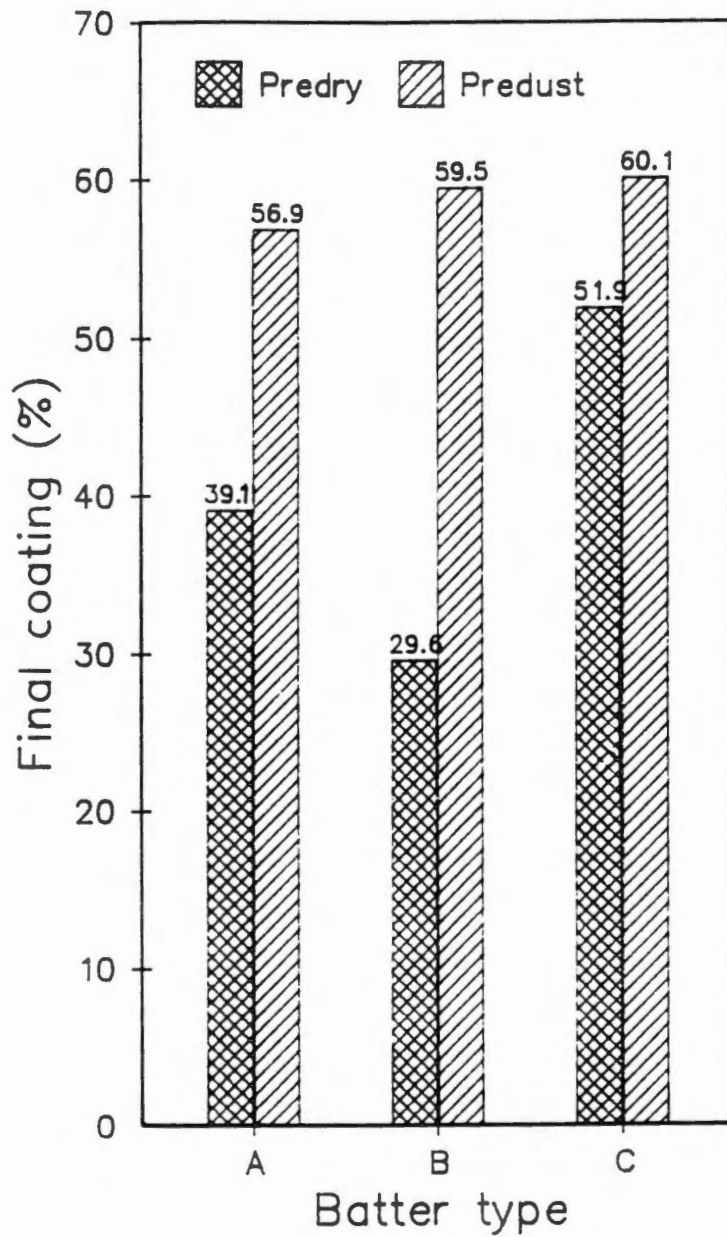


Figure IV.3--Coating percentage of reheated apple products as a function of pretreatment and batter type.

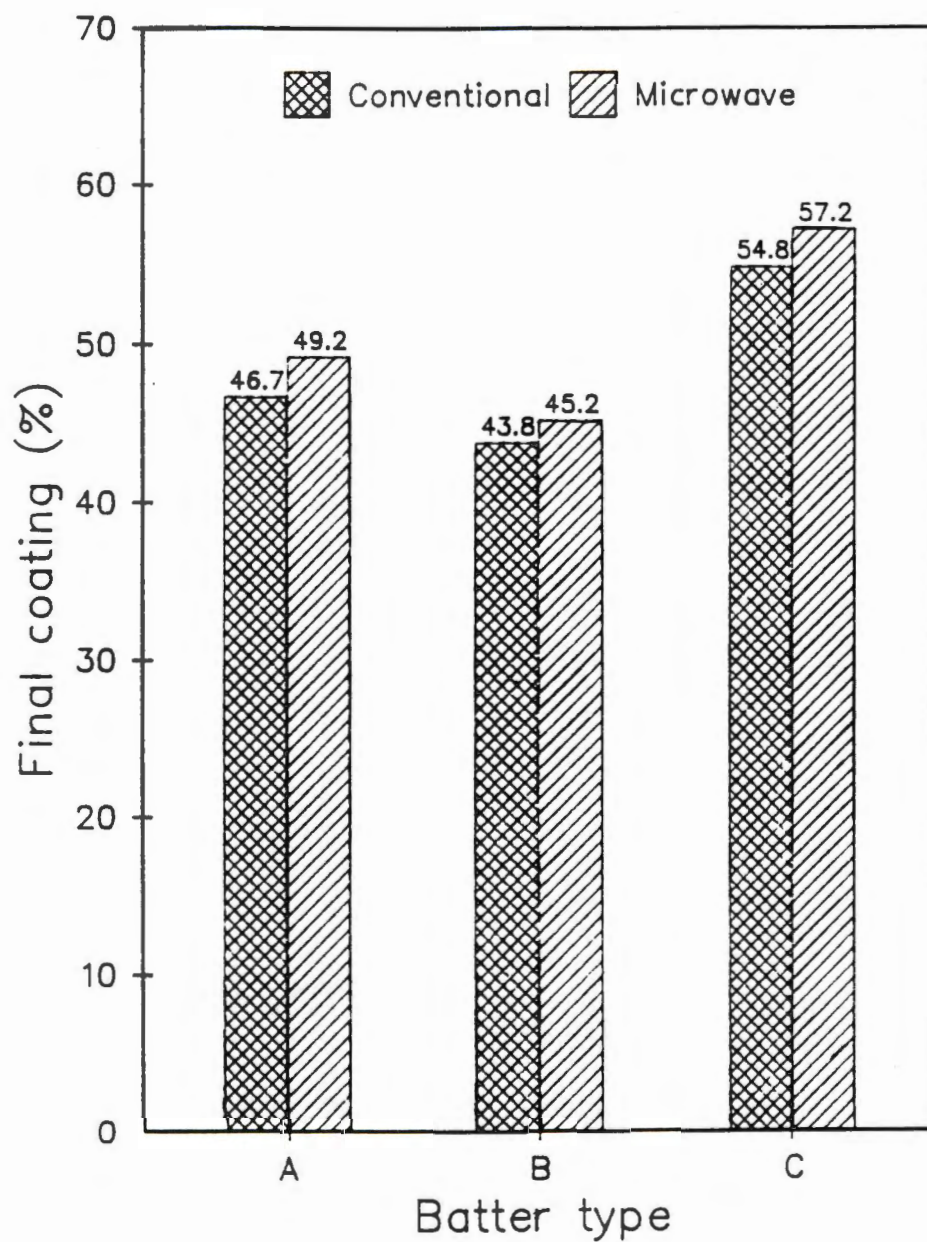


Figure IV.4--Coating percentage of reheated apple products as a function of reheating method and batter type.

method (Figure IV.5). The same was true for predusted products. There were, however, differences ($P < 0.05$) between the predried and predusted products, with batter C-coated products having the least difference and batter B-coated products the greatest. There is no legal limit on the amount of coating that can be applied to vegetables (Brown, 1990). Depending upon prices of substrate and coating ingredients, processors may benefit by increasing the coating percentage. In this research, that was accomplished by using a predust.

While a thick batter is important in obtaining a high final coating percentage, an excessively thick batter may reduce adherence of coating. Such thick batters tend to form coatings that peel away easily from the substrate (Hanson and Fletcher, 1963). A break in the coating could lead to loss of large pieces, thus decreasing coating percentage and rendering the product visually unacceptable. Also, a thick batter may trap steam generated during the reheating process. Trapped steam creates internal pressure which may lead to coating "blow-off." Often, corn flour is added to batters to dilute wheat gluten proteins and provide venting for steam (Burge, 1990).

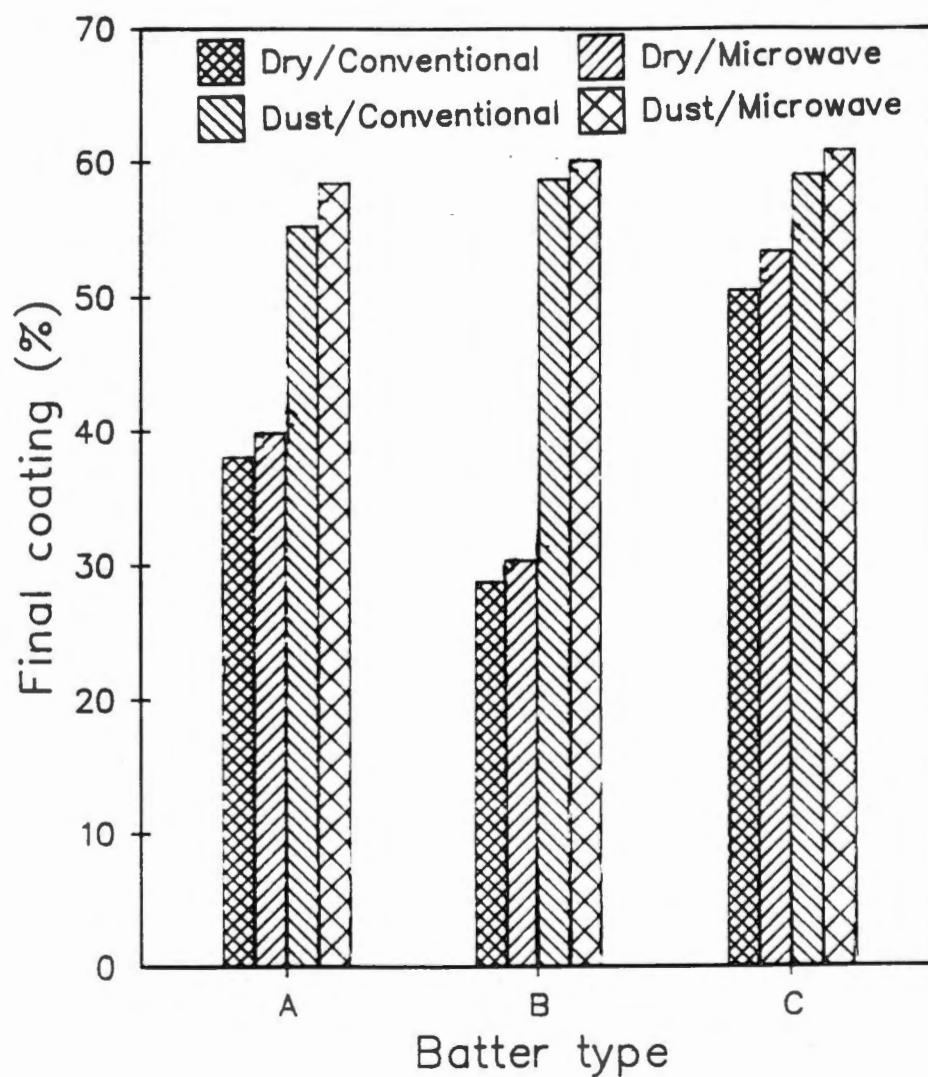


Figure IV.5--Coating percentage of reheated apple products as a function of pretreatment, reheating method and batter type.

E. MOISTURE CONTENT AFTER REHEATING

Moisture content of reheated apple was affected by batter type, reheating method, the batter*reheating method interaction, and the batter*pretreatment*reheating method interaction but not by pretreatment (Table IV.1). Reheated products coated with batter C had a lower moisture content than products coated with batters A or B, between which no difference existed (Table IV.2). The deep-fried products with batter C were expected to contain lower moisture because frying is a severe dehydration process. Reheated apple products had lower moisture after microwave reheating than after conventional oven reheating (Table IV.5).

There was no difference in moisture contents of apple coated with batters A or B regardless of reheating method (Figure IV.6). Products coated with batters A or B also were not different from batter C-coated products which were reheated in a conventional oven. Apple coated with batters A or B and products coated with batter C and reheated in the conventional oven had higher ($P < 0.05$) moisture than predusted or predried apple coated with batter C and microwave reheated (Figure IV.7). In general, reheating method affected primarily products which were coated with batter C and fried, with microwave reheating resulting in a lower moisture content. The high oil content of batter C-coated products may have produced an increased rate of

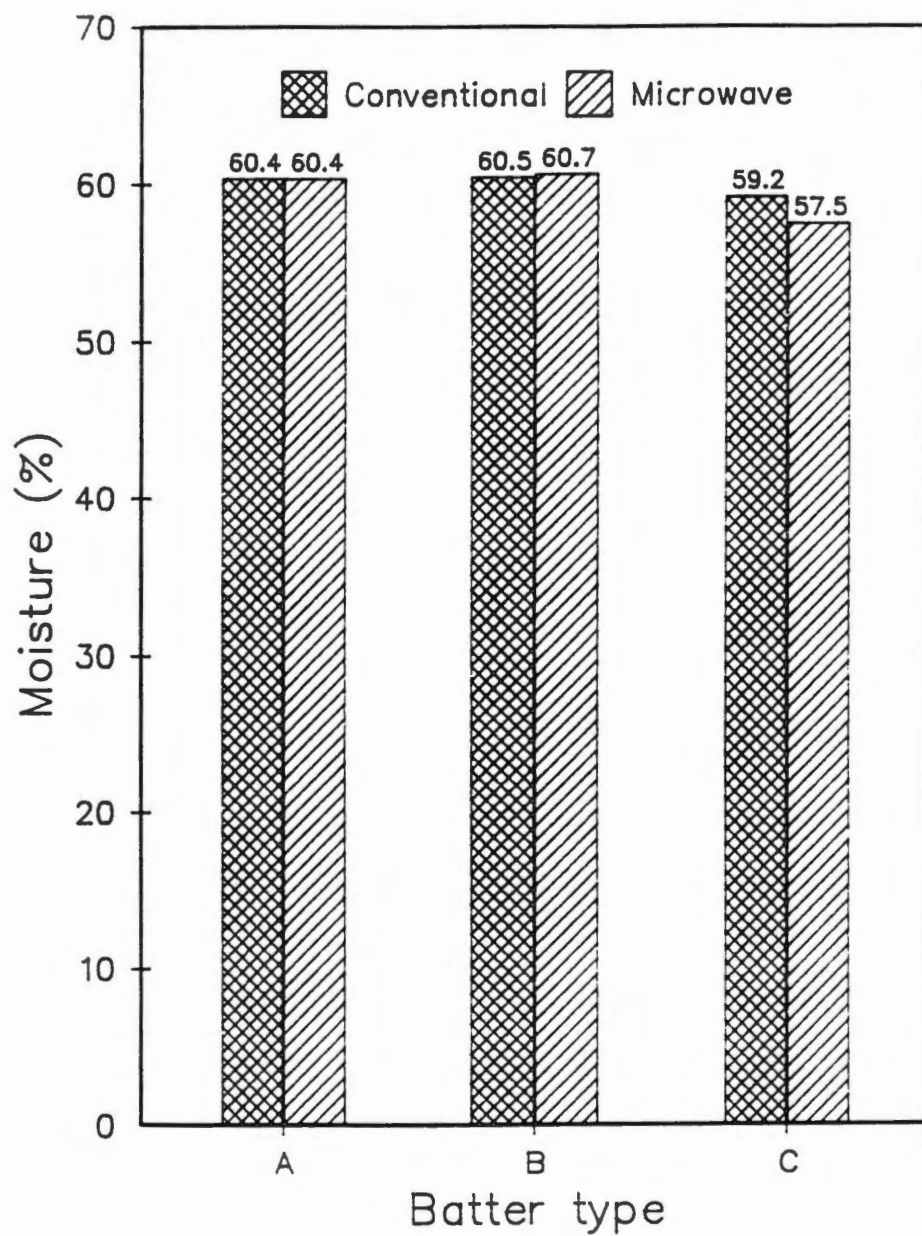


Figure IV.6--Moisture content of reheated apple products as a function of reheating method and batter type.

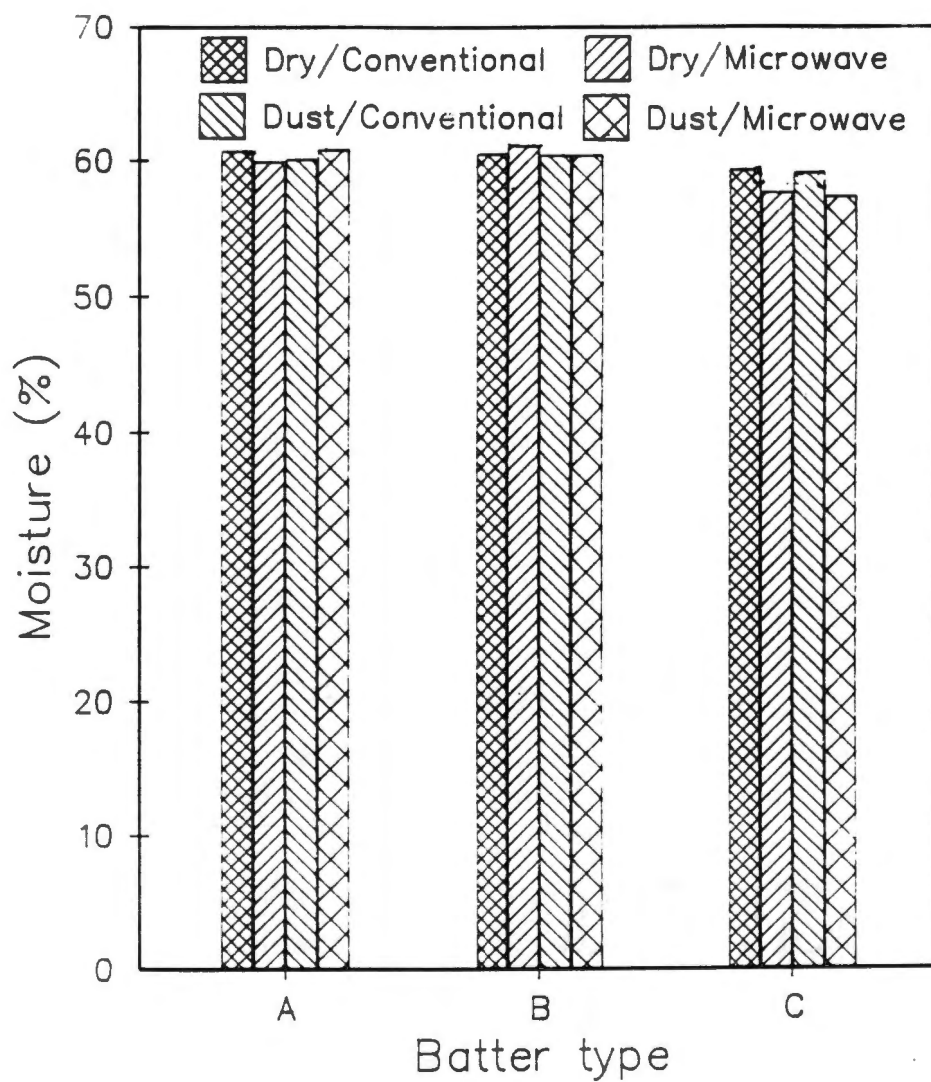


Figure IV.7--Moisture content of reheated apple products as a function of pretreatment, reheating method and batter type.

microwave heating (Best, 1987) and thus, greater dehydration.

During reheating by a conventional oven, moisture content of the coating is lowered, thus sealing in inner moisture. Microwave reheating, however, transforms inner moisture into steam which migrates to the surface and evaporates (Best, 1987). Van Zante (1973) reported that microwave cooking tended to dehydrate products to a greater extent than conventional cooking, but suggested that increased moisture loss may be due to excessive heating during microwave cooking.

F. COLOR OF COOKED AND REHEATED PRODUCTS

The Hunter L value of cooked apple products was affected by batter type and the batter*pretreatment interaction (Table IV.1); products coated with batters A or B were lighter than those coated with batter C (Table IV.2). Lightness of a product is represented by Hunter L values on a scale of 0 to 100, with 0 being equal to black, 100, to pure white (Francis and Clydesdale, 1975). Within batters, there was no difference between L values of predusted and predried apple products (Figure IV.8); however, predried products tended to be lighter when coated with batter A and darker when coated with batter C. Predusted and predried

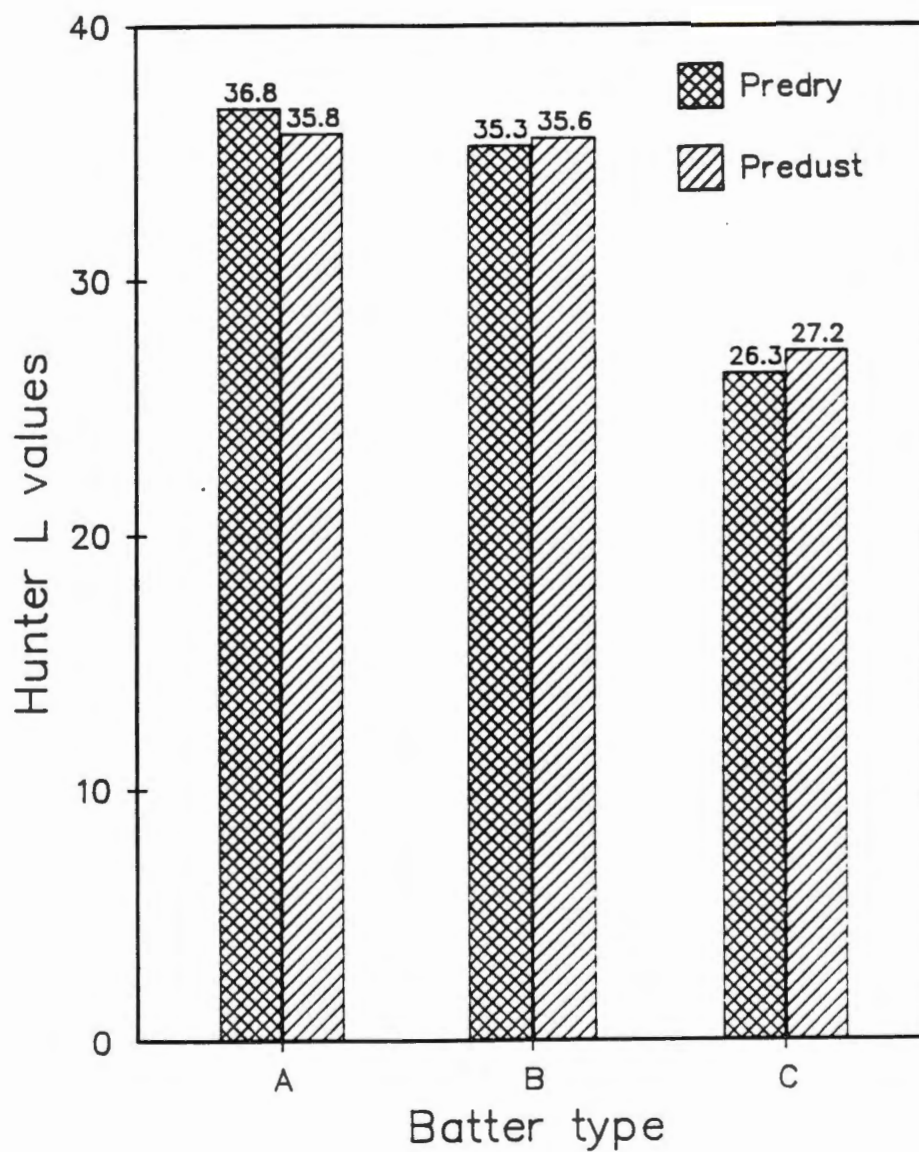


Figure IV.8--Hunter L values of cooked apple products as a function of pretreatment and batter type.

products coated with batter C were significantly darker than batter A- or B-coated products.

Hue angle values of the cooked product were affected only by batter type (Table IV.1) with higher values for products coated with batter C (Table IV.2). The mean hue angle values indicated that products coated with batters A or B were yellowish, while those coated with batter C tended to be yellowish orange (Francis and Clydesdale, 1975). Visually, products coated with batter C and fried appeared a dark, golden brown, compared to the golden yellow color of the baked products coated with batters A or B.

Only reheating method affected Delta E values (Table IV.1). Products reheated in a conventional oven had a greater amount of color change than did those reheated in a microwave oven (Table IV.5). Delta E values are also known as total color differences. Products are "commercial matches" if Delta E = 1; a value of 2 indicates a noticeable difference in color (Francis and Clydesdale, 1975). The mean Delta E values of products reheated in the conventional oven fell midway between 1 and 2; this author, however, could not visually discern a color difference between cooked and reheated products. Dyson (1990) stated that processors, not consumers, are responsible for product color because significant darkening does not occur during conventional oven reheating. Some changes did occur in mean L, 'a', and

'b' values as the result of reheating (data not presented), however, these differences were masked in the calculation of Delta E.

The dark, golden brown color of fried coatings is a very acceptable characteristic and cannot be duplicated easily in baked coatings. Loewe (1990) stated that oil and/or browning agents can be added to ovenable coatings. The protein and reducing sugar necessary for non-enzymatic browning are provided by non-fat dry milk (Davis, 1983). Corn flour can be used also to contribute color (Burge, 1990). Methods of color manipulation being considered by industry include use of a dark breading material (such as a double toasted crumb) or addition of substantial amounts of oil to batter to approximate an "oven fry" of the coating (Spencer, 1990). In the present study, reducing sugar and protein, corn flour, and oil were added to batters in an attempt to impart a fried color to the baked product.

G. SENSORY EVALUATION

1. Color

Color intensity scores of the reheated apple products was affected by batter type, reheating method, judge, and the batter type*reheating method interaction (Table IV.6). Panelists rated products coated with batter C as having the darkest color and those coated with batter A as having the

Table IV.6--F-values from analysis of variance for sensory evaluation of reheated apple products

Source	Df	F-ratio	P-value
COLOR			
Block	5	1.64	0.20
Batter (B)	2	281.21	0.01
Pretreatment	1	0.22	0.64
Reheat (R)	1	14.96	0.01
Judge	7	9.32	0.01
B*R	2	4.26	0.02
Error mean square = 273.47 with 251 degrees of freedom.			
GLOSS			
Block	5	0.93	0.42
Batter	2	412.57	0.01
Pretreatment	1	5.54	0.02
Reheat	1	1.61	0.21
Judge	9	11.29	0.01
Error mean square = 321.36 with 323 degrees of freedom.			
ADHESION OF COATING TO PRODUCT			
Block	5	1.75	0.12
Batter	2	17.54	0.01
Pretreatment	1	31.29	0.01
Reheat	1	7.02	0.01
Judge	7	22.91	0.01
Error mean square = 772.42 with 259 degrees of freedom.			
CRISPNESS			
Block	5	2.12	0.07
Batter (B)	2	17.45	0.01
Pretreatment (P)	1	9.53	0.01
Reheat	1	18.54	0.01
Judge	9	10.34	0.01
B*P	2	3.22	0.04
Error mean square = 571.13 with 321 degrees of freedom.			

Continued

Table IV.6 Continued

Source	Df	F-ratio	P-value
MOISTURE ABSORBED FROM MOUTH			
Block	5	1.22	0.36
Batter	2	16.88	0.01
Pretreatment	1	0.29	0.59
Reheat	1	52.17	0.01
Judge	7	3.89	0.01
Error mean square = 759.66 with 259 degrees of freedom.			
DEEP-FRIED FLAVOR			
Block	5	1.55	0.17
Batter	2	5.13	0.01
Pretreatment	1	1.72	0.19
Reheat	1	2.50	0.11
Judge	7	6.36	0.01
Error mean square = 391.61 with 259 degrees of freedom.			
ACCEPTABILITY			
Block	5	1.85	0.15
Batter (B)	2	0.25	0.78
Pretreatment	1	0.89	0.34
Reheat (R)	1	26.48	0.01
Judge	9	11.19	0.01
B*R	2	1.88	0.15
Error mean square = 422.73 with 321 degrees of freedom.			

lightest (Table IV.7). There was no difference in color due to pretreatment (Table IV.8). Microwave-reheated products were rated as darker than products reheated in a conventional oven (Table IV.9).

Products coated with batter C were darker ($P < 0.05$) than those coated with batters A or B (Figure IV.9). There was no difference in color of batter C-coated products due to reheating method; however, for products coated with batters A or B, those reheated in a microwave oven were rated as being darker than those reheated in a conventional oven. There was no difference in color ratings of batter A-coated products reheated in the microwave and products coated with batter B and reheated in a conventional oven. It is possible that the frying process fully developed the color of batter C-coated products, but baking A- or B-coated products did not. The reactants for non-enzymatic browning in batters A and B then were activated during microwave reheating, resulting in a darker color than for products reheated in the conventional oven. Batter B had a greater potential for "oven frying" than batter A due to a higher percentage of oil in batter B (Table III.2) and thus, developed a darker color during the initial cooking process. Batter A products contained higher percentages of non-fat dry milk and corn flour, both of which contribute to color formation (Burge, 1990). This combination was not

Table IV.7--Means for sensory characteristic ratings of reheated apple dipped in different batters

Characteristic ^c	Batter ^{a,b}		
	A	B	C
Color ^d	53.94z ±17.63	64.34y ±21.86	108.97x ±121.91
Gloss ^e	37.68z ±16.72	44.18y ±22.46	99.73x ±21.71
Adhesion of coating to product ^f	56.32z ±31.47	76.22y ±32.62	54.24z ±34.93
Crispness ^e	83.25y ±30.47	72.54z ±27.14	91.17x ±25.77
Moisture absorbed from mouth ^f	74.99y ±33.48	78.23y ±31.22	56.38z ±26.93
Deep-fried flavor ^f	23.47z ±13.41	26.25z ±14.86	105.82y ±27.61
Acceptability ^f	73.25z ±22.61	75.08z ±19.17	73.68z ±29.14

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

Means represent batter values across pretreatments and reheating methods.

^bBatter formulations are shown in Table III.2.

^cHigher numbers indicate that the characteristic is more intense, while low numbers indicate a lack of the characteristic.

^d90 observations were made for each batter type.

^e114 observations were made for each batter type.

^f92 observations were made for each batter type.

Table IV.8--Means for sensory characteristic ratings of reheated, pretreated apple products coated with 3 different batters

Characteristic ^b	Pretreatment ^a	
	Predry	Predust
Color ^c	75.96z ±31.73	75.54z ±29.61
Gloss ^d	62.74y ±34.61	58.32z ±38.13
Adhesion of coating to product ^e	71.41y ±36.49	53.10z ±34.79
Crispness ^d	86.30y ±30.28	78.33z ±28.42
Moisture absorbed from mouth ^e	68.45z ±31.68	71.28z ±29.90
Deep-fried flavor ^e	53.41z ±42.23	50.28z ±43.19
Acceptability ^e	72.95z ±25.25	75.05z ±22.58

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

Means represent pretreatment values across batter types and reheating methods.

^bHigher numbers indicate that the characteristic is more intense, while low numbers indicate a lack of the characteristic.

^c135 observations for each pretreatment type.

^d171 observations for each pretreatment type.

^e138 observations for each pretreatment type.

Table IV.9--Means for sensory characteristics ratings of coated apple products after reheating in conventional or microwave oven

Characteristic ^b	Reheating Oven ^a	
	Conventional	Microwave
Color ^c	71.86z ±32.55	79.64y ±28.98
Gloss ^d	59.30z ±38.72	61.76z ±35.61
Adhesion of coating to product ^e	57.83z ±36.91	66.69y ±38.54
Crispness ^d	88.08y ±30.17	76.55z ±29.61
Moisture absorbed from mouth ^e	57.90z ±29.02	81.83y ±29.67
Deep-fried flavor ^e	50.03z ±42.18	53.66z ±44.28
Acceptability ^e	79.66y ±24.08	68.34z ±22.49

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

Means represent reheated values across batter types and pretreatments.

^bHigher numbers indicate that the characteristic is more intense, while low numbers indicate a lack of the characteristic.

^c135 observations for each reheating method.

^d171 observations for each reheating method.

^e138 observations for each reheating method.

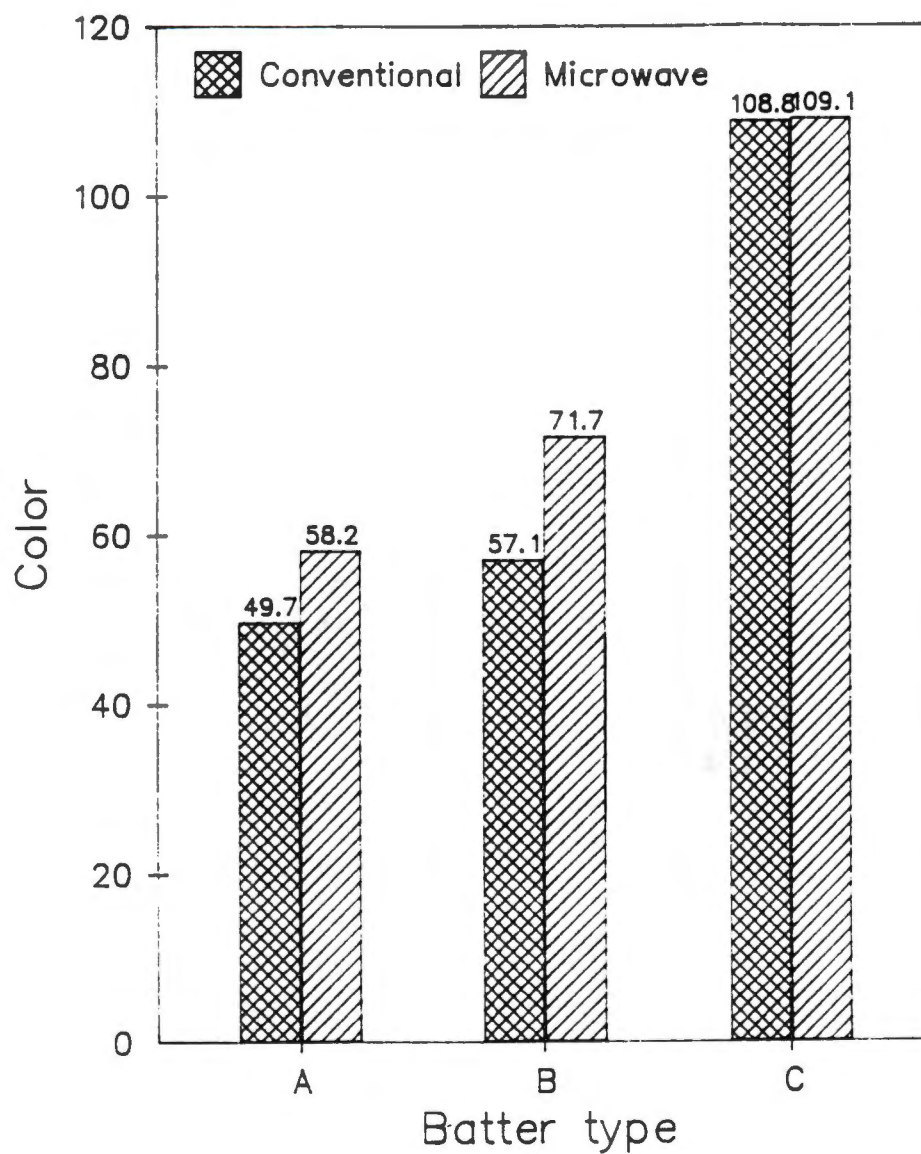


Figure IV.9--Sensory rating of color intensity of reheated apple products as a function of reheating method and batter type.

sufficient, however, for batter A-coated products to achieve the color intensity developed by microwave-reheated batter B products.

2. Gloss

Glossiness of the reheated apple products was affected by batter type, pretreatment and judge (Table IV.6). Products coated with batter C were rated as being most glossy, and those coated with batter A were least glossy (Table IV.7). Predried apple products were glossier than predusted products (Table IV.8).

As expected, batter C products (fried) were glossier than baked products due to the absorption of oil during frying (Table IV.7) (Melton, 1990). Batter B-coated products were rated as the glossier of the 2 baked products; batter B contained more oil than batter A (Table III.2).

Surprisingly, pretreatment was a significant factor in determining gloss of reheated apple products, with predried products being glossier than predusted (Table IV.8). This difference was likely due to the appearance of the substrate itself; this author noted that the surface of apple pieces appeared very shiny after predrying. The sheen may have resulted from crystallization of natural sugars as the surface dried. Coatings could have been sufficiently translucent that the sheen affected product gloss.

3. Adhesion of coating

Adhesion of coating to the reheated apple product was affected by batter type, pretreatment, reheating method, and judge (Table IV.6). Products coated with batter B were rated as having a greater degree of coating adherence than products coated with batters A or C (Table IV.7). Coating adhesion was higher for predried products than for predusted (Table IV.8). Microwave reheating resulted in greater coating adhesion than did conventional oven reheating (Table IV.9).

Although panelists rated products coated with batter B as having greater coating adherence than products coated with batters A or C (Table IV.7), batter B products exhibited the greatest percentage of coating loss, both as a percentage of product weight and a percentage of coating weight (Table IV.2). The low adhesion ratings for batters A and C may have occurred due to the tendency of these coatings to peel when the surface was broken. Batters A and C had greater pickup and final coating percentages and lower coating losses than batter B. With the greater amounts of coating, peeling is a drawback (Suderman, 1990b).

Predrying of apple resulted in significantly greater adhesion than predusting (Table IV.8). Adhesion was decreased due to evaporation of moisture during cooking which caused the substrate to shrink away from the coating.

Coating then lacked support and broke or crumbled (Hale and Goodwin, 1968; Hansen and Fletcher, 1963; Suderman and Cunningham, 1981). This is particularly a problem with fried foods because the structure of fried coatings sets very quickly. Severity of this problem can be lessened by applying a predust material containing film-forming ingredients. Moisture remains trapped inside the coated foods thus, minimizing shrinkage (Meyers, 1990; Suderman et al., 1981).

An alternative to use of predusts involves removing moisture from the substrate prior to coating. The use of a precooking step to increase adhesion of coatings to poultry was attempted (Hale and Goodwin, 1968; Hansen and Fletcher, 1963). A prefreezing/thawing process was investigated on the premise that drip loss would reduce the moisture content of the substrate (Suderman and Cunningham, 1981). These efforts showed that reduction of substrate moisture can increase coating adhesion slightly; however, the increase was not significant.

4. Crispness

The initial crispness of reheated apple products was affected by batter type, pretreatment, reheating method, judge and the batter type*pretreatment interaction (Table IV.6). Products coated with batter C were most crisp and those coated with batter B were least crisp (Table IV.7).

Predried products were crisper than predusted apple (Table IV.8). Products reheated in a conventional oven were crisper than the microwave-reheated counterparts (Table IV.9).

Olewnik and Kulp (1990) reported an increase in coating crispness as protein content was increased; batters A and C were formulated with higher amounts of protein (from flour and non-fat dry milk) (Table III.2). Higher corn flour contents of batters A and C could have been responsible also for increased crispness by decreasing steam retention (Burge, 1990; Loewe, 1990). Predusted products tended to be less crisp than the predried counterparts when coated with batters A or C; there was no difference in crispness of batter B-coated products due to pretreatment (Figure IV.10). Neither was there a difference in crispness of predried and predusted batter A-coated products and predusted products coated with batter C.

As expected, apple products were crisper when reheated in a conventional oven than in a microwave oven (Table IV.9). Lack of surface dehydration in microwave cooking is a significant drawback to this cooking method. Film-forming predusts are used to prevent moisture migration from substrate into the coating during microwave heating. Products such as microwave susceptors can be used also to increase crispness of coated, microwaved foods by increasing

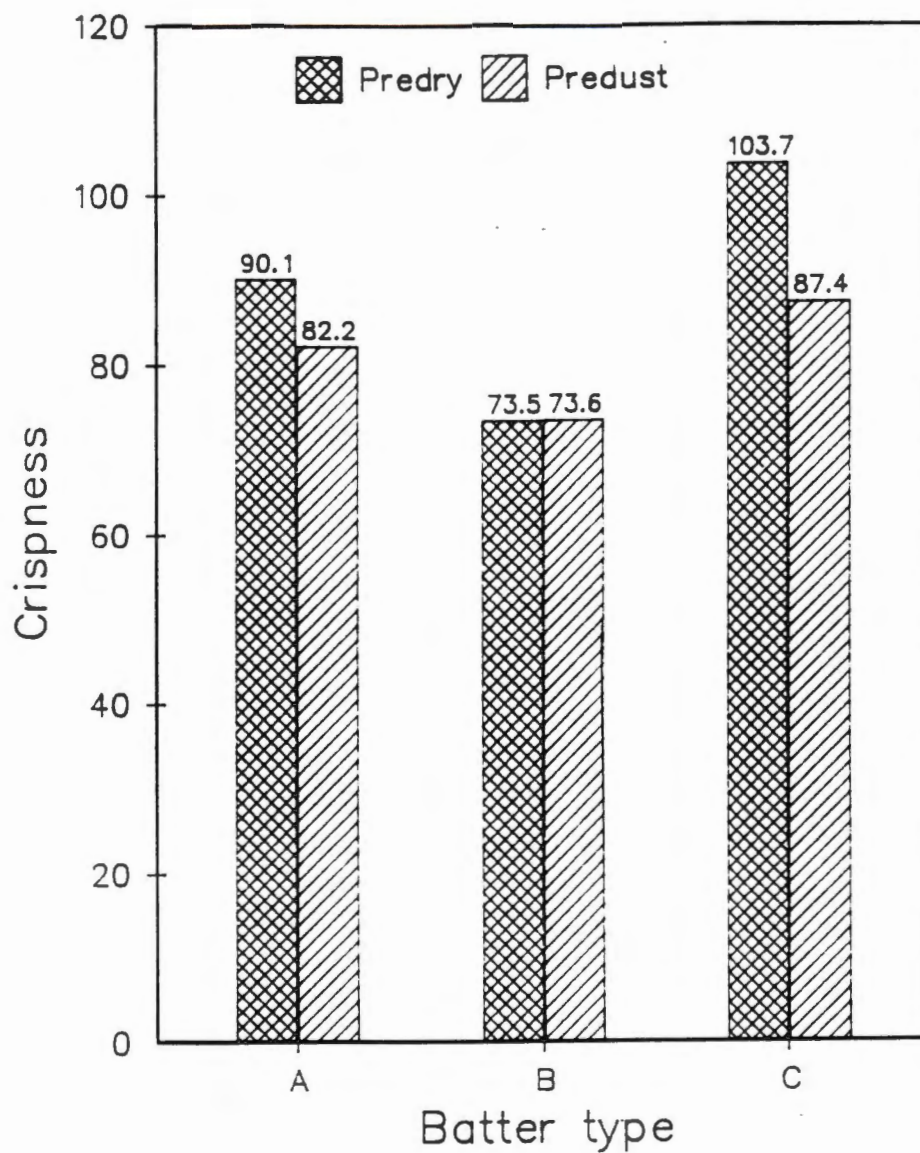


Figure IV.10--Sensory rating of crispness of reheated apple products as a function of pretreatment and batter type.

the temperature surrounding the product surface (Best, 1987; Hegenbart, 1989; Messenger, 1987; Schiffman, 1990).

5. Amount of moisture absorbed from mouth

The amount of moisture absorbed from the mouth during chewing was affected by batter type, reheating method and judge (Table IV.6). Products coated with batter C absorbed less moisture than those coated with batters A or B (Table IV.7). Microwave-reheated products absorbed more ($P < 0.05$) moisture than those reheated in the conventional oven (Table IV.8).

Fried, batter C-coated products absorbed less moisture from the mouth during chewing than did baked products coated with batters A and B (Table IV.7). Oil absorbed by the coating during frying would tend to coat the mouth and thus, retard moisture absorption. Baked coatings are commonly criticized for dryness. Although hydrocolloids can mimic the mouthfeel properties of fats, their use has been only slightly successful in baked coatings (Spencer, 1990).

For microwave-reheated products, oil in the coatings may have caused increased rates of heating for the coating itself (Best, 1987). Moisture evaporation rates would increase subsequently, resulting in a drier coating for microwaved products than for those reheated in a conventional oven (Table IV.9).

6. Deep-fried flavor

Deep-fried flavor of the product was affected only by batter type and judge (Table IV.6). Products coated with batter C and fried were rated as having a more intense ($P < 0.05$) deep-fried flavor than those coated with batters A or B and baked (Table IV.7). There was no difference in deep-fried flavor of the baked products although batter B contained twice as much oil as batter A (Table III.2). Available fried fat flavors were not appropriate for this application due to charring that occurred when subjected to air impingement baking.

7. Acceptability

The acceptability of reheated apple products was affected by reheating method, judge and batter*reheating method interaction (Table IV.6). Panelists rated products reheated in the microwave oven as being less acceptable than those reheated in a conventional oven (Table IV.9).

Products coated with batters A or B and reheated in the conventional oven were rated as being significantly more acceptable than other batter*reheating method combinations, among which there were no differences (Figure IV.11). Products reheated in a microwave tended to be less acceptable than those reheated in a conventional oven.

There was no difference in acceptability of apple snacks due to batter type (Table IV.7). Several panelists,

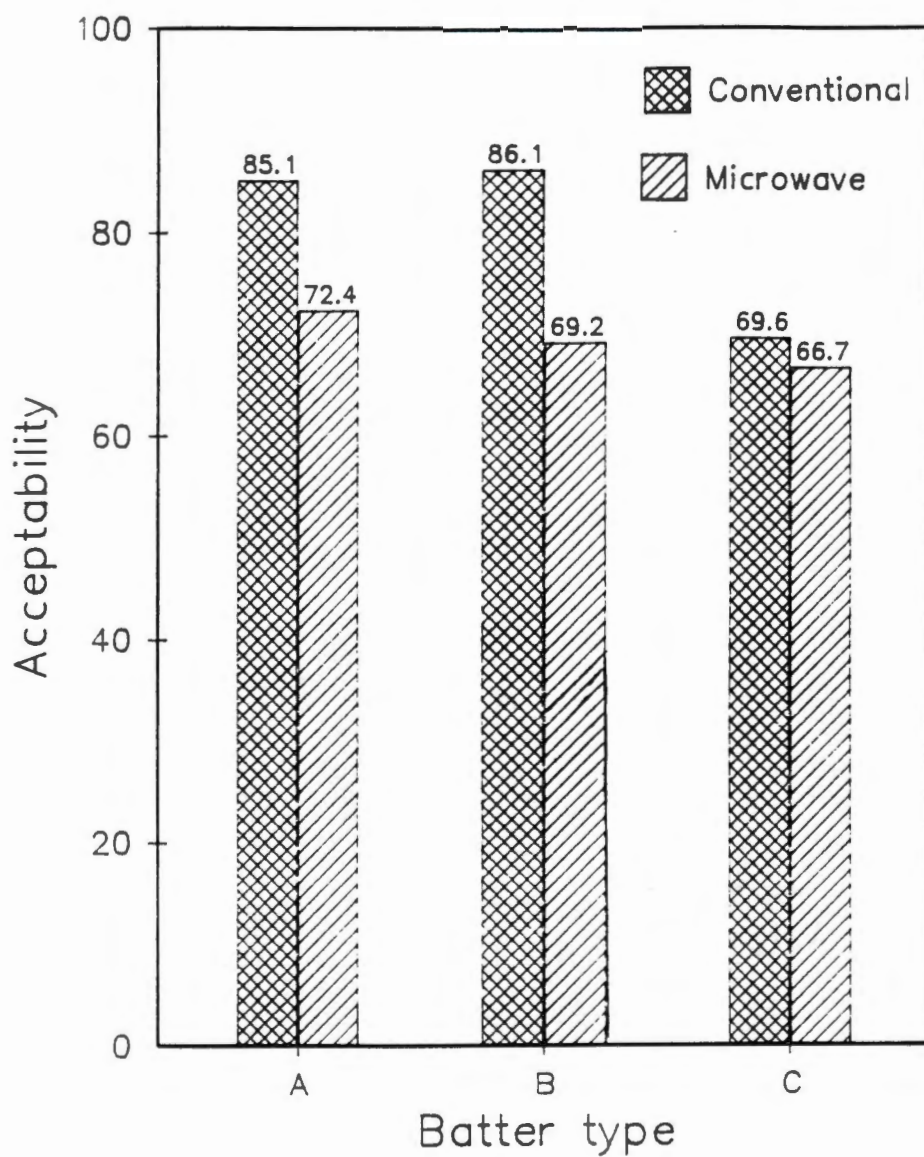


Figure IV.11--Sensory rating of acceptability of reheated apple products as a function of reheating method and batter type.

however, noted that the fried products were oily; panelists tended to associate a fried coating with a meat or vegetable product, but not a fruit. Cinnamon flavor of batter A coated apple was stronger than of those coated with batter B, probably due to a higher percentage of coating for batter A products.

H. CONCLUSIONS

Coating pickup, coating loss, final coating percentage, moisture content after reheating, color and sensory attributes are all important quality characteristics of coated foods. These characteristics were affected by 1 or more of the independent variables tested, and in some cases, their interactions.

Coating pickup, coating loss and final coating percentage appeared to be related and were affected by batter type and pretreatment. The 3 batters used for this research differed not only in the ingredient formulation, but also in viscosity. Products coated with more viscous batters tended to have a greater pickup of coating and final coating percentage and less coating loss. The same is true for products which were predusted instead of predried. The interaction of pretreatment and batter type was significant for coating loss and final coating percentage in that it resulted in predusted products coated with a low viscosity

batter having characteristics similar to predried products coated with a more viscous batter.

Coating loss is a measure of coating adhesion. Thus, it was surprising when sensory panelists rated batter B coated products as having significantly better adhesion than batter A-or C-coated products. This is most likely due to the tendency of thicker coatings to peel once broken.

Deep-fried products had less moisture than did baked products. Products reheated in the microwave oven had less moisture than those reheated in the conventional oven. Surprisingly, however, the moisture contents of predried and predusted products were not different. Most likely, the amount of moisture removed during the predrying step was approximately equal to that lost by predusted products during the cooking process.

Color of the baked products was significantly lighter than that of fried products, according to objective and sensory measurements. A greater amount of total color difference occurred as the result of reheating in the microwave oven than in the conventional oven.

Baked products were more acceptable than fried products, particularly those which were reheated in a conventional oven. Baked coatings were, however, rated as absorbing more moisture from the mouth, being less glossy and having essentially no deep-fried flavor.

Predried products coated with batter C (fried) were crisper than other treatments, but crispness comparable to predusted, batter C-coated products could be obtained using batter A in combination with either pretreatment. Products reheated in a conventional oven were crisper than the microwave-reheated counterparts.

It was possible through combinations of pretreatment, batter type and reheating method to obtain baked products with some attributes comparable to fried products. This occurred to a greater degree for products coated with batter A than for those coated with batter B. Thus, this author believes that overall, batter A was the more successful of the two baked batters.

I. MICROWAVE WATTAGE

The wattage output of the microwave oven can vary widely; thus, it was necessary to monitor the power output of microwave ovens used for research (Van Zante, 1973). There was no significant difference in wattage output due to experimental block. The average output was 415 watts/hr with a standard deviation of ± 24.6 .

CHAPTER V
RESULTS, DISCUSSION AND CONCLUSIONS
FOR MUSHROOM PRODUCTS

The effects of pretreatment, batter type and any significant interactions on the coating pickup (%), coating loss (%), proximate analysis values and cooked color of mushroom products are presented in Sections A, B, C and F, respectively. The effects of pretreatment, batter type, reheating method and any significant interactions on coating percentage, moisture, color change due to reheating and sensory evaluation are presented in Sections D, E, F and G, respectively.

A. COATING PICKUP (%)

The coating pickup of mushroom products was affected by batter type and pretreatment (Table V.1). Mushroom coated with batter C picked up a greater amount of coating than did mushroom coated with batters A or B (Table V.2). Predusting resulted in products with a greater coating pickup than predrying (Table V.3).

The viscosities of mushroom batters A, B and C were 1800, 1000 and 2600 cPs, respectively; the corresponding apple batters had viscosities of 1300, 700 and 1500 cPs, respectively. Mushroom batters contained the same

Table V.1--F-values from analysis of variance for characteristics of mushroom products

Source	Df	F-ratio	P-value
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COATING PICKUP (%)

Block	5	2.56	0.06
Batter	2	2.53	0.10
Pretreatment	1	9.39	0.01
Error mean square = 44.39 with 25 degrees of freedom.			

COATING LOSS (% OF TOTAL PRODUCT WEIGHT)

Block	5	1.48	0.26
Batter (B)	2	137.83	0.01
Pretreatment (P)	1	23.57	0.01
B*P	2	11.22	0.01
Error mean square = 0.15 with 25 degrees of freedom.			

COATING LOSS (% OF TOTAL COATING WEIGHT)

Block	5	1.29	0.37
Batter (B)	2	356.01	0.01
Pretreatment (P)	1	516.74	0.01
B*P	2	160.13	0.01
Error mean square = 2.52 with 25 degrees of freedom.			

COATING PERCENTAGE OF REHEATED MUSHROOM

Block	5	1.46	0.25
Batter (B)	2	257.73	0.01
Pretreatment (P)	1	7588.70	0.01
Reheat (R)	1	0.52	0.75
B*P	2	96.03	0.01
Error mean square = 6.26 with 20 degrees of freedom.			

Table V.1 Continued

Source	Df	F-ratio	P-value
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MOISTURE CONTENT OF REHEATED MUSHROOM

Block	5	0.28	0.81
Batter (B)	2	628.88	0.01
Pretreatment (P)	1	14.97	0.01
Reheat (R)	1	0.12	0.73

Error mean square = 0.82 with 26 degrees of freedom.

HUNTER L VALUE OF COOKED PRODUCT

Block	5	0.28	0.78
Batter	2	87.53	0.01
Pretreatment	1	1.44	0.24

Error mean square = 4.70 with 27 degrees of freedom.

HUE ANGLE OF COOKED PRODUCT

Block	5	1.19	0.39
Batter	2	6.38	0.01
Pretreatment	1	1.82	0.18

Error mean square = 3.87 with 27 degrees of freedom.

DELTA E VALUE

Block	5	1.42	0.25
Batter	2	1.93	0.11
Pretreatment	1	1.21	0.31
Reheat	1	5.67	0.02

Error mean square = 0.29 with 26 degrees of freedom.

Table V.2--Mean values for characteristics of mushroom dipped in different batter types

Characteristic	Batter ^{a,b}		
	A	B	C
Coating pickup (%) ^c	50.09z ±8.23	49.11z ±8.73	58.15y ±8.30
Coating loss (%) ^{de}	5.25z ±0.46	7.46y ±0.88	5.11z ±0.30
Coating loss (%) ^{ef}	14.42z ±2.87	29.02y ±13.44	13.70z ±3.17
Final coating (%) ^c	44.60y ±8.82	43.66z ±11.76	49.05x ±9.56
Moisture (%) ^e	70.72y ±1.46	70.36y ±1.40	59.22z ±0.65
Hunter L (Cooked) ^e	35.49x ±1.32	32.50y ±1.89	24.19z ±2.74
Hue Angle (Cooked) ^e	23.78z ±1.89	22.96z ±2.58	34.76z ±1.47
Delta E ^e	1.08z ±0.62	1.14z ±0.43	1.16z ±0.47

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

Means represent batter values across pretreatments and reheating methods.

^bBatter formulations are shown in Table III.3.

^c180 observations were made for each batter type.

^dExpressed as a percentage of total product weight.

^e12 observations were made for each batter type.

^fExpressed as a percentage of total coating weight.

Table V.3--Means for characteristics of pretreated mushroom products

Characteristic	Pretreatment ^a	
	Predry	Predust
Coating pickup (%) ^b	46.93z ±7.51	57.97y ±7.55
Coating loss (%) ^{cd}	6.25y ±1.44	5.62z ±0.92
Coating loss (%) ^{de}	25.06y ±12.25	13.03z ±2.74
Final coating (%) ^b	37.54z ±6.09	54.67y ±5.51
Moisture (%) ^d	67.35y ±6.25	66.19z ±4.86
Hunter L (Cooked) ^d	30.29z ±5.83	31.16z ±4.72
Hue angle (Cooked) ^d	25.64z ±6.01	26.69z ±5.32
Delta E ^d	1.16z *0.63	1.10z *0.28

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

Means represent pretreatment values across batter types and reheating methods.

^b270 observations were made for each pretreatment type.

^cExpressed as a percentage of total product weight.

^d18 observations were made for each pretreatment type.

^eExpressed as a percentage of total coating weight.

percentages of dry ingredients and oil as the respective apple batters, but a greater amount of water. There was, however, a difference in seasoning ingredients between the 2 types of batter (Tables III.2 and III.3). Salt in the mushroom batters may have contributed to water binding, thus increasing batter viscosity. Davis (1983) presented evidence for this concept. The increased viscosity proved beneficial, however, as thinner batters tended to flow off the mushroom during coating application.

There was no difference in coating pickup by mushroom between batters A and B, although batter A was more viscous than B (Table V.3). Possibly, the thinner batter B penetrated the exposed gill area of the mushroom and was retained to a greater extent than the more viscous batter A, while the thicker batter A adhered to the outer surface of the mushroom more effectively. In the case of mushroom batters A and B, a difference in coating pickup due to batter viscosity alone was most likely negated by differences in retention and adhesion characteristics.

Predusting increased ($P < 0.05$) coating pickup more than predrying (Table V.3). It was, however, difficult to obtain a uniform coating of predust on the smooth surface of the mushroom. Future research in this area should investigate the use of a predip for the mushroom product.

B. COATING LOSS (%)

Batter, pretreatment and the interaction affected coating loss from cooked mushroom when expressed as percentage of total product weight and total coating weight (Table V.1). As with apple products, mushroom coated with batter B had a greater coating loss than mushroom coated with batter A or C; predried mushroom had a greater loss of coating than did predusted (Tables V.2 and V.3).

Predried mushroom had higher ($P < 0.05$) coating loss as a percentage of total product weight than predusted when coated with batter B; there was no difference due to pretreatment for products coated with batter A or C (Figure V.1). Coating loss as a percentage of coating weight did not differ between batter A- and batter C-coated mushrooms of the same pretreatment (Figure V.2). Using the criterion of Suderman and Cunningham (1979), only predusted mushroom coated with batter A or C exhibited satisfactory adhesion (Figure V.2). For mushroom, the interaction of batter type and pretreatment was similar to that for apple, however, there was a greater difference in coating loss of mushroom due to pretreatment within batters. In general, mushroom products lost a greater amount of coating than did apple products of corresponding treatments (Figures IV.1 and IV.2), most likely due to the extremely slick surface of the mushroom.

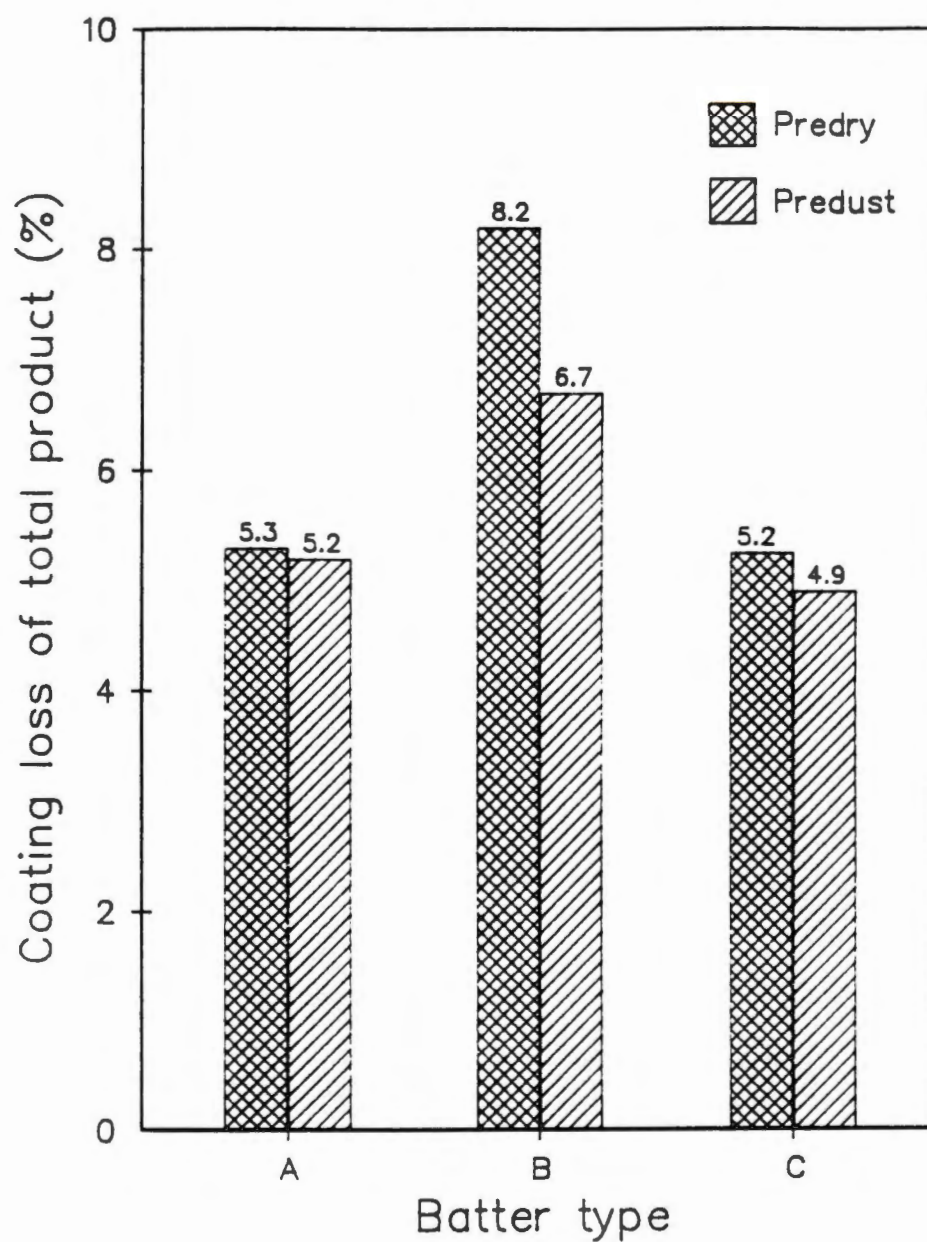


Figure V.1--Coating loss of cooked mushroom products (expressed as a percentage of total product weight) as a function of pretreatment and batter type.

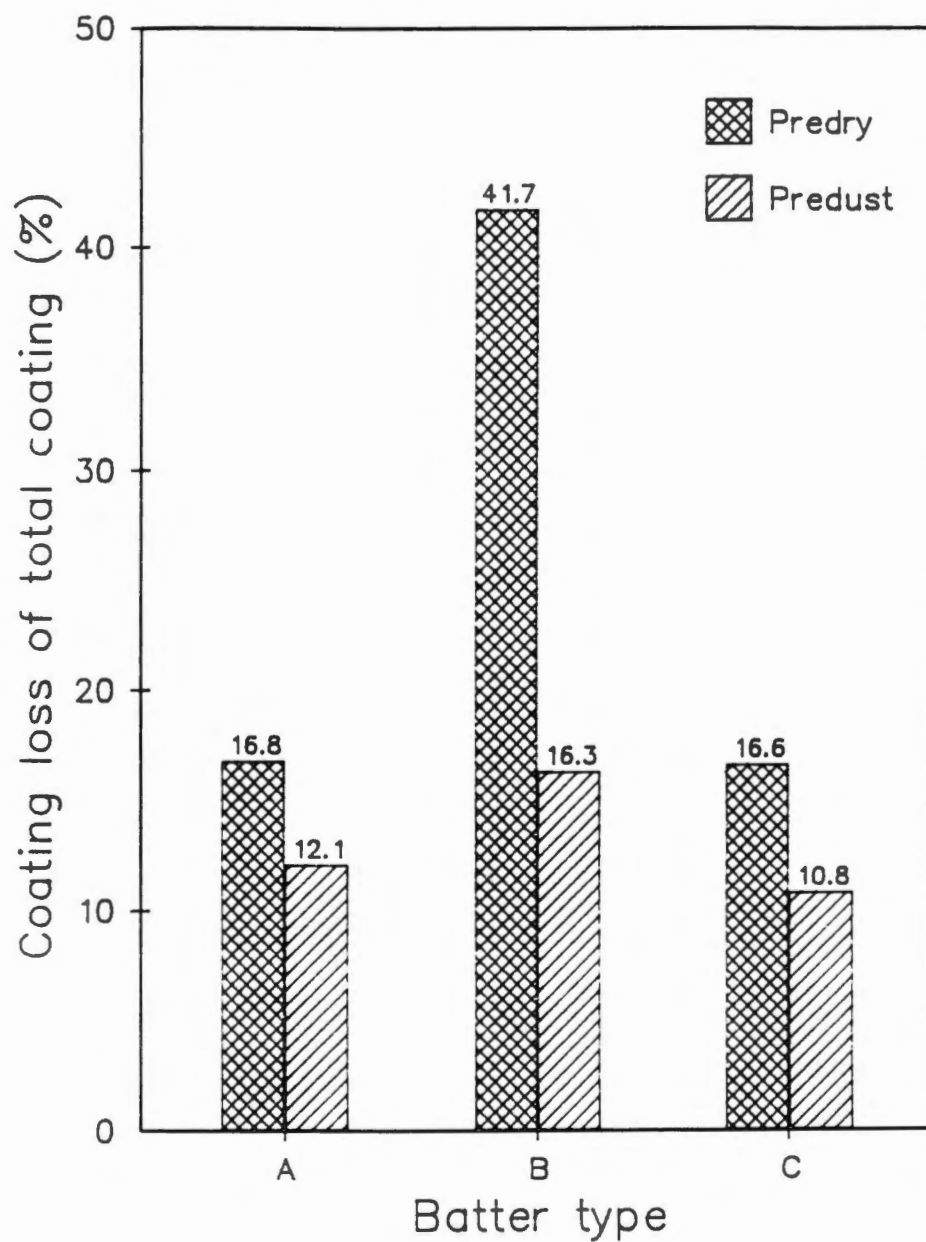


Figure V.2--Coating loss of cooked mushroom products (expressed as a percentage of total coating weight) as a function of pretreatment and batter type.

C. PROXIMATE ANALYSIS

Mushrooms are composed of 35% protein, 4% fat, 28% fiber, 15% ash and 18% carbohydrate on a dry weight basis (Scherz and Senser, 1989). Protein, fiber, ash and carbohydrate values were lower ($P < 0.05$) for products coated with batter C and fried due to the amount of oil absorbed by the coating (Table V.4). When proximate analysis values were converted to a fat-free basis, the product coated with batter A and baked contained 28.25% protein, 8.0% fiber, 6.55% ash and 57.20% carbohydrate. Fried products coated with batter C contained 26.96% protein, 8.96% fiber, 7.87% ash and 56.21% carbohydrate on a fat-free basis.

Products coated with batter C had a greater amount of coating pickup as did predusted products (Tables V.2 and V.3). The lower protein and higher ash contents (fat-free basis) of the batter C product were most likely due to a higher coating pickup than for the batter A-coated product. The amount of fiber was expected to be higher for batter A products because of lower coating pickup, however, this was not the case.

D. FINAL COATING PERCENTAGE

Final coating percentage of reheated mushroom products was affected by batter type, pretreatment and the interaction (Table V.1). The fried products coated with

Table V.4--Mean proximate analysis of cooked mushroom products

Component	Treatment ^{ab}	
	Batter A Predried	Batter C Predusted
Moisture (%)	42.73z ±1.06	44.12z ±1.79
Protein (%) ^c	26.17y ±0.50	16.52z ±0.47
Fat (%) ^c	7.35z ±0.20	38.73y ±0.14
Fiber (%) ^{cd}	7.41y ±0.18	5.49z ±0.16
Ash (%) ^c	6.07y ±0.13	4.82z ±0.12
Carbohydrate (%) ^{ce}	53.00y ±0.26	33.44z ±0.84

^aBatter formulation is shown in Table III.3.

^bMeans ± standard deviation within the same row are different at P<0.05. Analyses were performed in triplicate.

^cExpressed on a dry weight basis.

^dExpressed as total dietary fiber.

^e%Carbohydrate=100 - (% protein + % fat + % fiber + % ash).

batter C had the greatest coating percentage; baked products coated with batter B had the least amount of coating (Table V.2). Predusted products had a greater percentage of coating than predried products (Table V.3).

Final percentage of coating for predusted mushroom was greater ($P < 0.05$) than that of the predried counterparts (Figure V.3). Coating percentage of reheated, predusted mushroom dipped in batters A and B did not differ; there were differences ($P < 0.05$), however, in coating percentages of reheated mushroom among all other batter*pretreatment combinations. As with apple products, coating percentage of reheated mushroom is closely related to initial coating pickup and coating loss.

E. MOISTURE CONTENT AFTER REHEATING

Batter type and pretreatment of mushroom products affected the reheated moisture content (Table V.1). Products coated with batter C had a lower moisture content than those coated with batter A or B (Table V.2). Frying is a rapid dehydration process and would be expected to result in products with less moisture than baked products which lose moisture at a slower rate.

Predusted products had a greater percentage of moisture than predried mushroom products (Table V.3). Films formed by predust ingredients are capable of acting as moisture

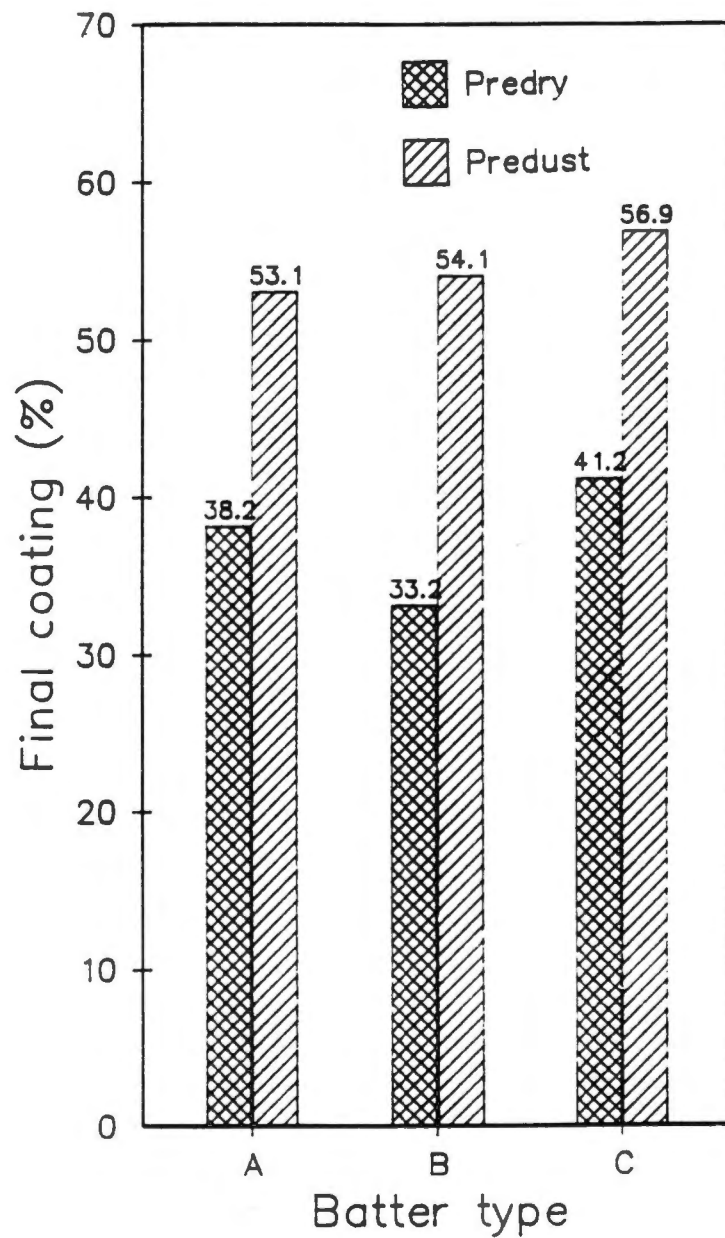


Figure V.3--Coating percentage of reheated mushroom products as a function of pretreatment and batter type.

barriers. By reducing the amount of moisture which may escape from the substrate through the coating, films retain product weight and coating integrity (Meyers, 1990). Moisture barriers particularly are beneficial for products held under heating lamps before serving or reheated in a microwave oven (Meyers, 1990; Yang and Chen, 1979). Methylcellulose and hydroxypropyl methylcellulose used as predest ingredients exhibit a unique characteristic known as "thermal gelation," the formation of a solid gel matrix or barrier produced by heating the gums to 50-55°C and 70-90°C, respectively. The barrier is very effective, also, in decreasing oil absorption by fried foods (Meyers, 1990).

F. COLOR OF COOKED AND REHEATED PRODUCTS

Hunter L values and hue angles of cooked mushroom products were affected by batter type (Table V.1). Mushroom products coated with batter C were the darkest (Table V.2). Products coated with batter B were lighter than those coated with batter C, but darker than batter A-coated mushroom. The hue angle value of products coated with batter C was greater than the values for products coated with batters A or B. As with apple products, the mean hue angle values indicated that products coated with batters A or B were yellowish, while those coated with batter C tended to be yellowish orange (Francis and Clydesdale, 1975).

Delta E values of mushroom products were affected by reheating method (Table V.1). Products reheated in a conventional oven had a greater total color difference than did those reheated in a microwave oven (Table V.5). As with apple products, the human eye was unable to detect color differences between cooked and reheated products although the mean Delta E values for products reheated in a conventional oven falls between values 1 and 2 (Francis and Clydesdale, 1975).

G. SENSORY EVALUATION

1. Color

Color of reheated mushroom products was affected by block, batter type, pretreatment, reheating method, judge, batter type*reheating method interaction and batter type*pretreatment*reheating method interaction (Table V.6). Color was darkest for products coated with batter C and lightest for those coated with batter A (Table V.7). Predried products were darker than predusted (Table V.8); microwave-reheated products had darker color than products reheated in a conventional oven (Table V.9).

Mushroom products coated with batters A or B were darker when reheated in a microwave than when reheated in a conventional oven; there was no difference due to reheating method for products coated with batter C (Figure V.4).

Table V.5--Means for characteristics of mushroom products after reheating in conventional or microwave ovens

Characteristic	Reheating Oven ^a	
	Conventional	Microwave
Final Coating (%) ^b	46.03z ±10.17	46.17z ±10.55
Moisture (%) ^c	66.82z ±5.65	66.72z ±5.61
Hunter L ^c	30.74z ±5.58	31.02z ±5.02
Hue angle (Cooked) ^c	26.86z ±5.72	27.50z ±6.05
Delta E ^c	1.52z ±0.28	0.74y ±0.20

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

Means represent reheated values across batter types and pretreatment methods.

^b270 observations were made for each reheating method.

^c18 observations were made for each reheating method.

Table V.6--F-values from analysis of variance for sensory evaluation of reheated mushroom products

Source	Df	F-ratio	P-value
COLOR			
Block	5	2.67	0.02
Batter (B)	2	323.26	0.01
Pretreatment (P)	1	1.49	0.30
Reheat (R)	1	10.15	0.01
Judge	7	6.11	0.01
B*R	2	2.13	0.12
B*P*R	4	3.76	0.01
Error mean square = 260.35 with 253 degrees of freedom.			
GLOSS			
Block	5	0.31	0.53
Batter (B)	2	809.11	0.01
Pretreatment (P)	1	0.16	0.69
Reheat (R)	1	7.02	0.01
Judge	9	7.53	0.01
B*P	2	6.10	0.01
B*R	2	3.24	0.04
B*P*R	2	2.05	0.13
Error mean square = 298.71 with 323 degrees of freedom.			
ADHESION OF COATING TO PRODUCT			
Block	5	5.29	0.01
Batter (B)	2	5.62	0.01
Pretreatment (P)	1	26.49	0.01
Reheat (R)	1	0.02	0.88
Judge	6	25.41	0.01
B*R	2	2.08	0.13
P*R ^a	1	19.27	0.04
Error mean square = 781.81 with 227 degrees of freedom.			
^a Error mean square = 78.32 with 2 degrees of freedom.			

Continued

Table V.6 Continued

Source	Df	F-ratio	P-value
CRISPNESS			
Block	5	2.08	0.06
Batter (B)	2	1.59	0.20
Pretreatment (P)	1	38.06	0.01
Reheat	1	64.02	0.01
Judge	6	8.77	0.01
B*P	2	3.54	0.03
Error mean square = 923.14 with 228 degrees of freedom.			
MOISTURE ABSORBED FROM MOUTH			
Block	5	1.49	0.22
Batter	2	12.46	0.01
Pretreatment	1	2.08	0.15
Reheat	1	13.92	0.01
Judge	6	2.04	0.06
Error mean square = 1089.28 with 230 degrees of freedom.			
DEEP-FRIED FLAVOR			
Block	5	0.19	0.85
Batter	2	188.44	0.01
Pretreatment	1	0.37	0.55
Reheat	1	0.82	0.36
Judge	9	4.58	0.01
Error mean square = 289.51 with 329 degrees of freedom.			
ACCEPTABILITY			
Block	5	4.68	0.01
Batter (B)	2	24.89	0.01
Pretreatment (P)	1	3.18	0.08
Reheat	1	10.57	0.01
Judge	9	17.51	0.01
B*P	2	1.87	0.15
Error mean square = 407.30 with 327 degrees of freedom.			

Table V.7--Means for sensory characteristic ratings of reheated mushroom dipped in different batters

Characteristic ^c	Batter ^{a,b}		
	A	B	C
Color ^d	45.35z ±17.13	75.79y ±20.13	102.84x ±21.11
Gloss ^e	28.44z ±13.62	30.60z ±16.52	108.56y ±25.26
Adhesion of coating to product ^f	59.94y ±41.60	63.99y ±38.53	49.78z ±31.75
Crispness ^f	79.95z ±39.78	72.60z ±37.04	79.92z ±40.08
Moisture absorbed from mouth ^f	79.37y ±32.08	74.28y ±34.29	54.98z ±36.99
Deep-fried flavor ^e	18.29z ±11.19	18.74z ±14.15	108.79y ±25.04
Acceptability ^e	55.25y ±24.66	49.81z ±21.46	67.99x ±27.91

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

Means represent batter values across pretreatments and reheating methods.

^bBatter formulations are shown in Table III.3.

^cHigher numbers indicate that the characteristic is more intense, while low numbers indicate a lack of the characteristic.

^d92 observations were made for each batter type.

^e116 observations were made for each batter type.

^f82 observations were made for each batter type.

Table V.8--Means for sensory characteristic ratings of reheated, pretreated mushroom products coated with 3 different batters

Characteristic ^b	Pretreatment ^a	
	Predry	Predust
Color ^c	76.28y ±31.58	61.04z ±29.57
Gloss ^d	56.24z ±44.23	55.50z ±39.58
Adhesion of coating to product ^e	67.08y ±35.34	48.72z ±38.17
Crispness ^e	89.44y ±38.35	65.54z ±35.97
Moisture absorbed from mouth ^e	66.50z ±36.42	72.58z ±35.36
Deep-fried flavor ^d	49.16z ±47.43	48.06z ±45.01
Acceptability ^d	55.76z ±25.72	59.61z ±26.00

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

^bHigher numbers indicate that the characteristic is more intense, while low numbers indicate a lack of the characteristic.

^c138 observations were made for each pretreatment type.

^d174 observations were made for each pretreatment type.

^e123 observations were made for each pretreatment type.

Table V.9--Means for sensory characteristic ratings of coated mushroom products reheated by conventional and microwave oven

Characteristic ^b	Reheating Oven ^a	
	Conventional	Microwave
Color ^c	65.56z ±32.30	71.75y ±30.44
Gloss ^d	53.41z ±43.76	58.32y ±39.95
Adhesion of coating to product ^e	58.18z ±37.04	57.63z ±38.78
Crispness ^e	92.69y ±33.97	62.29z ±37.85
Moisture absorbed from mouth ^e	61.62z ±36.15	77.46y ±34.08
Deep-fried flavor ^d	49.44z ±47.32	47.78z ±45.12
Acceptability ^d	61.20y ±26.59	54.17z ±24.75

^aMeans ± standard deviation within a row followed by different letters are different at P<0.05.

^bHigher numbers indicate that the characteristic is more intense, while low numbers indicate a lack of the characteristic.

^c138 observations were made for each reheating method.

^d174 observations were made for each reheating method.

^e123 observations were made for each reheating method.

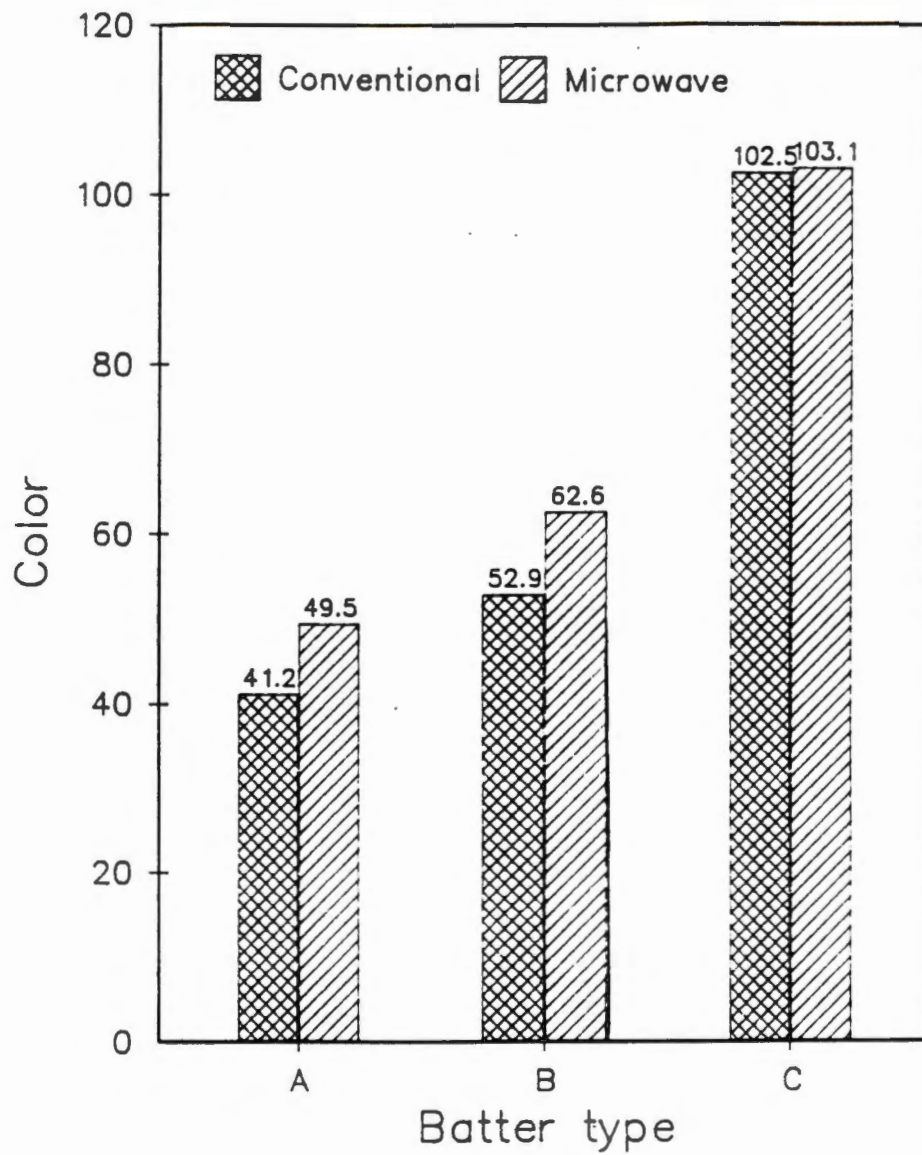


Figure V.4--Sensory rating of reheated mushroom product color as a function of reheating method and batter type.

The effect of batter*reheating method interaction on mushroom products is similar to that of the interaction effect on apple products (Figure IV.9).

Within batters A and B, predusted products which were reheated in the conventional oven were significantly lighter in color than other pretreatment*reheating method combinations (Figure V.5). Predusts contained non-fat dry milk which should have contributed to non-enzymatic browning. This was not the case, however, no explanation is currently available for this occurrence. Within batter C, predried products were significantly darker than predusted products. This is most likely due to the discoloration of the gill area of the substrate as the result of frying. Discoloration could be seen through the coating of predried products, but not of predusted mushroom. There was no difference in color of predusted products coated with batter C due to reheating method.

2. Gloss

Gloss of reheated mushroom products was affected by batter type, reheating method, judge and the batter*pretreatment, batter*reheating method and batter*pretreatment*reheating method interactions (Table V.6). Products coated with batter C were glossier than those coated with batters A or B (Table V.7). Microwave

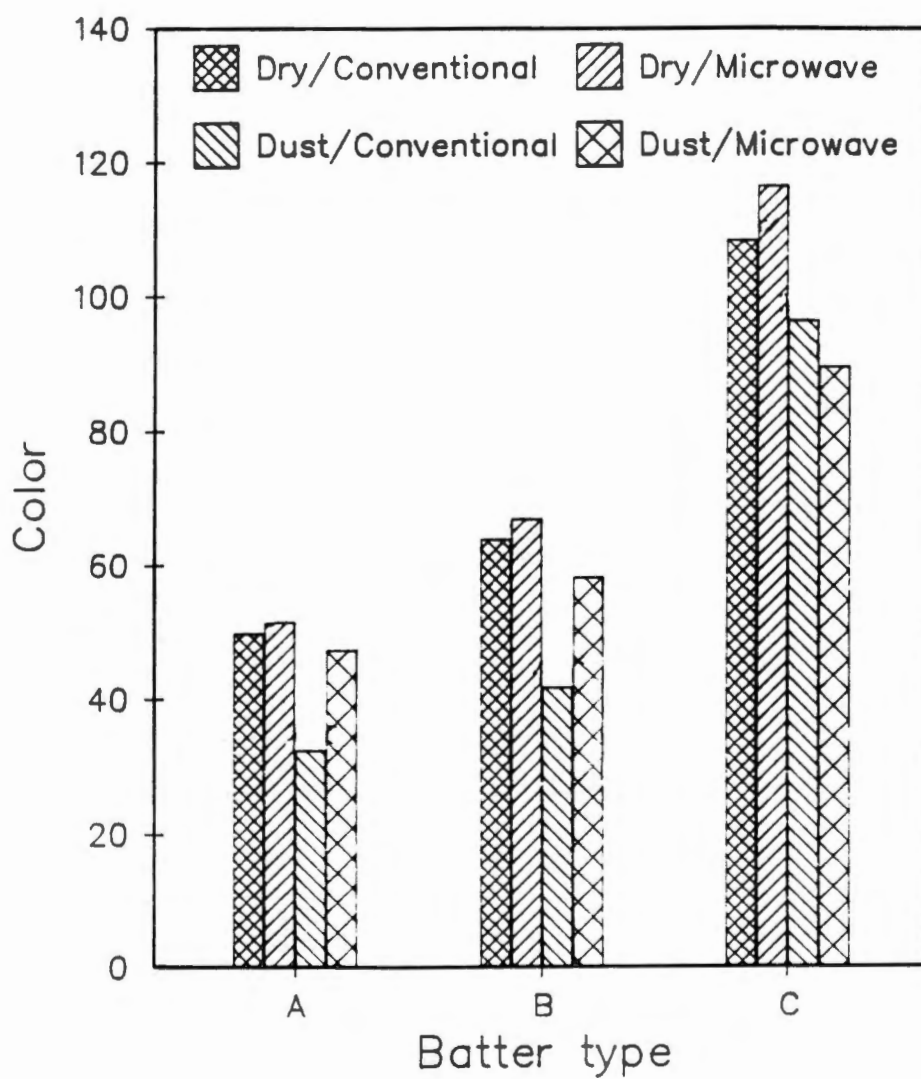


Figure V.5--Sensory rating of reheated mushroom product color as a function of pretreatment, reheating method and batter type.

reheated products were glossier than those reheated in a conventional oven (Table V.9).

Mushroom products coated with batter C were significantly more glossy than those coated with batter A or B (Figure V.6). Within batter C, predusted products were significantly less glossy than predried. One function of predusts is to decrease fat absorption during frying (Suderman, 1983). The difference in gloss may have resulted from decreased oil absorption by the predusted product. There was no difference in glossiness of products coated with batters A or B.

Products coated with batters A or B and reheated in a conventional oven did not differ in glossiness from each other but were less glossy than the microwave-reheated counterparts (Figure V.7). Products reheated in a microwave were glossier ($P < 0.05$) when coated with batter B than with batter A. There was no difference in glossiness due to reheating method for products coated with batter C. As with color, the higher degree of gloss for microwave reheated products is most likely a function of heating characteristics of the coating.

There were significant differences among the glossiness ratings of batter C-coated products, with predried, microwave-reheated products being the glossiest and predusted, microwave-reheated products being the least

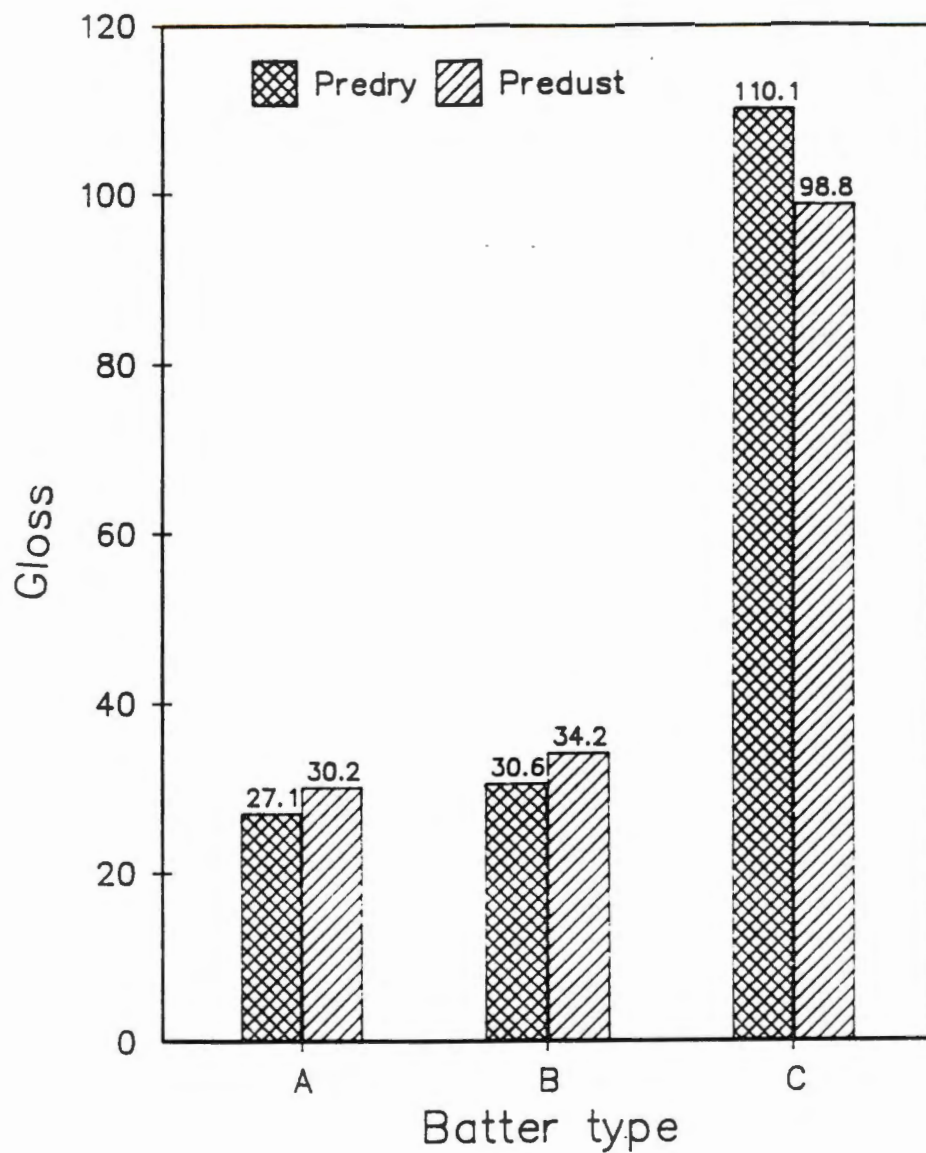


Figure V.6--Sensory rating of reheated mushroom product gloss as a function of pretreatment and batter type.

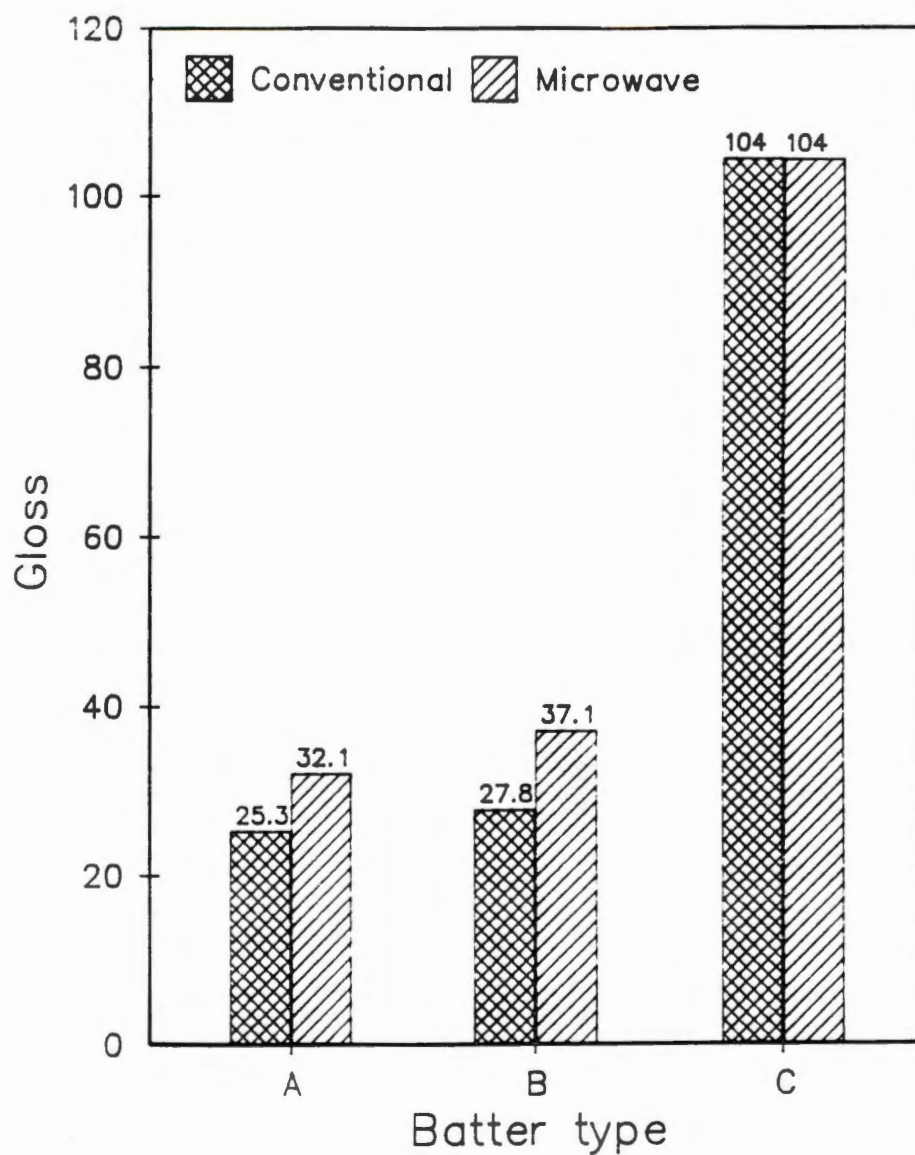


Figure V.7--Sensory rating of reheated mushroom product gloss as a function of reheating method and batter type.

glossy (Figure V.8). For products coated with batters A or B, predusted products reheated in the microwave were glossier ($P < 0.05$) than predried products reheated in a microwave or conventional oven. Products coated with batter C were glossier than products coated with batters A or B.

3. Adhesion of coating to product

Coating adhesion was affected by block, batter, pretreatment, judge and the batter*reheating method and pretreatment*reheating method interactions (Table V.6). Batter C-coated mushroom products had lower ($P < 0.05$) adhesion ratings than did the baked coatings (Table V.7) and predried products had greater adhesion than did predusted products (Table V.8).

Products coated with batters A or B exhibited greater adhesion than products coated with batter C (Table V.7). The adhesion rating of products coated with batter B was unexpected as coating adhered loosely to mushroom when coated with this batter, particularly for predried products. Coating loss for batter B-coated products was greater ($P < 0.05$) than that of products coated with batters A or C (Table V.2). There was, in fact, such little adhesion that if disturbed during storage, coating B would break off the predried mushroom. Consistent overall adhesion was difficult to achieve on mushroom products and several panelists noted that coatings did not adhere well to the top

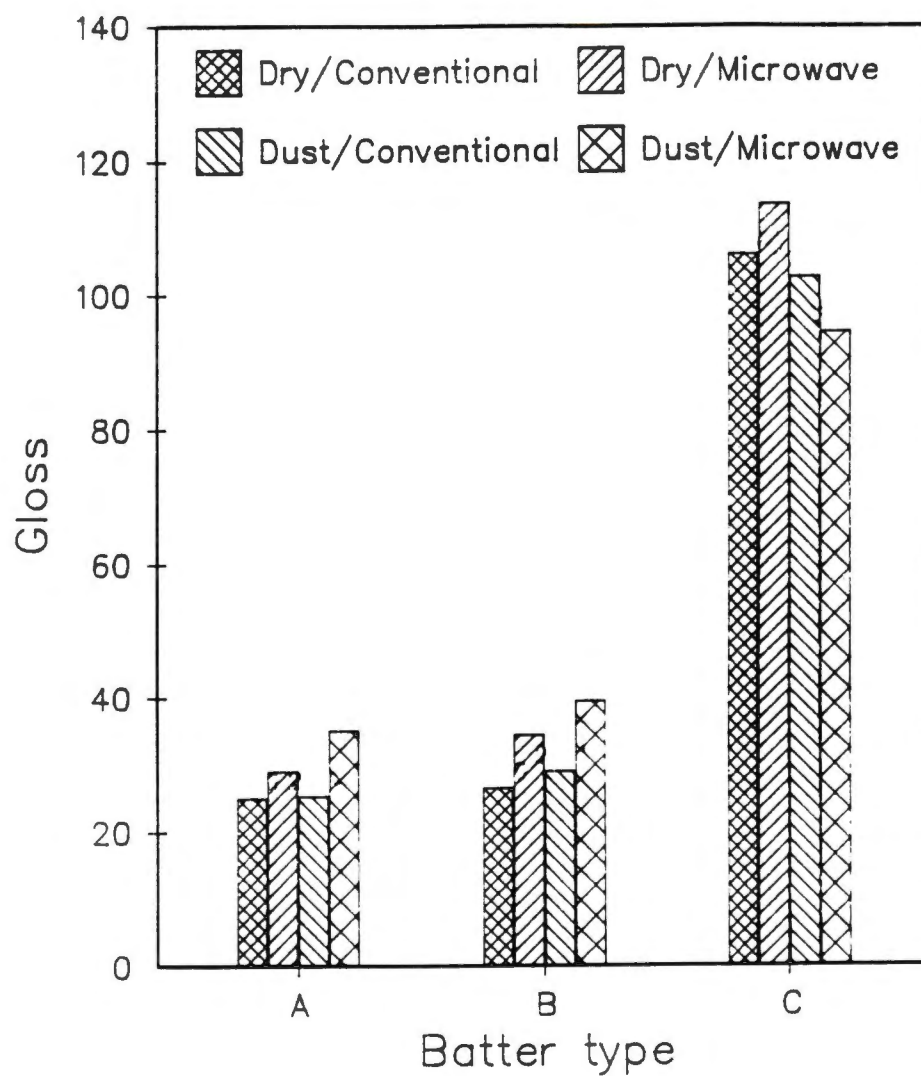


Figure V.8--Sensory rating of reheated mushroom product gloss as a function of pretreatment, reheating method and batter type.

of the mushroom cap and to the stem. However, the sides of the cap and the gill area had excellent adhesion.

Mushroom products coated with batter A had greater adhesion when reheated in a conventional oven; the opposite is true for products coated with batter C (Figure V.9). There was no difference in adhesion for batter B-coated products due to reheating method. Adhesion ratings for products coated with batter C and those coated with batter A and microwave-reheated were significantly lower than ratings for the other treatments, among which there was no difference.

Predried mushroom had greater ($P < 0.05$) adhesion when reheated in a microwave oven than in a conventional oven; the opposite is true for predusted mushroom (Figure V.10). Predusts form films which trap moisture inside the product (Meyers, 1990). Microwave reheating tends to result in a more rapid rate of steam formation than does conventional oven heating (Best, 1987). Thus, adhesion of predusted products after microwave reheating is likely lowered by entrapment of steam between the substrate and coating.

4. Crispness

Crispness of reheated mushroom products was affected by pretreatment, reheating method, judge and the batter type*pretreatment interaction (Table V.6). Predried products were crisper than predusted (Table V.8). Products

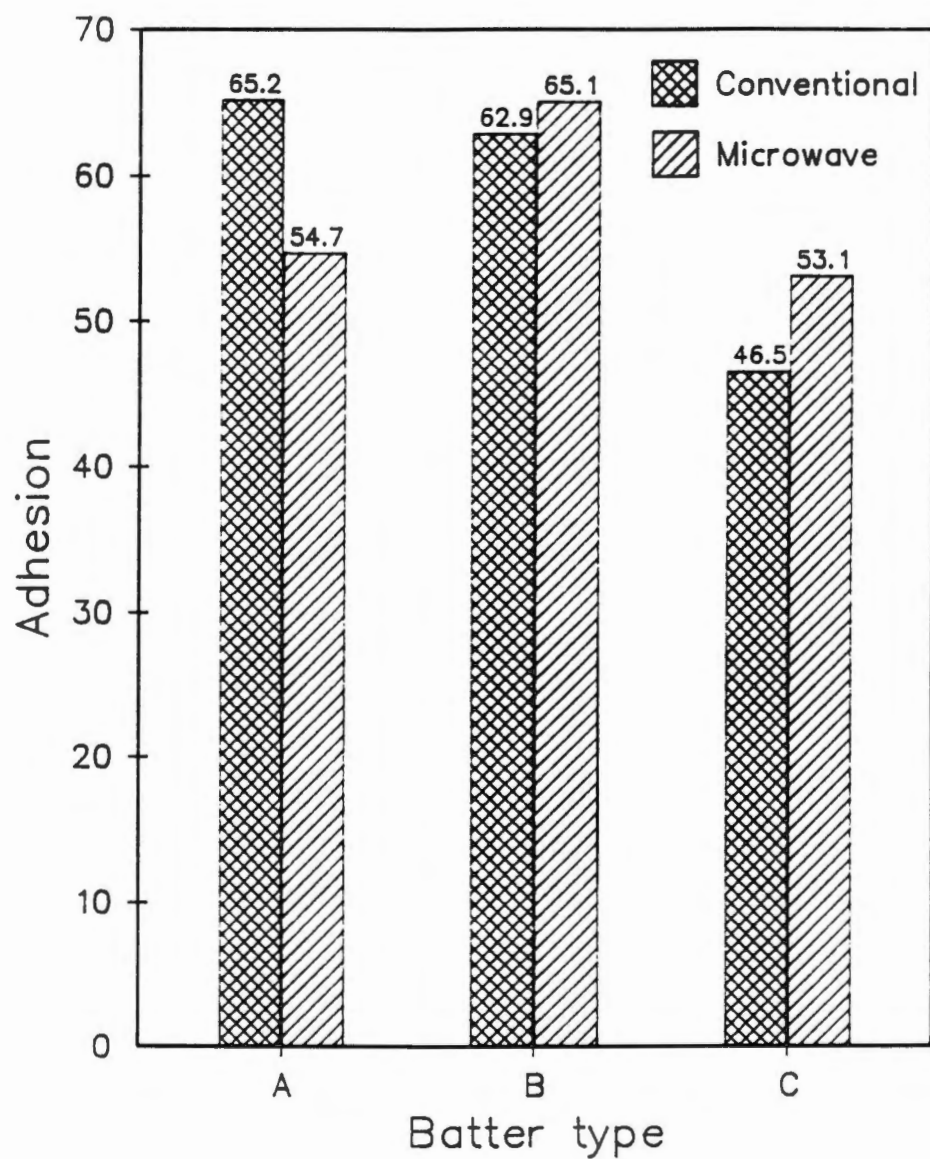


Figure V.9--Sensory rating of coating adhesion of reheated mushroom products as a function of reheating method and batter type.

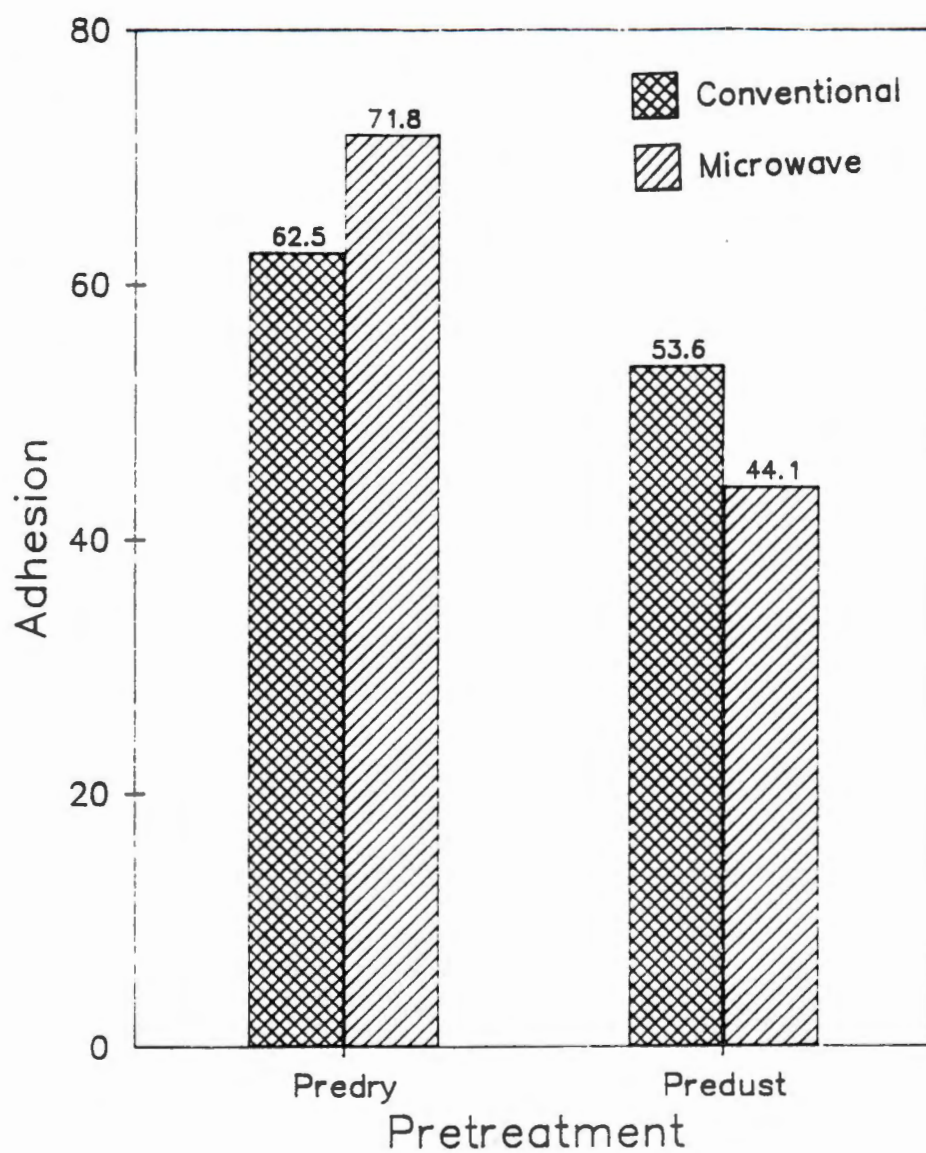


Figure V.10--Sensory rating of coating adhesion of reheated mushroom products as a function of reheating method and pretreatment.

reheated in a conventional oven were crisper than those reheated in a microwave oven (Table V.9).

Within batter type, predried products were crisper than the predusted counterparts (Figure V.11). There was no difference in crispness between predried products coated with batters B or C; nor was there a difference between predusted mushroom coated with batters A or B.

5. Moisture absorbed from mouth

The amount of moisture absorbed from the mouth was affected by batter type, reheating method and judge (Table V.6). As with apple, fried mushroom absorbed less moisture from the mouth, likely due to coating of the mouth by fat (Table V.7). Products reheated in a microwave absorbed more moisture than those reheated in a conventional oven (Table V.9).

6. Deep-fried flavor

Deep-fried flavor of mushroom products was affected by batter type and judge (Table V.6). Products coated with batter C and fried had a greater intensity of fried flavor than baked products (Table V.7). This result was similar to that of apple products (Table IV.7).

7. Acceptability

Acceptability of reheated mushroom products was affected by batter type, reheating method, judge and the batter type*pretreatment interaction (Table V.6). Products

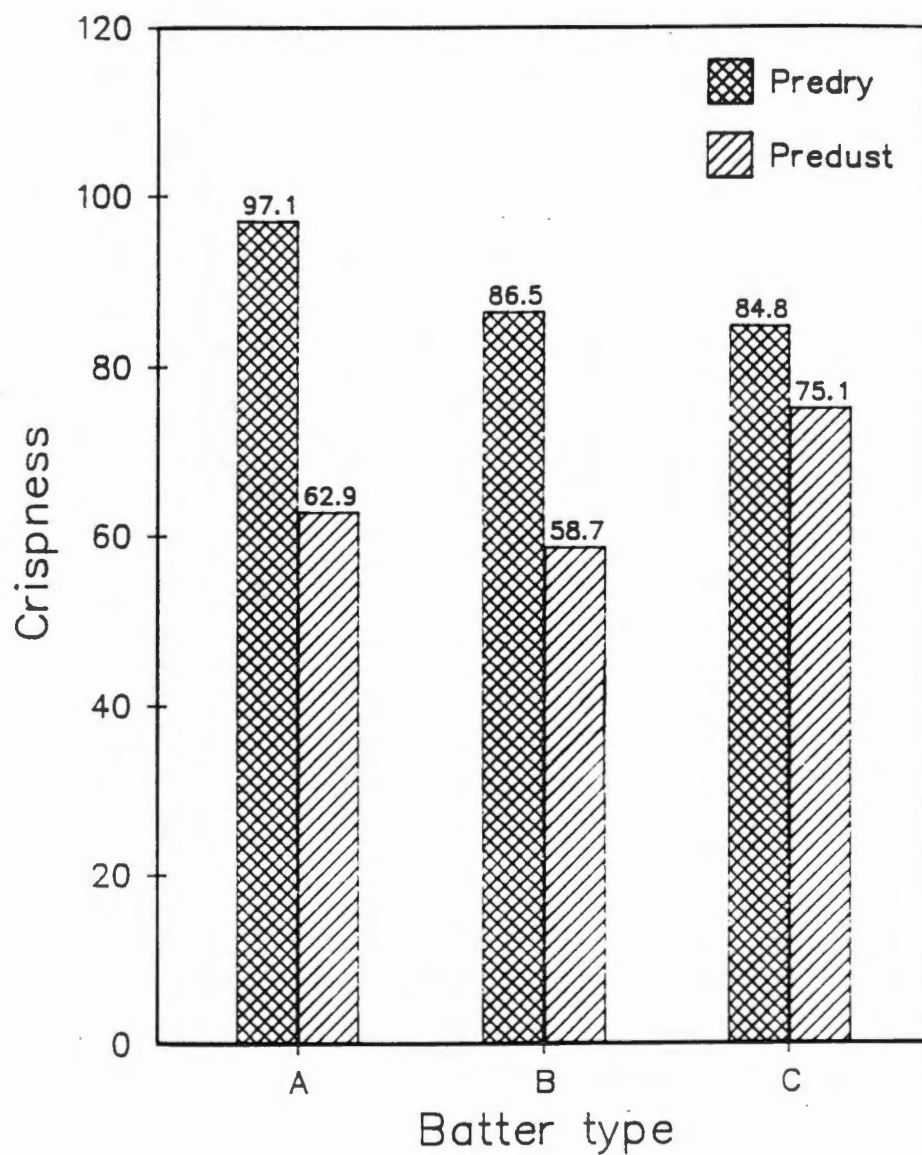


Figure V.11--Sensory rating of reheated mushroom product crispness as a function of pretreatment and batter type.

coated with batter C were rated as most acceptable; those coated with batter B were least acceptable (Table V.7). Products reheated in a conventional oven were more acceptable than microwave-reheated products (Table V.9).

Mushroom coated with batter C was significantly more acceptable than products coated with batters A or B, among which there was no difference (Figure V.12). Within batters, there was no difference in acceptability due to pretreatment, although for batters B and C, predusted products tended to be more acceptable. Although fried products were rated as being more acceptable than baked, panelists commented that the fried product was quite greasy.

H. CONCLUSIONS

Characteristics of the coated mushroom products were affected by 1 or more of the factors tested (batter type, pretreatment, reheating method) and in some cases, their interactions. Overall, the findings for mushroom products are similar to those for apple.

Coating pickup and loss and final coating percentage of mushroom were affected by batter type and pretreatment, with predusted products and those coated with batter C having greater pickup and final percentage and lower loss. These factors appeared also, however, to be affected by substrate characteristics, such as exposure of the gill area.

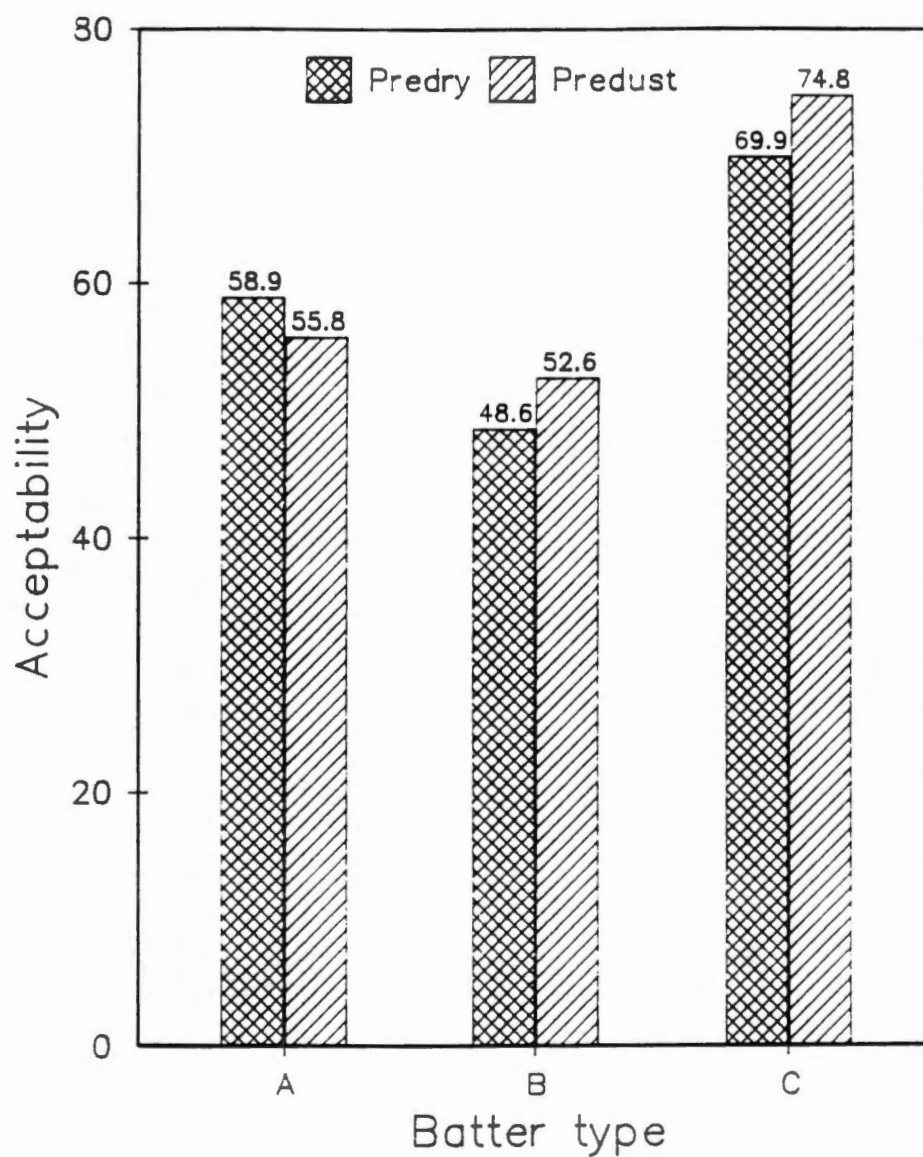


Figure V.12--Sensory rating of reheated mushroom product acceptability as a function of pretreatment and batter type.

The moisture content of the reheated product was affected also by batter type and pretreatment, with fried products and predried products having lower values. Unlike apple products, moisture of mushroom products was not affected by reheating method, possibly due to differences in substrate characteristics.

Products coated with batter C and fried were found to be darker than baked products in objective and sensory evaluations. According to the Delta E values, products reheated in a conventional oven had a greater total color difference than did those reheated in a microwave. Sensory panelists, however, rated microwave-reheated products as darker. Pretreatment affected sensory ratings of color, with predried products being darker, particularly when coated with batter C.

As with apple products, mushroom coated with batter C were rated glossier than predusted or baked mushroom. Unlike apple products, pretreatment had no effect on gloss. Mushroom products reheated in a microwave were glossier than those reheated in a conventional oven.

Panelists rated products coated with batter C as having less adhesion than baked products. Predried products were rated as having greater adhesion than predusted. These ratings are contradictory to results obtained for coating loss.

Predried products were crisper than predusted products. Products reheated in a conventional oven were crisper and more acceptable than those reheated in a microwave. Microwave reheated products, however, absorbed more moisture from the mouth during chewing than did oven reheated products. Products coated with batter C absorbed less moisture from the mouth, had a more intense deep-fried flavor and were more acceptable.

The effects of batter type, pretreatment and reheating method on mushroom products were highly variable. Overall, the most satisfactory product overall was obtained by predusting, deep-frying and reheating in a conventional oven.

CHAPTER VI

RECOMMENDATIONS FOR FUTURE RESEARCH

Although it was possible to obtain several acceptable products through combinations of batter type, pretreatment and reheating method, this author feels that the products were not acceptable enough to warrant commercial use of this type of coating system. Thus, should research in this area be continued, there are several ways in which the product may be improved.

Although reactants for non-enzymatic browning were present in the baked batters, color development was not sufficient to compare with fried products. The addition of colorants, possibly a caramel coloring for bakery use, should be considered.

The oil used in formulation of baked batters did not impart an intense deep-fried flavor to the product. During preliminary research, oil was heated prior to addition to batters. The heating process did not result in development of flavor at a level necessary to be detected in the baked product, and thus was pursued. Used oil from high volume frying operations, if available, could be used to provide deep-fried flavor. Also, an oil which is more flavorful than soybean oil could be utilized. Development of commercial fried flavors continues; thus, it may be possible in the

future to incorporate these flavors into baked coatings without the charring which occurs with present flavors.

Differences in texture between baked and fried coated products should also be addressed. This author believes that an acceptable texture can be obtained through the further manipulation of ingredients, particularly starches, gums, and "fat mimicking" hydrocolloids.

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APPENDICES

APPENDIX A--Experimental design for product preparation and sensory evaluation^a

	<u>Batter^b</u>	<u>Pretreat^c</u>	<u>Heat^d</u>
Block 1	1	1	1
	1	2	2
	2	1	1
	2	2	2
	3	1	1
	3	2	2
Block 2	1	1	2
	1	2	1
	2	1	2
	2	2	1
	3	1	2
	3	2	1

^aMontgomery, 1991.

^bBatter: 1=20% oil, impingement oven,
2=40% oil, impingement oven,
3=3% oil, fryer.

^cPretreat: 1=Predry,
2=Predust.

^dReheat: 1=Conventional oven,
2=Microwave oven.

- 1) COLOR
Anchors: Light brown ----- dark brown
Anchor samples: Dark brown - cornflake crumbs baked for 15 min. at 190°C
Light brown - unbaked cornflake crumbs
Evaluation Technique: Visually evaluate degree of brownness.
- 2) GLOSSINESS
Anchors: Very glossy ----- not glossy at all
Anchor samples: Very glossy - shiny tiles
Not glossy at all - dull tiles
Evaluation Technique: Visually evaluate glossiness.
- 3) ADHESION OF COATING TO PRODUCT
Anchors: Adheres very well ----- Does not adhere well
Anchor samples: Adheres very well - Farm Rich vegetable sticks (baked).
Does not adhere well - Ore Ida coated mushrooms (microwaved).
Evaluation Technique: Using tines of fork, determine difficulty in separating coating from product.
- 4) INITIAL CRISPNESS OF COATING
Anchors: Very crisp ----- Not crisp at all
Anchor samples: Very crisp - Unsalted cracker
Not crisp at all - Unsalted cracker (a^w about 0.28).
Evaluation Technique: Place sample between molars and bite down.
- 5) AMOUNT OF MOISTURE ABSORBED FROM MOUTH WHILE CHEWING
Anchors: Much ----- None
Anchor samples: Much - Unsalted cracker
None - Gummy bears
Evaluation Technique: Chew with molars 5 times, then evaluate.
- 6) DEEP FRIED FLAVOR
Anchors: Intense ----- None
Anchor samples: Intense - Unsalted potato chips
None - cracker
Evaluation Technique: Evaluate after chewing.
- 7) OVERALL ACCEPTABILITY
Anchors: Highly acceptable ----- Very unacceptable

APPENDIX C--Sensory evaluation scorecard

Sample _____

Panelist _____

You will receive 6 samples today. Evaluate each sample using the definitions provided as a guide. Place a mark (—|—) across the line indicating the point that corresponds to your evaluation of the intensity of the characteristic. Comments on the samples also are appropriate. Please rinse mouth between samples.

COLOR

light brown

dark brown

GLOSSINESS

very glossy

not glossy at all

ADHESION OF COATING TO PRODUCT

adheres very well

does not adhere well

INITIAL CRISPNESS OF COATING

very crisp

not crisp at all

AMOUNT OF MOISTURE ABSORBED FROM MOUTH WHILE CHEWING

much

none

DEEP FRIED FLAVOR

intense

none

OVERALL ACCEPTABILITY

extremely acceptable

not acceptable

COMMENTS:

VITA

Lori Lynn Huskey was born in Trumann, Arkansas on March 12, 1966. She attended Trumann Public Schools and graduated from Trumann High School in May, 1984. She entered the University of Arkansas, in Fayetteville, Arkansas, as a Food Science major and graduated from the University Honors Program in May, 1988 with a Bachelor of Science degree in Agriculture. Lori began Graduate School at the University of Arkansas in May, 1988, and completed her Master of Science degree in Food Science in August, 1989. In August, 1989, Lori entered The University of Tennessee at Knoxville. She received her Doctor of Philosophy degree in Food Science and Technology in May, 1993.