COMPOSITION AND CHARACTERISTICS OF COATED BROILER PARTS

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Foreword

Battered and breaded food items on the market have expanded greatly with the advent of not only coated fried chicken and seafoods but vegetables, fruits, and dairy products. Many of these items are common on menus of quality restaurants across the country and are consequently demanded by the consumer in the frozen food case or as do-it-yourself packages on the grocery shelf. Jessup (1981) referred to batters and breadings as industries lowest value-added cost, making them of particular interest to the food industry. This ever expanding area needs more research. The food item that is the stable of the batter and breading industry is poultry and was chosen as the medium for these studies.

One of the biggest problems within the batter and breading industry is adhesion of the coating to the food product. This area was included in all aspects of research done in this thesis. The research topics included in these investigations were:

1) Composition of broiler meat as influenced by different cooking methods and the presence or absence of a coating.

2) Effect of size and temperature of broiler drumsticks on coating characteristics.

3) Effect of the presence or absence of skin on broiler drumsticks on batter and breading characteristics.

4) Effect of temperature on % weight gain of broiler drumsticks after marinating.

5) Effect of different chemical groups on batter and breading characteristics and yield of broiler drumsticks.

The results of the experiments and a review of the literature are presented in the following four papers.

Paper 1

BATTERS AND BREADINGS--
A REVIEW

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Abstract

The consumer demand for battered and breaded foods is high and many of the commercially sold coated items have been absorbed into the frozen food industry. Total poundage of frozen breaded products in 1980 was 1855.7 million which utilized 581.1 million pounds of batter and breading. Coatings serve to remove monotony from common food items, giving the food a more attractive appearance and a better taste, aid in nutrition, act as a barrier during cooking and storage retarding moisture losses, and inhibit oxidation by excluding oxygen from the food product. Two major problems with batters and breadings are adhesion and encapsulation, which are improved by processing selections, ingredient manipulations, and cooking methods. Adhesion can be measured by using a sieve shaker and calculating the amount of crumb lost from a coated food piece after 1 min. of shaking on a 1/4" grid.

Introduction

Battered and breaded foods have become a staple in the American diet. They are not only important in the traditionally battered and breaded foods, such as seafoods and fried chicken, but are becoming the ingredients that remove the monotony from commodity items, turning them into promotable features in the supermarket. This rise in consumption of batter and breading is also seen in restaurants where battered and breaded vegetables, fruits, etc. are becoming more popular. The variety of foods that can be coated really has no limit. It depends on the imagination of the various companies, restaurants, or other food preparation establishments as to what foods are to be coated. Today there is a long list of foods which are coated, usually on an industrial basis, although many restaurants or food preparation centers apply coatings at their level. Below is a partial list of some of the coated foods on the market:

I. Meats

- A. Veal cutlets
- B. Chopped beef
- C. Beef patties
- D. Pork patties
- E. Pork, veal and lamb chops

II. Poultry

- A. Pre-cooked cutup chicken parts
- B. Raw cutup chicken parts
- C. Fabricated chicken patties
- D. Cutup breast strips
- E. Chicken livers and hearts

III. Vegetables

- A. Onions
- B. Green peppers
- C. Zucchini squash
- D. Califlower
- E. Okra
- F. Asparagus
- G. Broccoli
- H. Potatoes-potato puffs

I. Mushrooms

IV. Seafoods

A. Shrimp
B. Fishsticks and fish portions*
C. Natural fillets
D. Formed fillets and other shapes
E. Clams
F. Oysters
G. Mussels

*Note: Various species of fish are used, with cod, haddock, pollock, whiting, and hake being most common (Urban, 1981).

V. Fruits**

A. Apples
B. Bananas
C. Pineapples

**Note: First started in England and used as hors d'oevres (Johnson, 1981).

VI. Dairy Products

A. Cheese cubes
B. Cheese Sticks

A majority of commercially battered and breaded foods have been absorbed into the frozen food industry. At one time the frozen food industry had very few battered and breaded items, now nearly all battered and breaded foods are marketed in frozen form (Anonymous, 1975). The value of frozen foods in the U.S. in 1980 was $24,718.8 million with a total poundage of 21,063 million. That included sales of frozen fruits vegetables, concentrates, poultry, meats, seafoods, and prepared foods. Total poundage of frozen breaded products in 1980 was 1855.7 million which utilized 581.1 million pounds of batter and breading. That means that 31.3% of the food products was the breading itself (Anonymous, 1981).

According to Jessup (1981), commercial batters and breadings provide processors with their greatest value-added opportunity at the lowest cost. The market incentives are the demand for convenience by the consumers and the increased use of portion-packed items at restaurant and food service establishments.

The first item to be breaded in volume was shrimp, initially produced by William Mullis who formed the Trade Winds Company, Thunderbolt, Ga., in 1949. Within one year he had 250 people working in his plant and had achieved distribution in 32 states (Anonomyous, 1975). Today there are nearly 100 frozen breaded shrimp operations and in 1980 there were 8,474,000 pounds of breaded shrimp sold at a value of $415,583,000 (Anonomyous, 1981). The second item made possible by breading was fish sticks in 1951 and other frozen breaded seafood items followed. By 1980, 874 million pounds of breaded seafoods were produced commercially (Anonymous, 1981). Breaded seafood production has started to level off as other commodity food items become popular as battered and breaded items. Though high volume production of these standard items will be the foundation of the industry, emphasis has changed to producing innovative products with unique customer appeal and a high standard of quality control (Johnson, 1981). The consumer's quest for new food items and greater convenience, along with renewed interest from a nutritional point of view, has led the industry to batter and breaded vegetables, some fruits, and a variety of meats. Yet the leader in this area is still onion rings, comprising 155 million pounds, using 77.5 million pounds of breading in 1981 (Moore's Food Products, 1982).

The high cost of meat has made battered and breaded patties, with smooth to crunchy coating, economical for the consumer and profitable for the industry. This applies to poultry patties, veal patties, beef patties, pork patties, and cutlets. There are many shaped and/or formed coated products which are produced in high volume. Products shaped as pork chops, lamb chops, steaks, and other popular cuts are made up predominately of formed meat (Anonymous, 1975). The figure for breaded meat produced in 1980 was 105.8 million pounds using 26.4 million pounds of breading (Anonymous, 1981).

Breaded meats will continue to gain in popularity because they offer a chance for the processor to improve flavor through breading, which enhances its appeal.

One of the greatest growth areas for coated foods in recent years has been breaded, precooked, frozen chicken. There were always frozen breaded raw chicken parts but they made up a relatively small part of the business until chicken drive-ins became popular. Many fast food outlets preferred to receive the product precooked, just reheating it and maintaining their reputation for speed and efficiency of serving (Anonymous, 1975). Many forms of chicken such as patties, fillets, and strips have also become popular in fast food outlets and are now receiving more attention in the marketplace. Tyson Foods, Inc., Springdale, Arkansas, for example, has several frozen processed chicken items in the retail market including breast patties, breast fillets, Chick'n Hoagies, and Chick'n with cheddar cheese, all of which are breaded. They, as well as other frozen chicken products, are designed for convenience of preparation and can be warmed in a conventional oven, microwave or can be deep-fat fried.

Not everyone will buy a product already prepared but choose to batter and bread their own. Many homemakers serve fried chicken to their families on a regular basis. This is evident by the increasing consumption of broiler meat since the early 1970's, whereas per capita consumption of other meats has varied over time by type of meat.

Breading used by the frozen food industry on chicken in 1961 was only a little more than 3.7 million pounds. By 1973 the figure had grown to 56 million pounds and in 1980 they used 125.7 million pounds of breading on 510 million pounds of chicken (Anonymous, 1981).

The largest single selling frozen dinner, making up about 25% of the gross units, is the chicken dinner. Most chicken dinners are made with breaded chicken and 14.7 million pounds of breading was used on them in 1980 (Anonymous, 1975; Anonymous,

1981). Turkey dinners, the second best selling dinner line, comprising 20% of the total dinner volume, are not a breaded product, but all turkey dinners have stuffing, and the stuffing is made with breading. There were 18.8 million pounds of stuffing mix used in turkey dinners in 1980 at an approximate value of $3.9 million (Anonymous 1975; Anonymous, 1981). The use of chicken and turkey frozen dinners has declined steadily since 1974 as the use of other convenience foods were introduced with somewhat higher consumer appeal.

In summary, the battered and breaded food industry is large, and features promotable, value-adding ingredients to foods, including frozen prepared products and batter and breading mixes in the market-place, restaurants, institutions, and homes. In 1980, frozen food industry alone sold 1855.7 million pounds of frozen breaded products using 581.1 million pounds of breading (Anonymous, 1981).

Chicken was the major frozen breaded product made in 1980, comprision 27.5% of all breaded frozen food, and accounting for 21.9% of all breading used on frozen products. Seafood specialties used the second largest amount of breading (17.1%) and comprised 12.7% of all breaded frozen products sold. Those figures indicate the importance of poultry to the industry. Much work has gone into improving the quality of those products and even small improvements can be of high economical value to the industry.

Coating and Ingredient Functions

Batters and/or breadings are applied to food products for many reasons. They remove the monotony of some foods and increase their acceptance by giving the food product a more attractive appearance (Elston, 1975) and a better taste. Other researchers found that flavor and appearance could be enhanced by imparting a crispy texture (Elston, 1975; Zwiercan, 1974) contributing to the pleasure of eating (Vickers and Bourne, 1976) and adding a more desireable color (Libby, 1963; Elston,

1975). Coatings also contribute to the nutritional value of a food product (Elston, 1975), not only by the added ingredients but by protecting the nutrients within the the food product from direct contact with the cooking medium and from moisture loss where nutrients can be leeched out. It was suggested by Libby (1963) that coatings act as sealants preventing natural juices from flowing out.

Batters and breadings acting as moisture barriers (Suderman, 1979) not only prevent moisture and weight loss (Dawson et al., 1962; Love and Goodwin, 1974; and Harris and Lee, 1974) but improve juiciness and tenderness (Suderman, 1979; Baker et al., 1972a).

Considerable research has been done on the use of edible coatings on foods. In general, they have served to reduce moisture losses by acting as a barrier during cooking and storage (Zakib and Dawson, 1963) thus controlling weight loss in addition to limiting bacterial growth (Dawson et al., 1962). They also act as grease, oil, and nitrogen barriers in addition to adding nutritional value to the food (Kroger, 1971). Morgan (1971) reported they enhanced food appearance, reinforced food structure, inhibited oxidation by excluding oxygen from the food product, and extended shelf life.

Edible coatings have been made from 1) modified waxes; 2) cellulose-based products; 3) starch, dextrin and amylose-based materials; 4) acetylated glycerides; 5) collagen derivatives; 6) alginates and pectin; and 7) miscellaneous systems (Morgan, 1971). Some commercially prepared edible coatings are Myvacet (R) films (Eastman Chemical Products, Inc., Kingsport, Tenn.) and Ediflex (R) (American Maize Products Co., New York).

Krijewski (1966) has a patent on a process of coating frozen meat for the purpose of shielding the meat while thawing against adulteration from extractable oleaginous additive materials leeched from organic, thermoplastic, resinous packaging

films. The steps involved included, 1) freezing the meat product; 2) applying a prime, edible, barrier coating composition composed of an aqueous solution of an edible barrier material selected from one of the following: a) tapioca starch, b) corn starch, c) sodium oleate, d) sodium stearate, e) pectinic acid amid having an average methoxyl content of from 3.5 to 5.0%, and some others. The third step was to solidify the continuous coating, then finally; 4) enveloping the frozen, barrier-coated meat product in an outer casing of packaging composition for frozen meat products consisting of an adherent, moisture-impervious, protective, organic, thermoplastic, resinous packaging film such as ethylcellulose, polyvinyl chloride, saran, and others.

Flavor-Tex (R) (D.H. McKee, Inc., Tampa, Fla.), another edible coating is made from malto-dextrins, sodium alginate, calcium chloride, cellulose gums (CMC), and applied as a liquid by any of the conventional coating or film-forming techniques including airless spraying, dipping, or falling film enrobing. On battered and breaded products the film acts as a moisture barrier between the food and the batter and breading. As a result, overall appearance of the processed piece is more uniform in color and in breading distribution over the food, and the flavor constiuents are sealed in (McCormick, 1975).

The ingredients in batter and breadings function individually and collectively to give the many types of coatings associated with different food products. The ingredients can be grouped into one of five different categories: polysaccharides, proteins, fats and hydrogenated oils, water, and seasonings.

Polysaccharide-containing ingredients are: wheat flour, farinaceous material, corn flour, starch (corn or rice), modified derivatives of cellulose, and gums. The starches may be in many forms including ungelatinized, pregelatinized, hydrolyzed, or modified in other ways. Polysaccharides function in batters and breadings by interacting with themselves or other ingredient components such as proteins to

provide stability, lipids to provide viscosity, and sometimes emulsifying action. In this manner saccharides have control over the form, texture, and shelf life of battered and/or breaded foods (Suderman, 1979).

Proteins, the second ingredient category, are found in milk powders and milk protein fractions, egg albumen, cereal flours, seed proteins, and single-cell protein. Though their functions have not been well researched in batters and breadings, they have in other food products. Non-fat dry milk (NFDM) has been used to 1) improve the water absorption capacity of flour, which increases viscosity of the system; 2) improve baking qualities of weak flours; 3) strengthen structure and texture; 4) retard moisture loss; and 5) enhance crust color and flavor development. Egg proteins are structure forming and also act as thickeners. Seed proteins, soy protein being used the most, have functional properties that include emulsification, emulsion stabilization, and fat and water absorption. Single-cell protein has been used experimentally in batters and breadings to improve adhesion but has a drawback nutritionally because of its low concentration of sulfur-containing amino acids (Fennema, 1976).

The third set of ingredients, fats and hydrogenated oils, are known to be carriers of fat soluble vitamins and to contribute to food flavor and palatability as well as to the feeling of satiety after eating. Shortenings contribute to the tender quality or "shortness" of a baked product by their lubricating action. Other fatty materials such as mono and di-glycerides and lecithin, serve as emulsifiers and staling inhibitors (Fennema, 1976).

Water is used to form batter suspensions and aid in adhesion of breading to the surface of the food product. The ratio of water to solids is important as it affects both adhesion and viscosity (Cunningham and Tiede, 1981). This in turn will affect the amount of coating on the food, the thickness of it, its machinability, and drying time.

Water also acts in a structure forming role as it reacts with proteins and polysaccharides.

Seasonings are the fifth and last category and may include sugar, salt, pepper, paprika, and many other spices depending on the flavor desired. Sugar has a plasticizing effect (Morgan, 1971) and provides flavor by itself or, in combination with amines, forms melanodins and other by-products in Maillard browning that give a brown color and carmelizied flavors. Salt enhances the flavor of foods. Some spices serve functions other than just providing flavor. Paprika gives a pleasing pink color and is used where the products are to be frozen and used in a microwave oven or baked where little browning occurs.

Different combinations of the above ingredients are used to produce the various effects and flavors desired. A low viscosity batter was patented by Ajinomoto (1979), for frozen fried foods containing wheat flour, starch, emulsifier, starch degradation inhibitor, and water. A fry mix coating comprised of pregelatanized flour, modified starch and wheat gluten, was produced and patented by Bremner; General Foods Ltd. (Patent No. Can. 981,164), to coat meat products prior to cooking to preserve juices.

Harris and Lee (1974) also patented a food coating comprising a mixture of hydroxypropylmethylcellulose, dextrose, hydrolyzed cereal solids, and a pregelatinized tapioca starch, designed to improve the texture of meat or other solid foods by reducing the loss of moisture from the food during cooking.

A coating mix, composed of mixtures of 10-50% shortening, 8-35% farinaceous material, 15-30% corn starch hydrolysate and 5-18% of a modified food starch, was designed to give the appearance and texture of a fat-fried product without being fried was patented by General Food Corp. (Brit. 1,367,566). Another General Foods patent by Mancuso and Hagan (U.S. 3,586,512) described a product composed of a

water-soluble food dye, edible fat, and farinaceous material. Through the reaction from the baking heat and the moisture vapor from the food, the product develops an appearance, odor, texture, and color equivalent to coatings applied to deepfat fried foods.

Unilever Ltd. (1977), patented a food coating that gave raw foods, such as beef burgers, the appearance of being coated with a layer of bread crumbs when cooked by coating them with an adhesive fluid such as liquid egg and dehydrated potato flakes.

A Japanese patent (Nishiya Technical Service K.K., 1958) gave the compositon of a food coating to be used on vegetables or meats as salt, starch, condiments, and other additives added to minced fish or animal meat, mixed to yield a paste, then combined with sodium casein, calcium carbonate, and powdered soybean milk.

Batter and Breading Processing Selection

When selecting a batter/breading for a food product there are many factors to consider. Hanson and Fletcher (1963) found that batter ingredients, solid-water ratio of the batter, coating procedures, and/or cooking methods influenced the color, texture, toughness, fat, moisture, and general appearance of the cooked parts. All those factors affecting the battered and breaded food item must be carefully considered to produce the most acceptable product for the consumer. Different foods require different types of batters and breading. Also the form in which a food will be marketed must be considered when determining ingredients and processing steps.

Ingredients.

There are many batter and breading ingredients used to improve or give variation among batters and breadings. Suderman et al. (1981) studied the effect of protein and gum sources on the amount of adhesion of a commercial breading to poultry skin. They found that protein sources improved adhesion to poultry skin

better than gums. Of the proteins, gelatin improved adhesion best, followed in order by egg albmumin, NFDM, soy flour, and whey. Carboxy methylcellulose (CMC) was the only gum that improved adhesion. Suderman (1979) also found that volume and baking losses could be progressively lowered by using water, whole milk, and evaporated milk, respectively, in a batter mix. By increasing the amount of protein in a breading material, tenderness decreased, though the presence of a coating improved product tenderness. Soy protein improved meat tenderness and decreased baking loss, when added to the breading mix. Egg albumen decreased volume loss. Volume loss declined as protein level increased. Baker et al. (1972a) compared 15 predust materials in an effort to find a predust to increase the adhesion of the coating. Hydroxypropyl methyl cellulose (HMC) and egg white were incorporated into batters by Hale and Goodwin (1968). Single-cell protein (Schnell, 1976) and comminuted fish flesh (King et al., 1974) have also been used to improve adhesion of coatings. Seeley (1981) used phosphate solutions and acids as a predip on drumsticks to try and improve coating adhesion. Phosphates significantly decreased crumb loss but acid solutions did not have any effect.

Composition also plays an important role in the color of the coated product. The extent of Maillard browning will depend on the availability of protein and reducing sugars to form furfurals and other intermediate browning components. Abu (1979) used buttermilk solids in the batter for fried chicken at 5, 10, 15, and 20% buttermilk powder. The addition of 20% resulted in a darker color, a higher moisture content, and higher final yield, and a higher percentage of crust than the other concentrations. The buttermilk also produced a butter flavor which was desireable. To inhibit nonenyzmatic browning, this same researcher used sulfite in the form of sodium metabisulfite up to 2500 ppm initially in the batter mixture. The reducing

sugars reacting with casein through the Maillard reaction were in increasing order galactose, glucose, and lactose.

Hanson and Fletcher (1963) observed color differences due to thickening agents. A mixture of waxy rice flour and waxy corn starch produced coatings with a glossy brown appearance. Wheat flour contributed to a grayish-brown color and a very light color was produced from a mixture of waxy corn starch and corn starch. A greenish-yellow cast was produced by yellow corn flour and potato flour caused a golden brown appearance.

Crispness, texture, and thickness of the coating are affected by the composition. Hanson and Fletcher (1963) suggested that mixtures of thickening agents offered the most promise for achieving desirable crispiness in battered and breaded foods. Texture can vary with the ingredients used and the granulation size of the breading. Thicker coatings were formulated from waxy rice flour and corn flour but they were too smooth to be attractive. Thinner coatings allowed bubbles to appear on the surface. The bubbles were larger as the thickness of the coating increased (Hanson and Fletcher, 1963).

Granulation of the breading governs the amount of pickup to a degree and provides color highlights.

Hanson and Fletcher (1963) increased the egg yolk content from zero to 10% when the solids-water ratio remained the same and the coating weight decreased. They suggested that coating thickness could be increased by adding thickening agents or by adding layers of flour dredge, egg white, milk dips, and a final batter application.

Viscosity of the batter and breading will also affect crispness, texture, and thickness. Cunningham and Tiede (1981) found that as batter viscosity increased, the amount of breading pickup increased. Cooking losses were least and breading

adhesion the best when drumsticks were dipped in batters having a 1:2 water:solids ratio. Poorest adhesion of breading was noted for drumsticks dipped in batters of low viscosity having a 2:1 water:solids ratio. High viscosity batters have high absorption and, in turn, high absorption breadings provide better pickup. These properties are important in deciding the process of applying the batter and breading. The four processes most often used commercially are outlined in Figure 1. Viscosity and granulation will determine whether a single-pass line (battered and breaded once) or if a double pass (process repeated) is necessary. Single passlines usually produce 30-35% pickup while double passlines, yeild 35-50% (Anonymous, 1979).

The flavor of the battered and breaded food is also dependent on ingredients. Hale and Goodwin (1968) discovered that the addition of cooked skin in the batter formula enhanced the flavor of chicken microwave precooked and deep-fat fried. Dawson et al. (1962) improved the flavor of chicken by coating it with distilled acetylated monoglyceride when birds were stored one week in a household refrigerator. Coatings also improve flavor by influencing product juiciness. The coating seals in and/or soaks up the juices usually lost during the steam cooking process (Love and Goodwin, 1974).

Coating Procedures.

Foods have been coated in many ways to produce better adhesion or to give the desired breading texture and functional properties. Suderman and Cunningham (1977) reported an improved appearance and greater coating uniformity on fresh chicken, rather than on parts that had been frozen and thawed. Precooking was found to improve texture and hardness of the skin-batter complex by Hale and Goodwin (1968) and they discovered parts coated at 2°C had a significantly better coating texture than parts coated at 24°C. Baker et al. (1972a) found a more attractive appearance on products that had been precooked with steam and boiling water. Hanson and

Fletcher (1963) noted improved batter adhesion by precooking. Even though precooking did seem to improve adhesion, Carlin et al. (1959) found that precooked parts from frozen chicken averaged 20 to 26% loss from the raw state to the ready-to-eat product, whereas nonprecooked controls averaged 16% losses. Suderman and Cunningham (1981) found that freezing drumsticks before coating them improved adhesion but not significantly.

There are many variations of the same steps carried out in batter and breading application. They may be frozen, coated, fried; or fresh, coated, partially fried, and frozen. This would depend on the type of product the food processor is aiming for (Davis, 1981).

Figure 1 outlines four processes used to achieve the desired coating effect. The single-pass line runs the product through a batter and breading only once for a pickup of less then 30%. The tandem line coats the product twice with batter and breading for a pickup of more than 30%. Those two systems result in a dry breading as the last step, unlike tempura or batterfry lines where the last coating step is wet and there is an application of a batter or tempura. The wet processing pickup varies between 30 to 55%. Wet coatings are for nonbreaded foods and include batter-fry, tempura and puff-batter systems. Characterized by a rough to semi-rough texture, batter-fry products exhibit a homestyle appearance. Coatings usually have minimum sweetness, golden brown background color with darker highlights on rough areas and reasonably hard eating qualities. Tempura batters have a high leavening content that produces a cake-like texture. The ingredient blend tastes slightly sweet, cooks to a smooth, deep brown crust and is very crisp and hard to the bite. Tempura batters are suitable for use on fish fillets, seafood, precooked chicken, vegetables and fruits. The other wet coating, leavened batter is puff batter. It imparts smooth cake-type texture and a sweet taste, yet it is less crisp and more tender than its tempura

counterparts. The color of the batter after frying is a light golden brown. Wet batters retain texture and eating qualities when cooked in the oven (Anonymous, 1979).

Many of the wet batter systems and others outlined in Figure 1 use a predust. It was found by Baker et al. (1972b) that a high adhesion predust material increased the yields of deep-fat fried chicken parts. Yang and Chen (1979) found a slightly higher yield for fried chicken parts prepared with a flour predust, batter, a second flour dust, than prepared with the batter-breading method.

One of the latest developments in coatings involves using a combination of tempura batter and Japanese style bread crumbs, which is being very well received on the market. Japanese breading is a dry, flaky bread crumb, consisting of long slivers that provide highlights to breaded products, while imparting a tender crispy texture. They have been used separately in the past but are now being used together utilizing the same equipment but in a different configuration. The tempura is applied followed by the application of the Japanese breading. The final coating step is dry and the pickup varies from 30 to 55%. It is used primarily on seafood but there are strong indications that this type of coating will be introduced on other products, particularly poultry and red meat, but also on vegetables such as onions, zucchini slices, califlower pieces, and mushroom slices. The combination produces an especially crispy finished product giving a degree of highlighting, making it an attractive product. It gives the consumer the idea of more coated product than coating itself (Johnson, 1979).

Depending on how the coated product is to be sold, the composition and batter/breading processes will differ. Products to be sold raw and breaded should be fast drying and have long cooking tolerance. As an example, hand packed frozen items will show fingerprints if not completely dried. Kilpatrick (1978), assignor to

Ruperts' Certi-Fresh Foods, Inc., patented a process of setting uncooked raw batter to the outside of a food product by reducing the temperature by contact with carbon dioxide snow.

Wet batter systems such as tempura or batter-fry require more energy than breaded products because of their higher moisture content. About 1/3 more BTU's are needed to cook the same amount of batter versus breaded products. Production rates for tempura batter also are longer, about twice that of a breaded product. Further, special processing equipment is needed. However, return on investments is high. Figure 2 shows some of the equipment differences in conventional and wet batter systems (Anonymous, 1979).

Cooking Methods and Media

Landes and Blackshear (1971) found that the color and flavor of breading material depended on several factors including: a) cooking time and temperature, b) composition of the breading material, and c) composition and characteristics of the cooking oil. Baker et al. (1972a) found that cooking method affected coating appearance. Precooking in steam and boiling water produced an attractive appearance.

Many methods have been tested for cooking coated parts, such as: pan frying, deep-fat frying, pressurizied deep-fat frying, microwave, baking, broiling, steaming, boiling, and autoclaving. Many of these methods are used in combination for precooking and final cooking of the battered and breaded product.

Hale and Goodwin (1968) found no difference in breading color and flavor when chicken parts were precooked by microwave energy or autoclaving before being breaded and browned by deep-fat frying as compared to conventional deep-fat frying. Adhesion of the batter coating was found to be greater when the parts were precooked by either method and precooking tended to produce a more tender product

with a higher moisture and lower fat content in the muscle and the skin-batter complex. Love and Goodwin (1974) found that broiler parts breaded raw and steam cooked picked up more breading than parts breaded after being cooked in water. Water cooked chicken had more initial cooking loss than steam cooked parts during the precooking operation.

Browning in deep-fat resulted in greater weight loss for steam cooked parts than for water cooked parts. Steam cooked parts were found to be more tender than water cooked parts.

Because of the increase in convenient fast foods some work was done on the effect of breaded pieces frozen after precooking and reconstituted from the frozen state. Mickelberry and Stadelman (1962) found that cooking chicken meat before freezing resulted in a less tender product with a smaller freezer drip and greater total losses than freezing in the uncooked condition, slow thawing, and subsequent cooking. Mostert and Stadelman (1964) also found frozen cooked parts resulted in lower moisture retention with a higher cooking loss. Parts cooked in the frozen state by deep-fat-fry methods increased absorption of fat.

The use of the microwave oven, because of its convenience, has been studied in regard to batter and breaded products. New batter mixes that give the appearance of being deep-fat fried or prebrowned have been developed for microwave use. Some have used the microwave to precook pieces to be coated later.

Hale and Goodwin (1968) observed that chicken parts cooked in the microwave exuded blood from the bone and inner muscles, being especially noticeable for the thigh and drumstick where both large bones and large muscle masses were present. When cooled, the exudate solidified and detracted from the appearance of the piece. Deep-fat frying was also found to give a better flavor than microwaved chicken. Seeley (1981) found that baking coated drumsticks in a coventional oven resulted in

better coating adhesion and a more appealing product than microwaved drumsticks. Webb (1969) found that steam cooking did resulted in higher cooking losses than microwave cooking.

Deep-fat frying is very popular in food-serving establishments since most homes are not equipped to properly prepare these products. Weis (1970) reported that large pieces of chicken parts coated with batter and breading needed 10 to 15 min. of frying at 132.3°C; 7 to 10 min. at 138°C for small pieces, and 9 to 10 min. at 138°C for small turkey pieces. The Food Service Manual (American Hospital Association, 1972) suggested 8-14 min. at 130.4°C for large pieces and 7-10 min. at 138°C for small pieces of chicken. Deep-fat Frying Procedures (Thorner, 1973) suggested a frying time of 12-15 min. at 122.9°C. Thus, in fried chicken operations, temperatures range from 122.9°C to 138°C and times range from 7 to 15 min.

Yang and Chen (1979) using coated broiler pieces fried in a deep-fat fryer, found cooking yields of fried chicken decreased, with increased frying temperature at the doneness point. Overcooking reduced the yields. Wing parts had higher cooking yields than thigh, breast, or drumsticks. They also found that the weight loss of fried chicken parts, held under heat lamps, was greater than those held in an electric oven at the same holding temperature. Love and Goodwin (1974) cooked poultry parts in the deep-fat frier at three different temperatures and times. The temperatures were 149, 177, and 205°C and as the temperature increased less time was needed for browning the poultry parts. They found weight loss or cooking loss in the fryer parts to rise as the temperature decreased and the browning time increased. At 149°C the % cooking loss was 34.6%, at 177°C, 33.8%, and at 205°C the % cooking loss was reduced to 28.2%.

Mostert and Stadelman (1964) found deep-fat frying resulted in minimum cooking losses and maximum moisture retention. They suggested that minimum cooking losses

in the deep-fat fry methods were partly attributed to absorption of a small amount of fat.

Mostert and Stadelman (1964) found that breading increased fat absorption or retention when cooked by methods were fat was used. That would indicate that the oil or fat used would have pronounced effect on color and flavor of the breading material (Robertson, 1967).

Heath et al., (1971) also showed that cooking oils were absorbed into tissue during deep-fat frying as evidenced by a change in fatty acid composition. They found that cooking oils determined that fatty acid profile of the batter. Oleic and linoleic acids increased in the batter as cooking time increased. The absorbed fat served two useful functions; it tenderized the crust (just as shortening tenderizes pie crust) and caused "wetting" of the fried food (just as butter or margarine wets a piece of toast), both of which enhanced eating enjoyment.

Robertson (1967) described three parts of a deep fried food. Figure 3 represents a cross section of a piece of deep fried food. The inner zone is the moist interior or core consisting wholly of the food being fried. The food is cooked by the transfer of heat from the hot oil. The cooking process may or may not change the nature of the food depending upon the character of the food. Thin deep-fat fried items may not contain the inner zone and become a continuous crust.

The outer zone surface changes to a golden brown color during frying as a result of Maillard reaction. The degree of color development will depend on the composition of the surface of the food and the time and temperature of frying.

The outer zone, or crust, is a crisp exterior skin or shell produced by dehydration of the outer portion of the food as it is fried. This crust is what makes deep frying unique from other methods of cooking. The formation of the crust occurs as heat from the hot fat (above 118°C) drives water from the outer portion of the

fried food. As the moisture content drops to 3% or less the crust forms and the food is considered done.

Frying fat is absorbed by the food into the voids created by the loss of water. Each type of fried food characteristically absorbs a certain amount of the frying fat. For example, shrimp and scallops generally absorb 12-15% frying fat and fish sticks 10-12%.

Yang and Chen (1979) obtained slightly higher yields from chicken parts fried in solid shortening than those fried in liquid shortening.

Landes and Backshear (1971) fried breaded chicken in soybean or peanut oil (and used 1:1 and 1:4 mixtures of soybean-peanut oil) that had been heated for 0, 16, or 32 hr. at 141.8°C. They found that as oil heating time increased, the color and flavor of the breading material deteriorated for those pieces cooked in either soybean oil or the 1:1 combination. For the pure peanut oil and the 1:4 combination, quality of the chicken increased with oil heating time. They suggested that peanut oil may contain some heat labile compounds that inhibit good flavor and color development of breading material fried during the early stages of heating the oil. Their work also indicated that a blend of peanut and soybean oil may produce a fried chicken breading material more stable than either of the pure oils.

Ultrastructure of Poultry Skin

One of the newest areas of research in relation to batter and breading adhesion concerns the ultrastructure of poultry skin. Suderman and Cunningham (1980b) used the scanning electron microscope to study the effects of age, method of chilling, and scald temperature on poultry skin ultrastructure. They theorized that improved batter and breading adhesion would result if it was applied to poultry skin without the cuticle. This could be accomplished by increased scald temperatures where the cuticle is removed. The cuticle has a smooth surface and the next layer, the stratum

germinativum, has a rough pitted surface. Since the bond strength between the coating and a smooth surface should not be as strong as that between the coating and a rough surface a coating should have better adhesion. In addition, Montagna and Lobitz (1964) found the bond between the cuticle and the stratum germinativum to be the weakest bond interface within the skin which could lead to poor coating adhesion if a stronger bond developed between the coating and the cuticle. Figure 4 and 5 illustrates the structure of poultry skin layers and gives a theoretical model of the adhesion of a batter and breading with and without the cuticle.

Chen and Stinson (1979) used the scanning electron microscope to study the ultrastructure of poultry skin after it had been cooked by boiling, baking, or frying. The breast skin boiled in water had a smooth surface with some oozing of either gelatin or fat. Baked broiler skin had a few crater-like structures scattered on the surface which appeared to be caused by entrapped steam under the epidermis. Severe skin surface distortion with numerous crater type structures were observed on fried broiler breast skin. The eruption of vapor seemed to occur instantly and randomly. Baking and frying chicken parts with batter and breading resulted in a mixture of the breading and exudate on the surface. Baked broiler skin had a more compact structure than the fried product.

The rough surface caused by vapor eruptions (along with exudate which generally contains a gel that has a binding effect), aids in adhesion of coatings to fried and baked poultry skin surfaces. Those findings could be valuable when determining a method to precook frozen breaded poultry products.

Some researchers including Suderman and Cunningham (1979b and 1980a) and Seeley (1981) have studied the mineral content of the skin and the muscle of poultry under different processing and cooking conditions. The differences in mineral content have not been shown to correlate with batter and breading adhesion.

Problems Associated with Food Coatings.

Much of the research that has been done to improve batter and breading formulations has, in one way or another, been related to its adhesion to the food being coated. Cunningham and Suderman (1981) defined adhesion as "the chemical and physical binding of a coating, both with itself and with the food product it coats. Partial or total loss of the coating results from anything less than ideal or perfect adhesion." The aesthetic value of a coated food is lost from thinly coated or patchy areas on the product. Economic losses can occur to the processor from product weight loss. Crumb loss during eating can cause consumer rejection. Instances where coating loss can occur are during application, processing, transportation, handling, or consumption (Suderman, 1979).

There are two problems common to coated foods in reference to adhesion; coagulation of the coating to the size of the raw piece of food while the food shrinks away from the coating during cooking, and encapsulation, where the coating adheres more to itself then it does the food piece and peels off in large chunks.

Hanson and Fletcher (1963) discovered that during deep-fat frying, the coating would coagulate rapidly to the size and the shape of the original piece while the chicken itself shrinks away from the coating. To make matters worse, steam formed during heating would tend to force the coagulated coating away from the meat and may rupture it. A loose-fitting coating would result. Early coagulation is affected by coating ingredients and by the dehydration of the outer portion of the food as it is being deep-fat fried.

To alleviate this problem, Hanson and Fletcher (1963) suggested precooking before batter application. They found a 25% weight loss, from the original weight of the chicken parts, but the coating was tight fitting and less susceptible to adhesion problems. Suderman and Cunningham (1977) found precooking chicken parts prior to

coating, with a milk predip, decreased adhesion. Those results indicate that different batters and breadings will act differently on chicken parts during the cooking process.

Hale and Goodwin (1968) compared different precooking methods followed by deep-fat frying and microwaving. No significant differences were noted for batter adhesion characteristics, but panel members indicated that coating texture and hardness were better in precooked products. In a later test, workers compared conventional deep-fat frying, microwave precooking followed by deep-fat frying, and autoclave precooking followed by deep-fat frying. The deep-fat frying method produced coating that adhered significantly less ($P<0.05$) than the coatings on precooked products. The precooked products were judged to be more acceptable, with a better coating texture and hardness of the chicken. The texture of the skin-batter complex was improved ($P<0.05$) by cooling the parts to 2°C, in comparison to 24°C before breading.

Baker et al. (1972a) precooked poultry parts by steaming, simmering, or boiling. After cooking, the parts were predusted, battered, breaded, and deep-fat fried for 45 sec. Those methods produced an attractive product with good adhesion characteristics. Love and Goodwin (1974) found chicken parts breaded prior to steam cooking had better breading pickup and adhesion than those parts breaded after water cooking.

Hanson and Fletcher (1963) reported that egg content in their batter had little effect upon adhesion, but the coating toughened as egg content increased. The also found by using combinations of different thickening agents rather than just one, they acheived such desirable attributes as adhesive qualities, thickness, crispness, and an overall better appearance. A 2:1 coating of corn starch and waxy corn flour, with a solid-moisture ratio of 1:0.85 exhibited good adhesion. A solids-water ratio of 1:0.70

produced a thicker coating but it peeled off more easily. A mixture of equal parts of corn starch, waxy corn starch, and yellow corn flour also appeared to have good adhesive properties.

Predust materials are now commonly used to increase adhesion and pick-up on coated products. Baker et al., (1972b) compared 15 predust materials and found that protein materials generally produced better crust and improved adhesion more than did starches or gums. Of the proteins tested dried egg albumen produced the best results on the basis of visual scores, with wheat gluten a close second. The other scores were not significantly lower. The amount of predust pickup averaged less for the protein materials, about 1.5% for albumen, gluten and soy concentrate, than for starches which had an average pickup of 2.5%. Gums were intermediate. Batter coating adhered to wings better than to other pieces, probably because of the larger surface area and particular shape.

A wide variety of materials have been used to increase or influence adhesion. Sison (1972) found adhesion increased on chicken parts soaked in a polyphosphate solution overnight. He also found breadings to have better adhesion and be more suitable for chicken as a coating than batters. Schnell (1976) found single cell protein (SCP) saturated with vegetable oil increased adhesion and added structure and resilence to breadings and fillers. A patent (Fruin, 1973) described a batter starch which included an oxidizing agent, such as calcium hypochlorite, which caused bread crumbs to adhere to a frozen food product. Many other materials have been suggested as binding agents including modified starch, comminuted fish flesh (King et al., 1974), malto dextrins, sodium alginate, calcium chloride, and cellulose gums (CMC) (McCormick, 1975).

The other problem common with batters and breadings is encapsulation, where the coating peels off in large pieces. Hanson and Fletcher (1963) tried to overcome

this problem by manipulating coating ingredients. They found that batter thickening agents, egg content, and solids-water ratios influenced adhesive qualities, toughness, crispness, elasticity, smoothness, handling characteristics, and thickness of coatings on frozen fried chicken. They discovered that thicker coatings peeled more readily than thin ones. Coatings made from wheat, corn, waxy rice, or waxy corn flour as the thickening agent peeled more easily than those containing waxy flour or corn starch. Waxy cereal coatings were more elastic and less tough than those made from the common cereals and tended to peel in pieces, whereas coatings prepared from wheat flour were so strong that when peeling started, the entire coating peeled off intact. Zwiercan (1974) found that going from a low gluten flour to a high gluten flour gave the strength and tough film properties needed for a crisp fish coating.

Adhesion Measurement

There have been different methods described in the literature for measuring adhesion of coating. Most of the tests have been qualitative and not quantitative.

The earliest method reported applied to frozen, fried fish sticks. The U.S. Grade Standards of the U.S. Department of the Interior (1963) published a numerical system for grading defects. The defects recognized were: breaks - objectional bare spots in the coating through which the fish flesh is plainly visible; blisters - swellings of the coating during cooking that have burst, exposing areas of fish flesh; ridges - projections of excess breading along the edges of the fish stick; lumps - objectionable outcroppings of breading on the stick surface, and curd - white coagulated albumen found in crater-like holes in the breading. Each instance of a defect is measured in grid squared of a plastic 1/4 inch grid. A full or partial grid containing a defect is considered to be an instance. For example, a coating defect area of 1 1/2 grid squares is regarded as two instances. Up to two instances of coating defects per stick is considered to be minor, and one point is assessed for

each stick so affected. Four or more instances on a fish portion is considered to be a major degree of coating defect, and three points are assessed for each stick of like quality.

Other subjective tests have used taste panel systems. Baker et al. (1972b) had 10 judges score adhesion of coating on chicken using a scale of nine to one. Nine denoted perfect adhesion and one denoted no adhesion. Hale and Goodwin (1968) used an eight-member panel that scored coated chicken for color, adhesion of batter, texture of coating, and hardness.

In preparing battered and breaded poultry products, the batter and breading content of the finished product is limited to 30% of the finished product weight (U.S.D.A., 1973). Within the plant this limit can be controlled by weighing the product before and after the batter and breading are applied. But once the product has left the plant a system is needed to determine breading adhesion.

May et al. (1969) estimated breading content by weighing the breaded piece and submerging it in a pail of water and running compressed air through the pail for agitation. Agitation was continued for 15 min. (45 min. for fried chicken) then the air was turned off. Any breading still adhering to the product was rubbed off by hand and vigorously shaken in the water and then removed and placed between sheets of paper toweling for 2 min. The unbreaded weight was recorded and the percentage was calculated as follows:

$$\% \text{ breading} = \frac{\text{breaded weight - weight after breading removal}}{\text{breaded weight}} \times 100$$

This method of estimation was successful for estimating percentage breading on precooked battered and breaded chicken parts, battered and breaded fried chicken parts, and precooked battered and breaded fillet-style chicken, but was not suitable for use on the raw cutlet-style chicken or battered and breaded steam cooked

chicken. The raw cutlet style chicken was made from ground particles of chicken, which separated during agitation. Failure of the steam cooked chicken was due to the insoluble nature of the batter and breading.

The most recent method developed was designed to measure the adhesion of a coating from a quality control point of view, simulating the mechanical jarring that takes place from processing to consumption. The method, as developed by Suderman and Cunningham (1979a), takes only one minute. In this process a breaded product, such as a piece of chicken, is placed on a standard wire sieve in a portable sieve shaker, as illustrated in Figure 6. The shaker is activated for one minute, after which the bread crumb weight can be calculated from the weight difference in the breaded product. An automatic top-loading balance is suitable for quick accurate measurements. The percent breading loss is based on the predip and breading pickup weight. The breading loss percentage can be calculated as follows:

$$\% \text{ breading loss} = \frac{\text{breading crumb weight}}{\text{drumstick weight with predip and breading} - \text{towel dried drumstick weight ("dry" weight).}} \times 100$$

The value for "wet" weight can be calculated by dividing the breadcrumb loss by the weight of breading adhering to a control product or drumstick after cooking and then multipling by 100. For satisfactory adhesion, 85% of the coating should remain on the breaded piece after 60 sec. of shaking. This method was used by Suderman (1979) to compare adhesion of breading on poultry parts under various conditions, such as comparing predips of different protein sources gums, and the shelf life stability of poultry.

Conclusion

The batter and breading industry is extensive and increasing, with the frozen food industry marketing 1855.7 million pounds of frozen coated products using 581.1 million pounds of breading (Anonymous, 1981). Batters and breadings are value-adding

ingredients to the processor while removing the monotony from some meats and vegetables for the consumer. Coatings enhance food taste, color, juiciness, crispness, texture, and acceptability (Suderman, 1979). There are many ingredients used in batters and breadings in various combinations. Coatings are affected not only by the ingredients but by the water-solids ratio of the batter, coating procedure, cooking methods, and times (Hanson and Fletcher, 1963). The adhesion of batter and breading is important not only from an aesthetic point of view but from an economical standpoint; therefore, much work has been done to improve adhesion while retaining the quality of the batter and breading. The two major coating defects are: when the food piece shrinks away from the coagulated batter and breading, and encapsulation, where the coating peels off in large chunks. To reduce these problems, precooking, and various batter and breading ingredients are used. As consumers taste and styles change, new products, different batter and breading formulations, and the adhesion problems associated, will all need to be studied as the market grows and expands for coated food items.

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Figure 1. A diagram of the four basic types of coating systems that duplicate traditional methods of preparing products manually (Johnson, 1979).

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

THIS IS AS RECEIVED FROM CUSTOMER.

COATING CHART

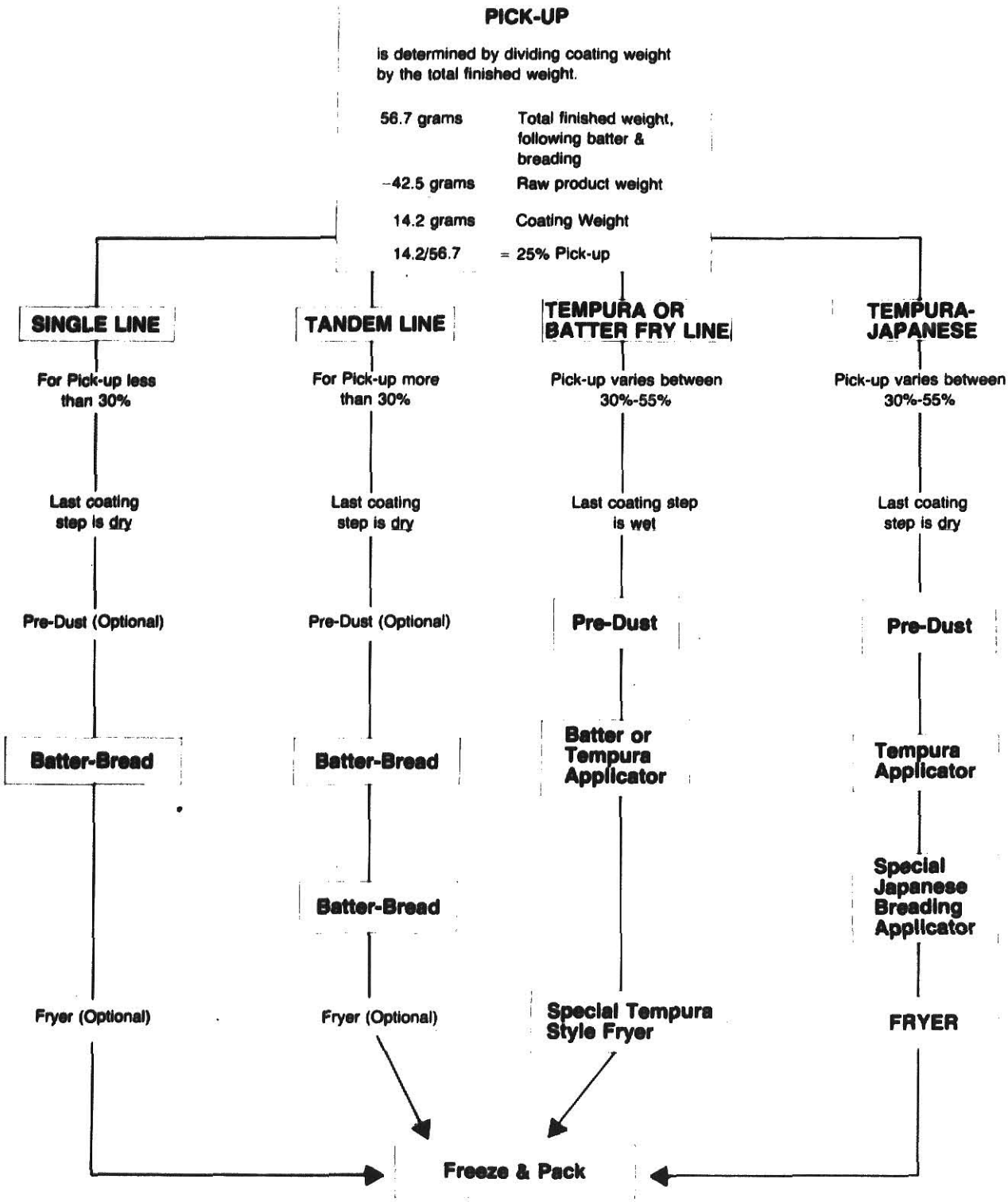
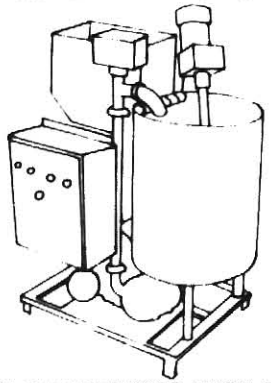
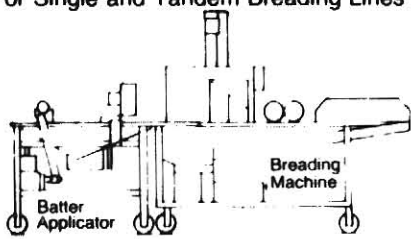
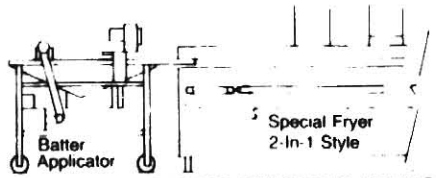
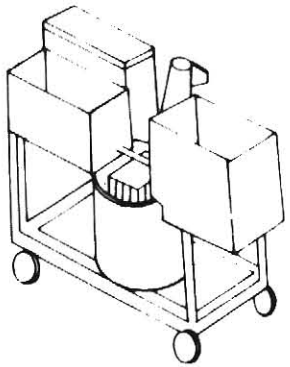
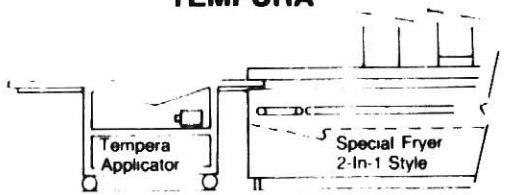
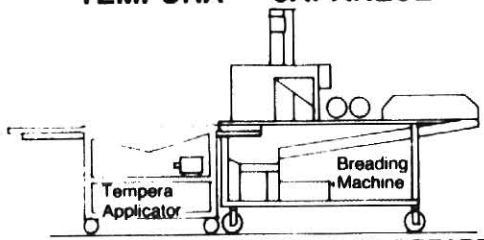


Diagram shows the four basic types of coating systems that duplicate traditional methods of preparing products manually.

Figure 2. Batter and breading application chart for equipment differences between conventional and wet batter systems (Johnson, 1979).

BATTER APPLICATOR CHART

BATTER PREPARATION	CATEGORY — APPLICATORS	MACHINE CHARACTERISTICS
VISCOSITY MACHINE DESIGNED TO AUTOMATICALLY CONTROL THE THICKNESS OF BATTERS FOR CONSISTENT PICK-UP.  UNIT CAN BE USED WITH EITHER CONVENTIONAL OR BATTER-FRY APPLICATORS.	**CONVENTIONAL** For Single and Tandem Breading Lines  BATTER APPLICATOR PRIOR TO BREADING UNIT	Batter is *pumpable*, recirculated in the system. Product travels through batter curtain for uniform coverage. Pick-up of dry coating material primarily dependent on thickness of batter. Once the proper ratio is determined, it should be maintained.
	BATTER-FRY  BATTER APPLICATOR PRIOR TO FRYER	Product transfer to Breading Machine is level. Transfer to fryer is by moving it into the oil prior to touching conveyor belt.
TEMPURA BATTER MIXER MIXES AND TRANSFERS WIDE RANGE OF LEAVENED AND HEAVY BATTER.  UNIT CAN BE USED WITH EITHER TEMPURA OR TEMPURA-JAPANESE APPLICATORS.	**TEMPURA**  TEMPURA BATTER APPLICATOR PRIOR TO FRYER	TEMPURA BATTER IS LEAVENED, cannot be pumped. Product is coated by being totally submerged in the batter. Top submerger prevents product from floating.
	TEMPURA — JAPANESE  TEMPURA APPLICATOR PRIOR TO BREADER	Transfer of product is via a unique device into a special fryer or breading machine.

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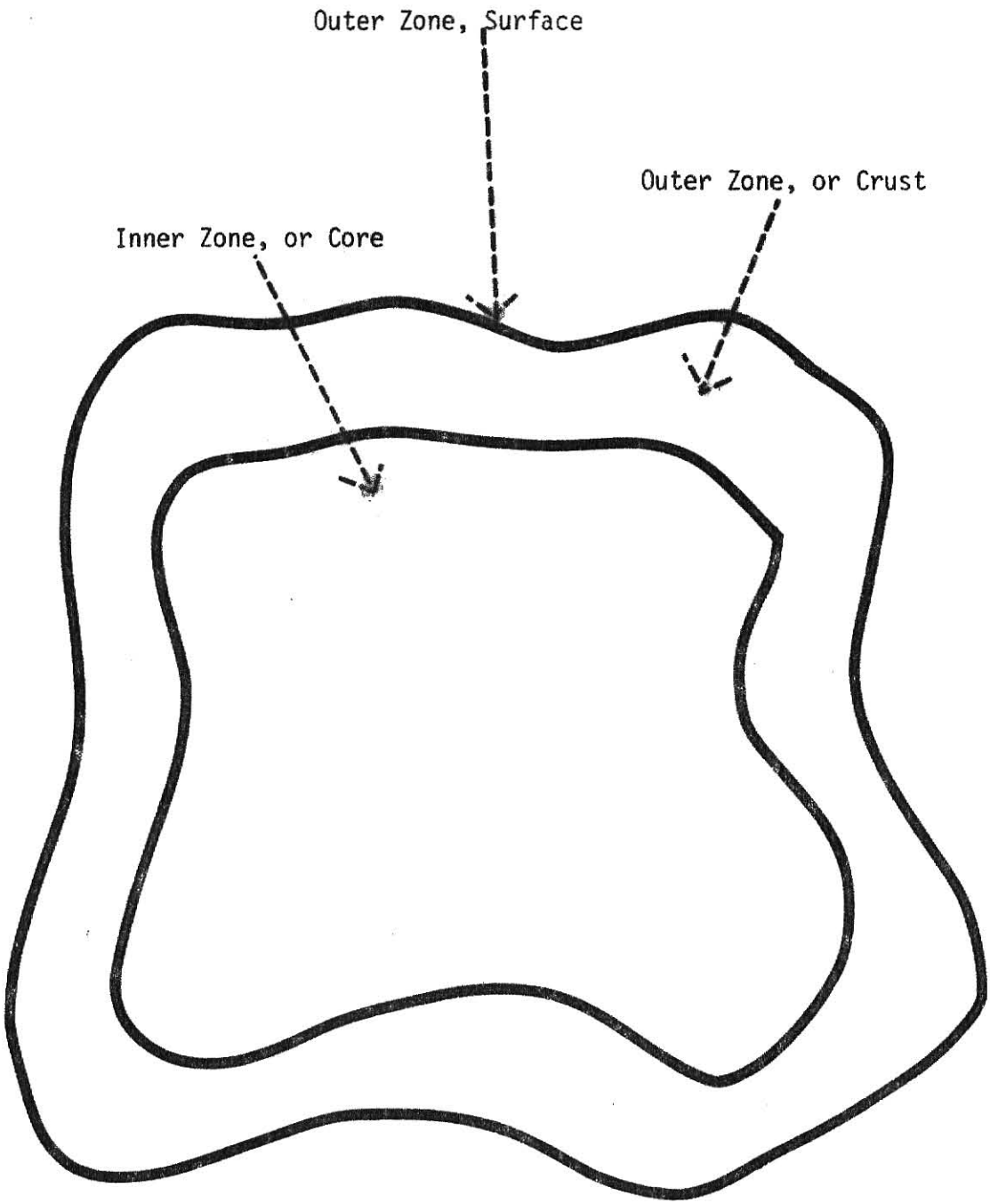

Figure 3: Basic structure of deep-fried foods (Robertson, 1967).

Figure 4. Theoretical model of physical adhesion of breading to poultry skin without the cuticle. The model features are (A) dermis, (B) stratum germinativum, (D) coating matrix, (e) coating ground substance, (f) coating particles, (g) primary binding forces, and (e) secondary binding forces. (Suderman and Cunningham, 1980)

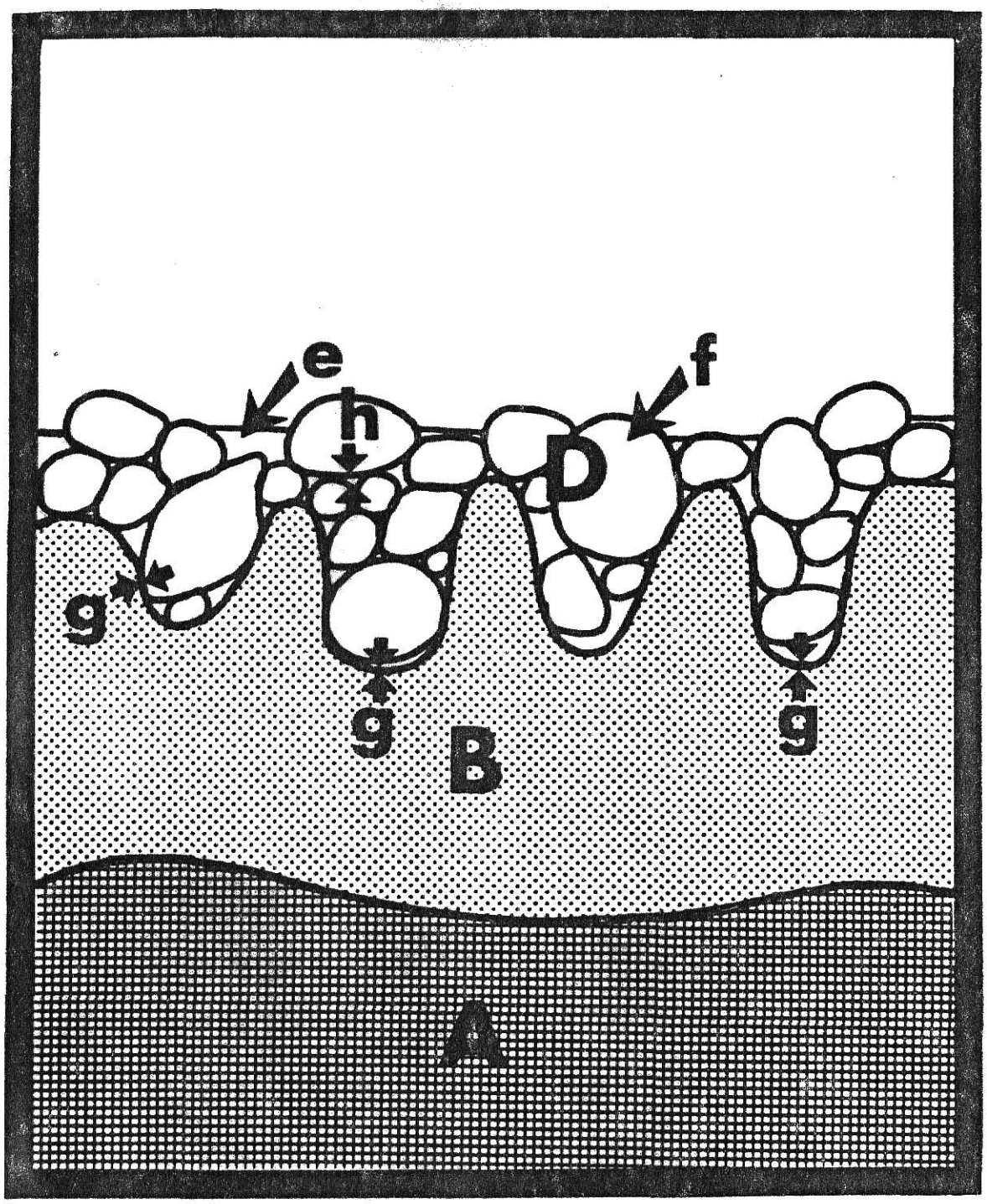
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Figure 5. Theoretical model of physical adhesion of breading to poultry skin with cuticle. The model features are (A) dermis, (B) stratum germinativum, (C) stratum corneum (cuticle), (D) coating matrix, (e) coating ground substance, (f) coating particles, (g) primary binding forces, and (h) secondary binding forces. (Suderman and Cunningham, 1980)

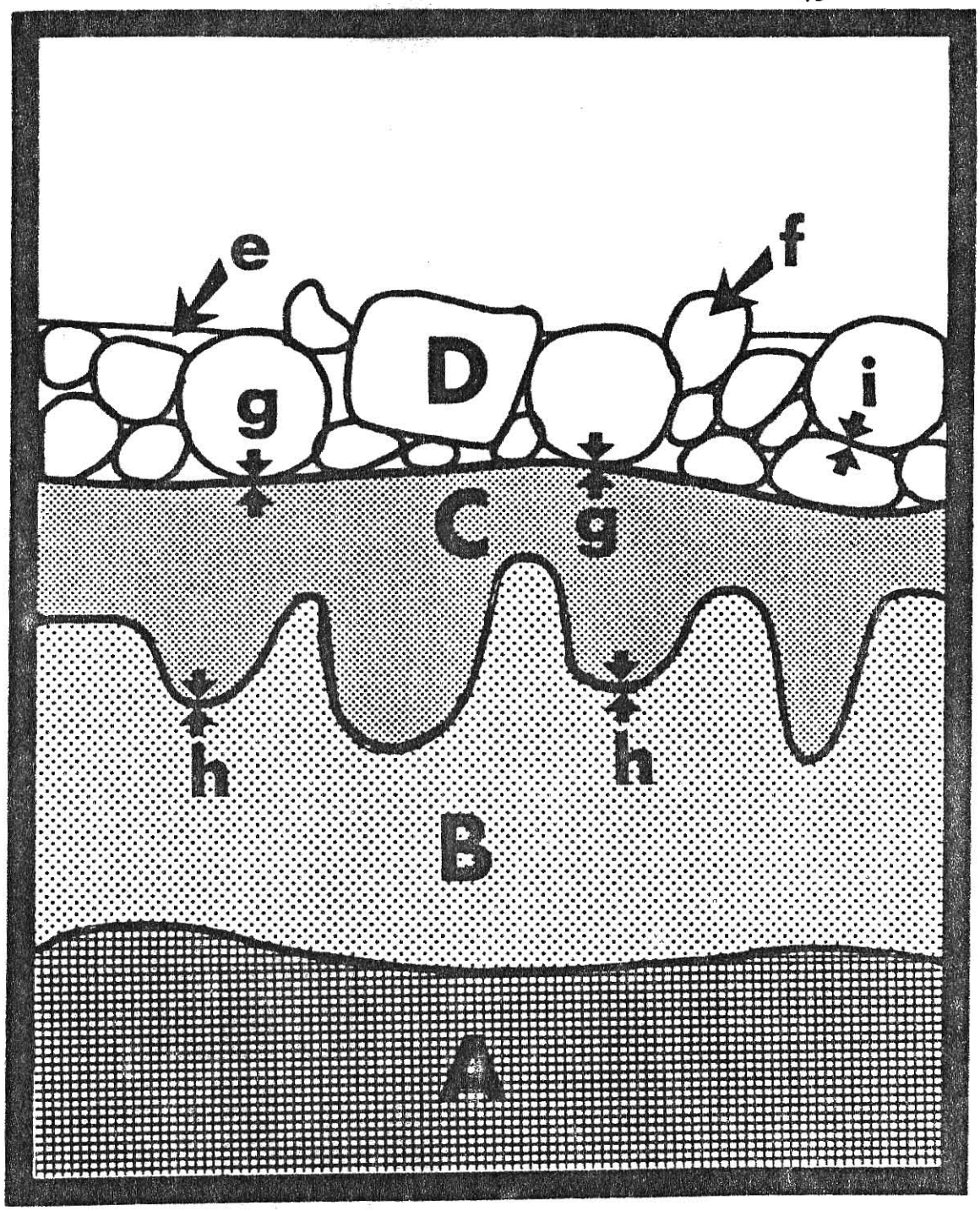
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Figure 6. Automatic sieve shaker used to measure adhesion of breading to food products.

Composition of Broiler Meat as Influenced by Cooking Methods and Coating.

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ABSTRACT

Forty broiler breasts and thighs were cooked, coated or uncoated, by five different cooking methods, including panfrying, baking, broiling, deepfat frying, and microwave treatment, to determine the effect upon moisture, protein, crude fat, and mineral content of the white and dark meat. Cooking methods resulted in increased cooking losses as follows: baking< broiling< microwaving< panfrying < pressurized deepfat frying. The presence of a food coating greatly reduced moisture loss. More moisture was retained in the poultry meat after broiling, baking, and panfrying than in microwave treatment and deepfat frying. Furthermore, there was more moisture in breasts than thighs after cooking. Protein was highest in breasts, in coated rather than uncoated meat, and in parts cooked by microwave treatment, deepfat frying, and panfrying, than in baking and broiling. Crude fat was higher in uncoated thigh meat, cooked by deepfat frying, but the differences in cooking methods were not significant. Higher concentrations of minerals were found in poultry after microwave treatment and in uncoated rather than coated meat. This may have been due to less loss of fat soluble minerals, since more crude fat was retained during microwaving and in uncoated meat. Those minerals tested that were affected by cooking methods included Fe, Mg, Na, and Zn. Those not affected by cooking methods included Ca, P, K, S, Cu, and Mn.

INTRODUCTION

The nutritional value of poultry meat is affected by many factors before it reaches the consumer to be cooked and served. Nutritional composition of chicken is influenced by the region where the birds are grown, strain, and sex (Hamm et al.,1980), the type and composition of feeds, and other production and processing factors (Mickelberry et al., 1966; Marion and Woodruff, 1963).

Broilers or fryers are normally marketed at seven to eight weeks of age; whereas very young birds are marketed as Rock Cornish Game hens at 4 wks. of age. Twining et al. (1978) found that 28-day old birds had statistically significant less protein and fat but higher moisture than 59-day old birds. Goodwin and Simpson (1973) found a higher moisture content and a lower fat content in Rock Cornish hens than in older broilers, while the amount of protein was approximately the same. Kravis and Morley (1960) found that potassium (K) and sodium (Na) increased in meat from birds up to five weeks of age, but remained constant in older birds. Helander (1966) believed that the concentration of K, magnesium (Mg), and phosphorous (P) decreased with age of birds, and that the concentration of Na, chlorine (Cl), and calcium (Ca) increased. However, almost all polyvalent metals accumulate on aging, particularly in the aorta, but also in other organs in close contact with blood circulation according to Vavak et al. (1976). Edwards and Denman (1975), and Twining et al. (1978), reported that male broiler carcasses were significantly higher in moisture and protein but lower in fat than female broilers. Ash values were approximately the same. Edwards and Denman (1975) and other workers also found that body compositions varied among breeds of chicken, with certain breeds having consistently higher nutritional values than others. Hamm et al. (1980) found that the region where the bird was grown affected composition significantly, even within the same breed. Region influenced levels of all minerals significantly, except phosphorous in both breast and thigh flesh.

There are also changes that occur during commercial processing as reviewed by Demby and Cunningham (1980). Many of the nutrients present in chicken meat, water soluble vitamins, and minerals are susceptible to loss or destruction during cooking. Cooking methods affect nutrient retention differently.

1. Boiling or stewing: a moist type of heat cookery usually applied to older, tougher birds. Hwang et al. (1975) reported increased fat, protein, and energy content, but reduced moisture and ash in stewed chicken, compared to the raw bird. Cooking losses of 16 and 25% were reported by Ragnewd (1972) and Matthews and Garrison (1975), respectively. The biggest problem associated with stewing is the leaching of water soluble vitamins and minerals. Hewston et al. (1948) listed ash losses of over 50% after stewing, with 45.4% loss of P and 30.8% loss of iron (Fe). Posati (1978) found significant reduction in various minerals during stewing. Seiler et al. (1977) reported losses of 40- 50% in Na, K, Mg, and cobalt (Co) after stewing.

2. Roasting or baking: a dry type of heat cookery, which can be especially deterimental to nutrients if overcooking occurs, due to high temperatures and over-extended cooking times. Matthews and Garrison (1975) found an average cooking loss of 29% for broilers roasted to 123.3°C internally. Mickelberry and Stadelman (1962) used the following combinations to study cooking losses: microwave, deepfat fry, deepfat fry and microwave combined, rotary-reel oven, steam and deepfat fry combined. The lowest cooking loss was obtained in the rotary reel oven. Loss of minerals from broiler meat during roasting at 220°C was 30- 40% for Na, K, and Mg, but was less (3- 12%) for copper (Cu) and zinc (Zn), according to Seiler et al. (1977). Nutrient loss during roasting or baking can be reduced by using lower cooking temperatures or shorter cooking times.

3. Microwave: Many researchers (Harris and Karmas, 1975; Lorenz, 1976) have reported little difference in nutritional values of foods cooked by microwave versus conventional methods, but many other reports have found conflicting results (Cross

and Fung, 1982). The majority of the reports indicate microwave cooking results in less loss of nutrients.

Cooking losses were compared by Wing and Alexander (1972) for chicken cooked by microwave or conventional oven roasting. They found microwave treatment resulted in higher moisture losses, but less drip than in roasting. Cunningham and Lee (1975) compared cooking losses of broilers cooked by oven roasting, microwave, panfrying, and deepfat frying. Losses were 21.6%, 23.6%, 37.2%, and 40.5%, respectively, indicating that microwave cooking gave significantly less cooking losses than frying, but more than roasting.

Lorenz (1976) found microwave cooking resulted in less protein denaturation, possibly because of less drip loss due to faster cooking times. Microwave energy was believed to be too low in frequency to cause chemical changes due to direct interaction of molecules and chemical bonds (Rosen, 1972).

4. Frying methods: Standard pan frying, deepfat frying, and pressurized frying (broasting) are the methods commonly employed to fry chicken. The first two are most commonly used in the home, and the last two are used commercially (Demby and Cunningham, 1980).

Little research has been done on mineral losses during frying, but much research has been done on cooking yields during frying. Smith and Vail (1963) found skillet frying gave a higher cooked yield than deepfat or oven frying. Mickelberry and Stadelman (1962) reported that cooking methods involving the deepfat fryer resulted in higher cooking losses. They used, singly and in combinations, deepfat frying, microwaving, steaming and baking, and cooking in a rotary reel oven. They explained that the higher cooking losses were because liquid is a better heat-transfer medium than air. Heat penetrates rapidly and internal temperatures rise uniformly, causing the collagen to convert to gelatin and the fat to exude as cooking loss. Yang and Chen (1979) found that cooking yields of deepfat fried chicken decreased at the doneness

point with an increase in frying temperature. Overcooking reduced yields. Mostert and Stadelman (1964) found that pressurized deepfat frying resulted in minimum cooking losses and maximum moisture retention, partly due to the absorption of a small amount of fat.

Different poultry parts vary in composition and yields. Smith and Vail (1963) found the breast and thigh to yield the highest percentage of meat and the wing the lowest. Deepfat fried birds contained the highest percentage of fat, with the back, ribs, and heart containing higher percentages of fat and the breast containing the lowest. Love and Goodwin (1974) found drumsticks and wings to have the highest final yield in deepfat frying and thighs to have the lowest yield. Stadelman (1978) reported cooked wing, breast, leg, and thigh meat to rank highest in percent moisture. He found that moisture loss affected the size of the part and that changes in fat content compensated for changes in moisture. The mean protein content of the breast and thigh was 32.6% and 29.4%, respectively.

USDA handbook No. 8-5 (U.S. Dept. of Ag., 1979) lists mineral content for raw chicken and the effects of cooking on minerals. One of the most abundant minerals that is also very important nutritionally is P. Raw breast and thigh meat contained 196 and 168mg/100g, respectively. One hundred grams of broiler breast meat supply between 24.9 and 30.6% of the RDA for an average 19 to 22 year-old male. Thigh meat, being slightly lower in P than breast meat, supplies 20.4-22.9% of the RDA (Hamm et al., 1980).

Nutrient losses are often caused by moisture losses and high cooking temperatures. Love and Goodwin (1974) showed that food coatings were a moisture barrier. Morgan (1971) found coatings enhanced food appearance, reinforced food structure, excluded oxygen from the food product, and extended shelflife. Breading increased tenderness and increased fat absorption when meat was cooked by methods where fat was used (Mostert and Stadelman, 1964).

These experiments using broilers were designed to determine the effects of different cooking methods, the presence of a food coating, and type of meat, (light or dark), on cooking losses and nutritional qualities such as moisture, protein, fat, and mineral retention.

MATERIALS AND METHODS

Broiler breasts (light meat) and thighs (dark meat) were used throughout this experiment. Packages of breasts and thighs were purchased from a local supermarket and used the same day. The pieces were divided into two groups, those that were coated with batter and breading before being cooked, and those that were cooked without coating. Twenty thighs and 20 breasts were used for each variable. The breast and thigh meat was cooked by one of five different cooking methods: panfried, baked, broiled, deepfat fried, or microwaved. Two thighs coated and two thighs uncoated, along with two breasts coated and two breasts uncoated, were used in each of the five cooking methods. Data were collected to determine breading and batter pickup and cooking loss.

Following the last weighing, the coating and/or skin was removed from each piece and the meat separated manually from the bone. The meat was ground in an Oster electric food grinder using a 5mm grid. The sample was ground twice to insure uniform mixing and small particle sizes. All utensils and the meat grinder were washed and dried between each sample. The meat was placed quickly in a small plastic bag and frozen until analyzed. Each sample was analyzed for moisture, dry matter, crude protein, crude fat, Ca, P, Mg, K, sulfur (S), Fe, Cu, Zn, manganese (Mn), and Na. Analysis of variance was performed on the data to determine significant differences ($P<.05$).

Batter and breading procedure: Each breast or thigh was individually coated as follows: The part was immersed in a whole milk predip for 10 seconds; placed in a 10" by 10" plastic bag containing 70 grams of breading mix and shaken for 10 seconds. The

breading mix was composed of the following ingredients: wheat flour, partially hydrogenated soybean, cottonseed and palm oils, salt, malted barley, sugar, spices, paprika, yeast, cornstarch, dried garlic, monosodium glutamate (flavor enhancer), natural hickory smoke flavor, artificial color, and dried onion.

Cooking methods: Panfrying - Two breasts and two thighs were placed in a electric skillet (Sunbeam) in 6.35mm of oil (Crisco). The pieces were browned with the lid off at 160°C for 10 minutes, and turned once. The heat was reduced, the chicken was simmered for 30 minutes with the lid on, and turned two or three times. The heat was increased again to 160°C for 5 minutes with the lid off to crisp the coating.

Low Pressure Deepfat Frying - An electric low pressure deepfat fryer (Presto) was used to prepare deepfat fried chicken. 1.419 l of oil (Crisco) was heated to 204.5°C and 0.6 kg. to 0.8 kg. of breasts and thighs were pressure cooked at 5psi for 15 minutes according to manufacturer's instructions.

Baked - Two breasts and two thighs were placed on metal cooling racks over a cookie sheet to facilitate draining and an even heat distribution to the poultry parts. A commercial sized Partlow oven (National Mfg. Co., Lincoln, Nebraska) was preheated to 204.5°C and the breasts and thighs were baked for 40 minutes.

Microwave- Two breasts, or two thighs were placed in a 1 1/2 qt. Corning Ware dish. They were cooked in a Sharp Carousel Browning Oven (R-8200,2450 MHz) on full power for 9 minutes; 6 minutes on one side and 3 on the other.

Broiled - Two breasts or two thighs were placed on cooling racks over a cookie sheet. The pieces were placed seven inches from the broiling element of a Kenmore Continuous Cleaning Oven, and broiled for nine minutes on each side.

Analytical Procedures:

Moisture - Samples were weighed with an analytical balance and dried in a forced air oven at 70°C for 12 hours.

Crude Protein- Samples were weighed and digested on an 'as is' basis by the standard Kjeldahl digestion procedure for total nitrogen using mercuric oxide as the catalyst in potassium sulfate and sulfuric acid. After digestion, the ammonia was distilled and captured in boric acid and titrated to determine ammonia content and then crude protein was calculated.

Crude Fat - Crude fat was extracted by the Rafatec system manufactured by Tecator, Inc. The sample (as is) was tared into a thimble, mixed with sand, and dried in a forced air oven at 70°C for 12 hours. The thimble was submerged in 50 ml. of anhydrous ethyl ether in a tared collection flask. The sample was refluxed in boiling ethyl ether for 15 minutes and then suspended above the boiling ether and refluxed for an additional 20 minutes. The ether was evaporated from the flask, and the flask dried in a forced air oven for 5 minutes at 100°C. After cooling, the flask was weighed and the percent fat determined.

Sulfur - Sulfur was analyzed according to a method developed by Chaudry and Cornfield (1966). Samples were analyzed on an 'as is' basis using approximately 300 mg. Sulfate was determined in the water extract using the Bausch and Lomb barium sulfate turbidity test kit.

Minerals - Approximately 500 mg. of sample (as is) was wet digested in nitric acid and perchloric acid. The digest was taken to 50 ml. and filtered. The sample solutions and standard solution (containing all elements in approximate concentration to samples) were buffered with .45% lithium and analyzed by Direct-Current Argon Plasma Emission Spectrophotometry.

RESULTS AND DISCUSSION

The 20 thighs had a percentage average breading pickup of 10.2%. The 20 breasts averaged 10.3% breading pickup. The overall mean for both thigh and breast breading pickup was 10.3%. The weight gain was determined by dividing the weight of the coated part by the towel dried weight of the uncoated poultry part, multiplied by 100.

Cooking losses.

In Table 1 the cooking losses of parts with and without coating and of parts cooked by different methods are summarized. The use of a batter and breading greatly reduced cooking loss, regardless of the cooking methods or type of meat. Table 1 lists the cooking methods in the order of percentage cooking loss. Baking gave the least cooking loss, followed by broiling, microwaving, panfrying, and pressurized deepfat frying. Frying caused the highest percent cooking loss for both breast and thighs. Thigh meat tended to have greater cooking loss than breast meat, probably because thigh meat contained more moisture and fat than breast meat initially (U.S.D.A., 1979).

Baking and broiling are dry cooking methods where the coating and skin usually coalesce and dry to form a layer impermeable to moisture, holding cooking losses down. Panfrying and deepfat frying require contact of the poultry part with the cooking medium or the oil, which leaves a porous skin and coating, allowing some moisture out and some cooking oil in. However, more weight is lost by moisture removal than is gained by oil absorption. In microwaving, which resulted in intermediate percent cooking loss, the skin-coating-collagen complex does seem to form, but since the cooking is so quick, the escaping moisture from the broiler flesh prevents dehydration of the coating. During microwaving, the poultry parts remained in contact with the cooking drip, which also contributed to the porousness of the skin-coating complex, whereas in baking or broiling, the poultry part was separated from its cooking loss.

Mineral analysis.

Table 2 summarizes the composition of the combined light and dark meat as cooked by different methods. The underlined values are the highest found for that particular nutrient. Broiled meat contained the highest percent moisture at 69.08%, but this was not significantly different from panfryed or baked poultry parts. At the

5% level of significance, broiling gave a poultry part higher in percent moisture than did deepfat frying or microwaving.

Crude protein was significantly higher in meat cooked by microwaving, deepfat frying, and panfrying, than in meat cooked by baking or broiling. Probably the localization of the dry heat caused greater protein denaturation than in cooking methods where the poultry part was in contact with the cooking medium and the heat was more evenly distributed throughout the poultry part.

No significant differences were found among cooking methods for the amount of crude fat, Ca, P, K, S, Cu, or Mn remaining in the meat. Although differences were not significant, more minerals were generally found after microwaving than after cooking by other methods. The shorter heating time seemed to retain more nutrients.

Mg was retained in the meat better by microwaving and deepfat frying than by panfrying or baking. Fe was higher in breasts and thighs after microwaving and deepfat frying. Zn was most abundant in meat following microwaving. Broiling was the most destructive method of cooking for both Fe and Zn. More Na was retained during microwaving and baking than during other methods of cooking.

Table 3 summarizes the analysis of variance of cooking method, type of meat and coating presence on the composition of broiler meat.

Moisture retention in meat was significantly affected at the 5% level by the presence or absence of a coating. Thighs had a cooked moisture level of 62.8% and breasts had 67.0% moisture after cooking. Although thigh meat had a higher moisture content than breast before cooking, after cooking the breast meat was higher in moisture. According to the U.S.D.A. (1979), raw thigh meat has 75.76% moisture and breast meat 74.76% moisture. After frying, thigh and breast meat contains 59.39% and 60.21% moisture respectively, and after roasting, 62.87% and 65.26% moisture. Therefore, the results of this experiment agree with those previously found.

Protein was affected by the cooking method, the type of meat, and by the presence or absence of a coating. More protein was found in breast meat than thigh meat, and on a dry basis more protein was found in coated meat than in uncoated . These data agree with previous reports (U.S.D.A., 1979).

Crude fat was significantly dependent on the type of meat and the presence of a coating, but not by the cooking method. Crude fat was much higher in thighs than in breasts, and those pieces cooked without a coating tended to retain more fat in the muscle, especially in those cooking methods where oil was used.

Retention of Ca and P was affected by the presence or absence of a coating but not by the type of meat or cooking method. There tended to be more retention in uncoated pieces. The presence of a food coating significantly affected Mg retention (at the .0001 level). Cooking methods also significantly affected Mg content, as shown in Table 2. K and S were very stable and were unaffected by any of the three parameters. Fe on the other hand was unstable, and was dependent not only on the cooking method, but on the type of meat and presence of coating. More Fe was found in the thigh meat than the breast meat. The values were 35.0ppm and 19.5ppm respectively, averaged for the different cooking methods. More Fe was found in the uncoated meat than in the coated meat. The average Fe for parts cooked with coating was 21.5ppm and for parts without a coating was 32.9ppm. The data were consistent on this point. The fact that several minerals have been found to be higher in uncoated pieces may be because these minerals are fat soluble and are lost in the fat that cooks out of the chicken. In all cases crude fat content of uncoated pieces was higher than those coated. This may also explain why microwaved pieces seemed to retain more minerals. Microwaved poultry parts were cooked in their own juices, without being on a rack for drainage, and without being exposed to any extra fat or oil, which would dilute the cooking losses. This resulted in microwaved parts containing a higher fat content and retaining the minerals.

Cu was significantly affected by the type of meat, with thighs containing more Cu than did breasts. More Zn was found in thigh meat than breast meat (P=.0003), and more was found in uncoated than in coated poultry pieces. Mn was more prevalent in thigh than breast meat. Na was significantly affected by cooking method, type of meat, and coating. Na was found in higher concentrations in thighs than breasts. More Na was found in poultry pieces that had been coated rather than those uncoated. This may have been due to the absorption of some of the salt used in the breading.

CONCLUSION

Cooking losses were greater in thigh meat than breast meat, and the presence of a coating significantly reduced cooking losses for all five cooking methods used. The cooking method resulted in increased weight losses as follows: baking< broiling< microwaving< panfrying< pressurized deepfat frying. More moisture was retained in both thigh and breast meat during broiling, but it was not significantly different from that retained during baking or panfrying. More protein was found in breast meat than thigh meat after cooking and in coated rather than uncoated pieces. More protein was retained after microwaving, deepfat frying, and panfrying than after baking and broiling. More crude fat was found in thighs than breasts, and in uncoated rather than coated pieces. More minerals were retained during microwave cooking than during other methods of cooking. Some minerals were retained better in uncoated meat than coated meat, including Fe, Mg, Ca, P, Zn. This may have been due to the minerals being fat soluble, and therefore lost in fat cooked out of the chicken. Since uncoated pieces retained more fat than coated pieces, this could explain why more minerals were lost in coated poultry parts. It also helps explain why microwaved parts retained more minerals than pieces cooked by other methods, because during microwave cooking the pieces were cooked in their own fat, not on a rack, and with no added

oils. The minerals that seemed most affected by the cooking method were, Fe, Zn, Na, Mg. The nutrients stable during cooking included, Ca, P, K, S, Cu and Mn.

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Table 1. Percent cooking losses of breast and thigh poultry meat after cooking by 5 different cooking methods, with and without a food coating.

With coating

	Thighs	Breast	Average Total*
Baked	17.9	16.9	17.4
Broiled	21.5	21.0	21.3
Microwave	33.6	21.7	27.7
Panfry	30.4	27.8	29.1
Deepfat	36.4	33.2	34.8

*Avg. of 8 determinations

Without coating

	Thighs	Breast	Average Total*
Baked	30.6	23.5	27.1
Broiled	29.5	27.3	28.4
Microwave	52.1	31.4	41.8
Panfry	42.4	38.2	40.3
Deepfat	49.6	45.6	47.6

*Avg. of 4-8 determinations

Table 2. The analysis of variance of the effect of 5 different cooking methods on poultry muscle composition.

	Cooking Method				
Analysis	Panfry	Bake	Broil	Deepfat	Microwave
Moisture (%)	64.69^{abc}	68.42^{ab}	$\underline{69.08}^{a}$	61.64^{bc}	60.79^{c}
Crude Protein	27.77^{a}	24.04^{b}	24.30^{b}	30.20^{a}	$\underline{30.40}^{a}$
Crude Fat (%)	5.67^{a}	5.01^{a}	5.11^{a}	$\underline{6.82}^{a}$	5.84^{a}
Ca(%)	$\underline{0.025}^{a}$	0.023^{a}	0.019^{a}	$\underline{0.025}^{a}$	0.024^{a}
P(%)	0.218^{a}	0.186^{a}	0.203^{a}	0.229^{a}	$\underline{0.230}^{a}$
Mg(%)	0.021^{b}	0.023^{b}	0.025^{ab}	$\underline{0.028}^{a}$	$\underline{0.028}^{a}$
K(%)	0.288^{a}	$\underline{0.901}^{a}$	0.286^{a}	0.288^{a}	0.306^{a}
S(%)	0.293^{a}	0.275^{a}	0.281^{a}	0.315^{a}	$\underline{0.331}^{a}$
Fe(ppm)	26.63^{ab}	24.38^{ab}	16.50^{b}	33.88^{a}	$\underline{34.75}^{a}$
Cu(ppm)	1.50^{a}	1.63^{a}	1.88^{a}	2.00^{a}	$\underline{2.25}^{a}$
Zn(ppm)	10.50^{ab}	17.25^{ab}	16.63^{b}	20.88^{ab}	$\underline{24.25}^{a}$
Mn(ppm)	0.125^{a}	0.250^{a}	0.125^{a}	0.250^{a}	0.625^{a}
Na(%)	0.118^{c}	0.171^{a}	0.155^{ab}	0.131^{bc}	$\underline{0.181}^{a}$

Means with different letters are significant at the 5% level.

Means are the average of 20 values.

Underlined values are the highest within that analysis.

Table 3. The analysis of variance of cooking method, type of meat, and coating presence on composition of broiler meat. The following are the probabilities of getting a greater F value with 15 degrees of freedom.

Analysis	Cooking Method	Type of meat (light or dark)	Coating (with or without)
Moisture	0.0858**	0.0569**	0.0184*
Crude Protein	0.0157*	0.0210*	0.0164*
Crude Fat	0.2804	0.0002*	0.0023*
Ca	0.2797	0.5870	0.0240*
P	0.3276	0.2921	0.0108*
Mg	0.0486	0.6433	0.0001*
K	0.5334	0.5159	0.5586
S	0.4748	0.1616	0.3050
Fe	0.0388*	0.0032*	0.0099*
Cu	0.3047	0.0114*	0.6483*
Zn	0.1603	0.0003*	0.0374*
Mn	0.2482	0.0516**	0.7149
Na	0.0216*	0.0030*	0.0003*

* significantly different at the 5% level.

** significantly different at the 10% level.

Effect of Weight and Temperature of Broiler Drumsticks, and the Absence of Skin, on Batter and Breading Adhesion.

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ABSTRACT

The relationship of the original weight of a broiler drumstick to % coating pickup, % cooking loss, % crumb loss, and % overall yield was studied. No significant correlation was found between size and % coating pickup, but there were significant correlations between the other variables. Correlation between originial weight of a broiler drumstick and cooking loss was highly significant (P=.0001), and the regression equation y = 32.58 - 0.1081x was calculated. Similiarly, the relation between % crumb loss and original weight of a drumstick was highly significant (P=.0001) and the regression equation y = -0.2196 + 0.0207x was calculated. The % overall yield also was dependent upon original weight (P=.0003). The regression equation y = 72.97 + .1010x describes that relationship.

The effect of temperature of broiler drumsticks prior to batter and breading, on % coating pickup, % cooking loss, % crumb loss, and % overall yield was studied. The % coating pickup of drumsticks coated at room temperature (23°C) was not significantly different (P<0.05) from those coated at refrigerator temperatures (4°C), with means of 5.34%, and 5.05%, respectively. Those drumsticks coated at 110°C had a lower % coating pickup, possibly due to a drier skin surface and those coated at -15.5°C had the least coating pickup. Poultry parts frozen before being coated had the highest cooking loss and those coated at 23°C and 4°C had significantly lower % cooking losses of 24.52% and 24.55%, respectively. The % crumb loss of broiler parts coated at 4°C, 23°C, and -15.5°C of 1.72%, 1.52%, and 1.50% was significantly higher than drumsticks coated at 110°C with 1.13% crumb loss, but the drumsticks coated frozen had very little coating pickup in the first place. The % overall yield of drumsticks coated at 23°C (79.30%), and 4°C (78.78%) was significantly higher than those coated at 110°C (76.40%), and those had a significantly higher yield than drumsticks coated at -15.5°C.

The same variables used to study size and temperature effects were used to study differences in broiler drumsticks with and without skin, at 4°C. Broiler drumsticks coated without skin had significantly increased coating pickup and decreased crumb loss over drumsticks with the skin intact. Cooking losses were significantly lower for drumsticks coated with the skin on, but the % overall yields of 77.97% for those without skin, and 78.78% for those with skin were not significantly different.

INTRODUCTION

There are many factors affecting the adhesion of batters and breadings. Cunningham and Tiede (1981) found that as batter viscosity increased, the amount of breading pickup increased, cooking losses decreased, and a 1:2 water:solids ratio was best for breading adhesion.

Other researchers have used various cooking methods to improve batter and breading adhesion. Precooking of poultry parts prior to batter and breading was found useful by Hanson and Fletcher (1963). Mickelberry and Stadelman (1962), Hale and Goodwin (1968), and Baker et al. (1972) all used various precooking methods in conjunction with the popular poultry cooking method, deep-fat frying.

Cooking from the frozen state has the advantages of eliminating the time and bother of thawing, reducing nutritional losses, and eliminating the possibility of spoilage due to improper thawing. Mostert and Stadelman (1964) found that poultry parts cooked from the frozen state resulted in lower moisture retention with higher cooking loss. The frozen raw meat had a lower moisture content than the nonfrozen raw meat.

Suderman and Cunningham (1981) found that freezing drumsticks improved coating adhesion over non-frozen drumsticks, but the difference was not significant. Both groups of drumsticks were at room temperature when battered and breaded.

Hale and Goodwin (1968) found that the breaded yield of poultry parts cooled to 2°C (rather than 24°C) before dredging was significantly higher after microwave and retort precooking. However, the deep-fat-fried parts showed a lower breaded yield when coated at lower temperatures. The deep-fat-fried parts coated at 2°C were very moist compared to those coated at 24°C. It was postulated that drier parts tended to pick up more batter. Cooling the poultry parts to 2°C before dredging improved the texture of the coating.

Seeley (1981) coated broiler drumsticks with a commercial seasoned coating mix, baked them in a conventional oven, cooled the drumsticks to different temperatures, and then shook them on a portable sieve shaker to compare crumb loss between the different cooling temperatures. It was observed that coating adhesion improved as the temperature of the drumstick decreased. Table 1 gives the temperatures used and the mean crumb loss. Cooling the drumsticks to below 15.2°C significantly reduced crumb loss. The decreased crumb loss with decreased temperatures may have been due to the starch fraction. Starch gelatinizes through the combination of heat and moisture, during baking, to form a paste. When the temperature is reduced and the starch cools, it thickens as intermolecular hydrogen bonds form, creating a three-dimensional gel network. Extensive hydrogen bonding (starch retrogradation) among the polysaccharide molecules increases micellar regions, which results in the gel becoming firmer and, in time, causes shrinkage of varying degrees, depending on the number of micellar regions, their size, and their distribution.

It is speculated that as the starch fraction retrogrades, the coating shrinks to the conformation of the drumstick, resulting in better adhesion. Retrogradation occurs rapidly near 0°C, and this may be why those drumsticks cooled to 15.2°C and 10.4°C had significantly improved adhesion (Seeley, 1981).

Suderman et al. (1981) studied the effect of proteins and gum sources in relationship to coating adhesion. Protein sources studied included whey, soy, nonfat dry milk, egg albumen, and gelatin. Gums included sodium carboxymethyl cellulose (CMC), guar, tragacanth, and xanthan. Among the proteins, gelatin and egg albumen were the most effective in improving adhesion and of the gums, only CMC significantly improved adhesion. Increased levels of gums and proteins in the coating did not affect adhesion significantly. Hanson and Fletcher (1963) had previously studied the influence of thickening agents, egg content, and solids-water ratio on batter adhesion. Baker et al. (1972) compared 15 predust materials in an effort to find one that would increase adhesion of crust to chicken parts. They found protein predust materials generally improved adhesion of batter and breaded coatings more than starches or gums. Gums and proteins were combined when Hale and Goodwin (1968) incorporated egg white and hydroxypropyl methyl-l-cellulose (HMC) with batters and reported no significant adhesion differences. Other ingredients that have been used to improve adhesion of coatings have included single-cell protein (Schnell, 1976) and comminuted fish flesh (King et al., 1974).

Not only have researchers tried to improve batter and breading adhesion by manipulating coating ingredients but by studying other factors related to the broiler itself, its composition and method of processing, and various cooking methods. Suderman and Cunningham (1980) studied the effect of age of the bird, method of chilling, and scald temperature on poultry skin ultrastructure. Using the electron microscope to study the changes in poultry skin, they found that age (3, 5, 7 or 9 wks), ice-slush chilling, and nonchilling of broiler carcasses did not change the appearance of the poultry skin ultrastructure and therefore should not affect batter and breading adhesion. The removal of the cuticle by increased scald temperature, however, was theorized to improve batter and breading adhesion.

The purpose of this experiment was to determine if there was a relationship between the size of a broiler drumstick and the cooking loss, the crumb loss,(which is a measure of adhesion), and overall yield of the poultry part. These same measurements were also used to compare poultry parts tempered to four different temperatures before battering and breading, including frozen (-15.5°C), refrigerated (4°C), room temperature (23°C), and heated (110.0°C), and poultry drumsticks with and without skin.

MATERIALS AND METHODS

Size difference.

Sixty-four frozen broiler drumsticks were purchased from a local supermarket and thawed overnight in a refrigerator at 4°C. The thawed drumsticks were individually weighed, immersed in a whole milk predip for 10 seconds; drained for 10 seconds; placed in a 10" by 10" plastic bag containing 70 grams of breading mix and shaken for 10 seconds. The drumsticks were reweighed to determine coating pickup. The breading mix was composed of the following ingredients: wheat flour, partially hydrogenated soybean, cottonseed and palm oils, salt, malted barley, sugar, spices, paprika, yeast, cornstarch, dried garlic, monosodium glutamate (flavor enhancer), natural hickory smoke flavor, artificial color, and dried onion. The coated drumsticks were baked for 40 minutes in a commercial sized Partlow oven (National Mfg. Co., Lincoln, Nebraska) at 204.5°C. After a 20 minute cooling period, the drumsticks were reweighed and shaken for 1 minute on a portable sieve shaker on a 1/4" grid (Suderman and Cunningham, 1979). After each piece was shaken, it was reweighed to determine the crumb loss. Data were recorded and calculations made to determine means of the % coating pickup, % cooking loss, % crumb loss and % overall yield. Calculations were performed as follows:

$$\% \text{ coating pickup} = \frac{\text{coated wt. - towel dried wt.}}{\text{towel-dried wt.}} \times 100$$

$$\% \text{ cooking loss} = \frac{\text{coated wt. - cooked wt.}}{\text{towel-dried wt.}} \times 100$$

$$\% \text{ crumb loss} = \frac{\text{cooked wt. - shaken wt.}}{\text{towel-dried wt.}} \times 100$$

$$\% \text{ overall yield} = \frac{\text{shaken wt.}}{\text{towel-dried wt.}} \times 100$$

A regression equation relating the size of the drumstick to cooking loss, crumb loss, and overall yield was calculated if statistically significant relations existed (Snedecor and Cochran, 1976).

Temperature differences.

Twenty-four broiler drumsticks were tempered before battering and breading, to each of four different temperatures, which included frozen (-15.5°C), refrigerated (4°C), room temperature (23°C) and heated (110°C). The milk predip was also tempered to the same temperature as the drumsticks except in the case of frozen drumsticks, where refrigerated milk was used. Batter and breading ingredients and procedure were the same as previously described. Analysis of variance was calculated for differences in the % coating pickup, % cooking losses, % crumb loss, and % overall yield.

Absence of skin.

The skin from 24 drumsticks tempered to 4°C was removed and the skinless drumsticks were battered and breaded as already described. Data were recorded and the calculations were the same as those for the drumsticks coated at different temperatures. The drumsticks were compared with those having skin and also coated at 4°C. Significant differences at the 5% level were determined.

RESULTS AND DISCUSSION

Size differences.

Table 2 shows the relationship between broiler drumstick size and % coating pickup, % cooking loss, and % crumb loss. No significant correlation was found between % coating pickup and the size of the drumstick, but the mean average pickup was 6.615%. There was a highly significant correlation between the other three measurements. The % cooking loss decreased as the drumstick size increased. Figure 1 illustrates the regression equation that shows this relationship. This may be because all the drumsticks were cooked for 40 min. so the smaller ones might have been slightly overcooked, while the large ones were slightly undercooked, and the surface area was much greater for the smaller drumsticks.

Figure 2 is the graph of the regression equation illustrating the relationship between % crumb loss and original drumstick weight. This regression equation has a high significance level, and a positive slope of 0.0207 indicating that the larger the broiler drumstick, the more coating that is lost. Larger drumsticks may cause a greater impact between the drumstick and the contact surface, making it more difficult for the coating to adhere to the drumstick. Thus, during shipping and handling, coating will adhere better to smaller pieces of battered and breaded products than to larger ones.

Figure 3 shows the relationship between the overall % yield and the original weight of the drumstick. The regression equation of $y = 72.97 + 0.1010x$, has a positive slope and is highly significant, with the probability of getting a greater F value being 0.0003. This indicates that as the drumstick increased in size, so did the percent overall yield.

The cooking loss decreased as the drumstick weight increased, and that affected the % overall yield the greatest. Though crumb loss increased with increased drumstick weight, the % was small, with a mean crumb loss of 1.723%, compared to a mean cooking loss of 22.45%.

The large circle on the three figures indicates the position of the mean of the three variables. The average weight of each drumstick was 95 - 100g apiece.

Temperature differences.

Analysis of variance indicated significant differences at the 5% level for all treatments studied. Table 3 depicts how temperature differences of broiler drumsticks before coating affects the % coating pickup. Those drumsticks coated at 23°C, with an average % coating pickup of 5.34%, were not significantly different from those coated at 4°C with an average of 5.05%. Both these averages were significantly higher than the mean for those drumsticks coated at -15.5°C. The milk predip on the frozen drumsticks quickly froze and left little moisture on the surface of the skin to aid breading adhesion.

Parts coated at 23°C also were significantly higher in % coating pickup than those coated at 110°C, though drumsticks coated at 4°C were not significantly higher. The surface of the parts coated at 110.0°C was slightly dry and starting to cook, allowing less coating to adhere.

Table 4 shows the differences in % cooking loss as treatments varied. Poultry parts frozen before being coated also had a high cooking loss, since they had not lost any of their moisture during thawing as had those coated at room or refrigerator temperatures. Parts heated to 110°C before dredging probably had lost more of their moisture during the time they were being heated than had refrigerator (4°C), or room temperature (23°C) drumsticks. Drumsticks coated at room temperature or refrigerated temperature had significantly less cooking loss than drumsticks coated at other temperatures.

The % crumb loss as affected by the drumstick temperature at the time of battering and breading is outlined in Table 5. Drumsticks coated at 23°C and 4°C had significantly higher crumb loss than those coated at 110°C. Though drumsticks coated

at refrigerator and room temperatures had the least cooking loss, they had the largest crumb loss, partly because they had picked up more coating than those coated at 110°C or -15.5°C so they had more to lose. The frozen drumsticks did not have much coating pickup in the first place, but still lost a high percentage. It is speculated that there was no protein-carbohydrate matrix present when the drumsticks were coated and apparently little was formed to hold the breading to the poultry part. The broiler drumsticks coated at 110°C did not have much coating pickup, but the coating adhered more readily in this treatment than in others.

Table 6 gives Duncan's Multiple Range Test grouping for the % overall yield, relating the original weight of the drumstick to the weight of the final product. Drumsticks coated at room temperature had the highest % overall mean (79.30), but it was not significantly different from those coated at refrigerator temperature (78.78). Those coated at 110°C had significantly lower yield with a mean of 76.40%, and those frozen prior to coating had the least overall yield at 74.42%.

Absence of skin

Table 7 shows the coating characteristic variables for broiler drumsticks with and without skin, coated at 4°C. Skinning the drumsticks prior to batter and breading was very effective in increasing % coating pickup and reducing % crumb loss. The skinned chicken parts had a sticky subcutaeous tissue layer, largely composed of protein, that caused more breading to be picked up and to adhere more tenaciously than drumsticks with the skin intact.

The skinned drumsticks had the largest cooking loss due to the absence of the skin, which acts as a barrier to cooking losses. Proctor and Cunningham (1983) found that the skin reduced cooking and mineral losses. Though significant differences were shown in the % cooking loss, the differences in % overall yield were not significant

because the increase in coating pickup and decrease in crumb loss made up the difference in skinned broiler drumsticks.

CONCLUSION

There was no significant correlation between % coating pickup and original drumstick weight. There were significant relationships between % cooking loss (P =.0001), % crumb loss (P = .0001), and % overall yield (P = .0003). Regression equations were calculated for each variable. Results indicated that as the weight of the drumstick increased, % cooking loss decreased, % crumb loss increased and the % overall yield increased.

These data indicate that the most profitable temperature at which to batter and bread a poultry product is room temperature (23°C). The drumsticks coated at 23°C had the highest % overall yield and lowest % cooking loss. They had a higher % coating pickup than those coated at refrigerator temperatures and had less crumb loss. The results from those coated at room temperature and refrigerator temperature were very similiar. In consideration of microbial aspects the latter may prove to be the method of choice.

There seems to be no benefit to heating poultry parts before coating. Coating parts from the frozen state may be more profitable with a different type of batter and breading, but in these experiments, it produced a very poor and unattractive product, with little coating pickup and adhesion.

The use of skinned battered and breaded poultry products should be considered. Their final yield was not significantly different from those coated at refrigerator temperatures. Cooking losses caused by the absence of the skin, which acts as a barrier, were counterbalanced by a large coating pickup and good adhesion. An informal taste panel preferred the skinned drumsticks for flavor and appearance. The tenacious adhesion of the coating to the drumstick produced an attractive product.

Baker et al. (1972) and Suderman et al. (1981) both found protein materials to be better at improving coating pickup and adhesion over carbohydrate sources. The subcutaneous tissue is a natural source of protein within poultry parts that has proved to be very good at improving batter and breading pickup and adhesion. The skinned drumsticks also would contain less fat which would be appealing to those on a low fat diet.

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Table 1: Crumb loss of breaded broiler drumsticks as a function of temperature.

Temperature	Mean	Std. Deviation
73.3°C	17.97	10.01
45.0°C	16.70	8.24
30.0°C	15.80	4.83
15.2°C	6.15*	2.51
10.4°C	0.07*	0.48

* = significant at a 95% confidence interval

(Seeley, 1981)

Table 2: The relationship of the original broiler drumstick weight on % coating pickup, % cooking loss, and % crumb loss as shown by a regression equation and the mean for these variables.

Variable	Mean	Regression Equation	Probability > F value
% coating pickup	6.615	not significant	
% cooking loss	22.45	y = 32.58 - (.1081)X	.0001
% crumb loss	1.723	y = -.2196 + (.0207)X	.0001
% overall yield	82.44	y = 72.97 + (.1010)X	.0003

Table 3: The % coating pickup as effected by temperature of the broiler drumstick prior to batter and breading.

Treatment	Mean	Duncan's grouping
23°C (Room temp.)	5.34	A
4°C (Refrigerator temp.)	5.05	AB
110°C	4.74	B
-15.5°C (Frozen)	3.97	C

Number of samples per treatment = 24.

Alpha level = 0.05.

Means with the same letter are not significantly different.

Table 4: The % cooking loss as effected by temperature of the broiler drumstick prior to batter and breading.

Treatment	Mean	Duncan's grouping
-15.5°C (Frozen)	28.05	A
110°C	27.22	A
4°C (Refrigerated temp.)	24.55	B
23°C (Room temp.)	24.52	B

Number of samples per treatment = 24.

Alpha level = 0.05.

Means with the same letter are not significantly different.

Table 5: The % crumb loss as affected by temperature of broiler drumstick prior to batter and breading.

Treatment	Mean	Duncan's grouping
4°C (Refrigerator temp.)	1.72	A
23°C (Room temp.)	1.52	A
-15.5°C (Frozen)	1.50	A
110°C	1.13	B

Number of samples per treatment = 24.

Alpha level = 0.05.

Means with the same letter are not significantly different.

Table 6: The % overall yield as effected by temperature of broiler drumstick prior to batter and breading.

Treatment	Mean	Duncan's grouping
23°C (Room temp.)	79.30	A
4°C (Refrigerator temp.)	78.78	A
110°C	76.40	B
-15.5°C (Frozen)	74.42	C

Number of samples per treatment = 24.

Alpha level = 0.05.

Means with the same letter are not significantly different.

Table 7. Coating characteristics of broiler drumsticks (with and without skin) battered and breaded at 4°C.

Variable	with skin	without skin	
% coating pickup	5.05	8.08	*
% cooking loss	24.55	29.20	*
% crumb loss	1.72	0.912	*
% overall yield	78.78	77.97	

* The means were significantly different at the 5% level.

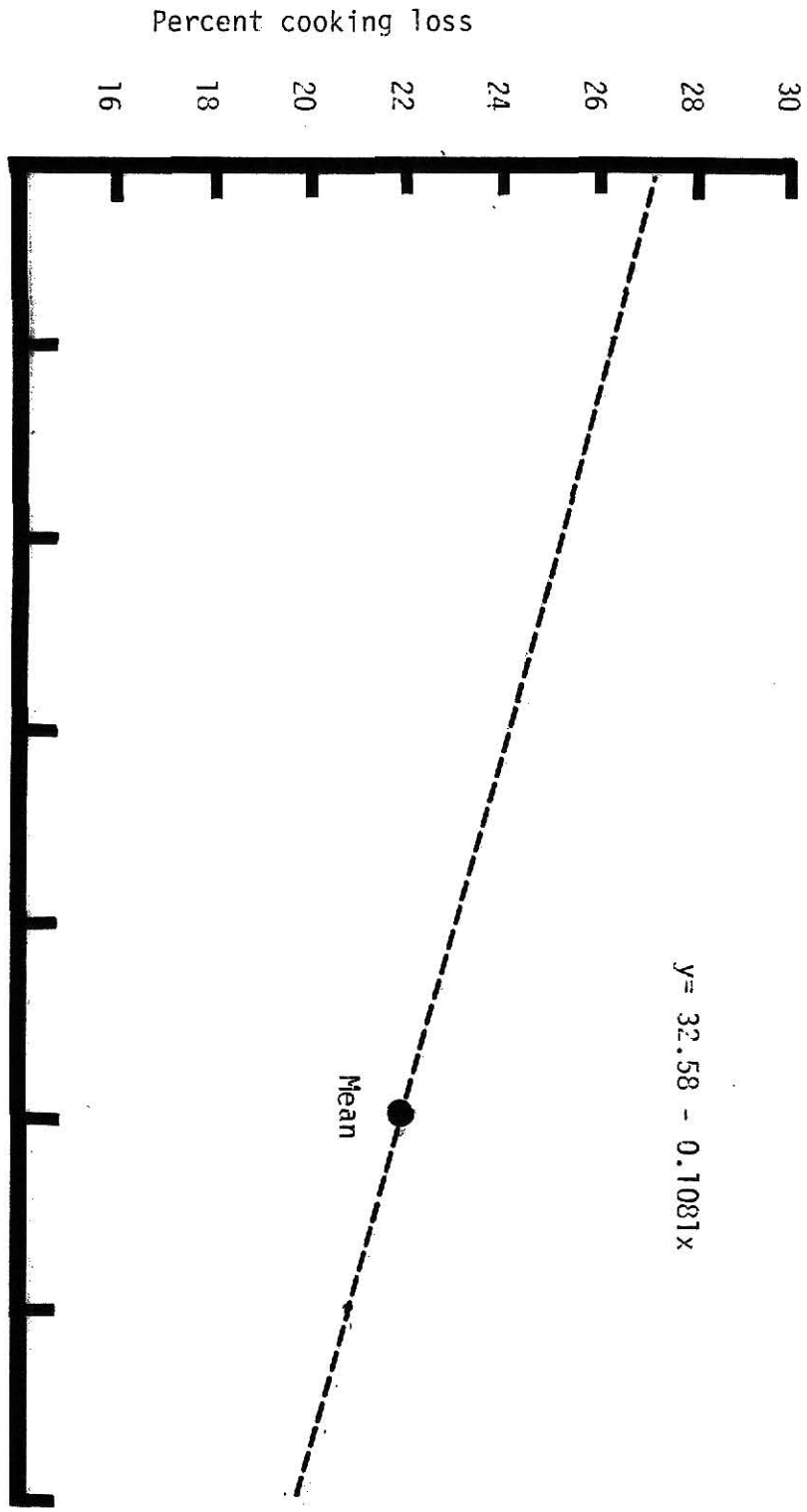

Figure 1: The relationship of percent cooking loss to the original weight of the broiler drumstick.

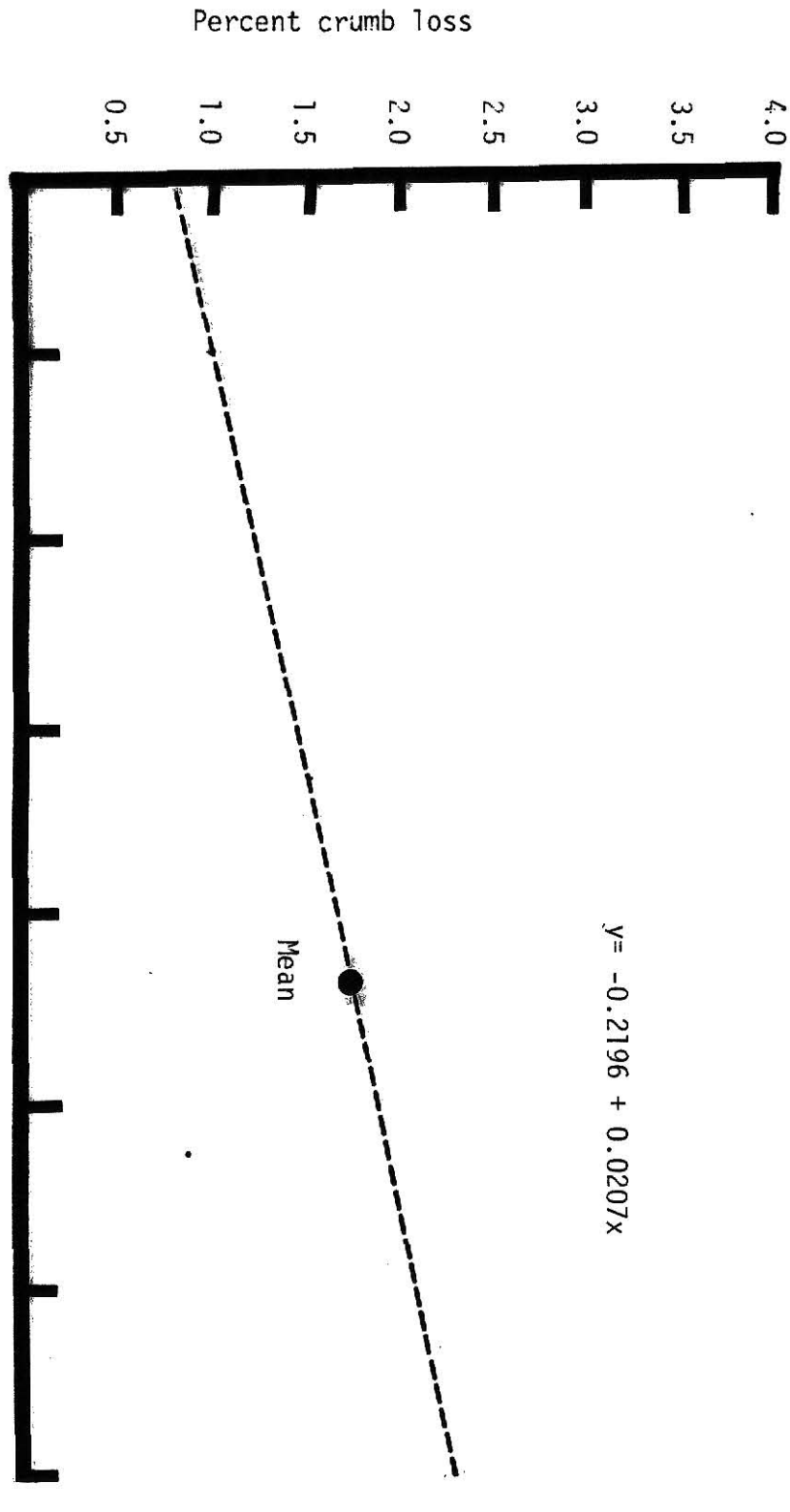

Figure 2: The relationship of percent crumb loss to the orginal weight of the broiler drumstick.

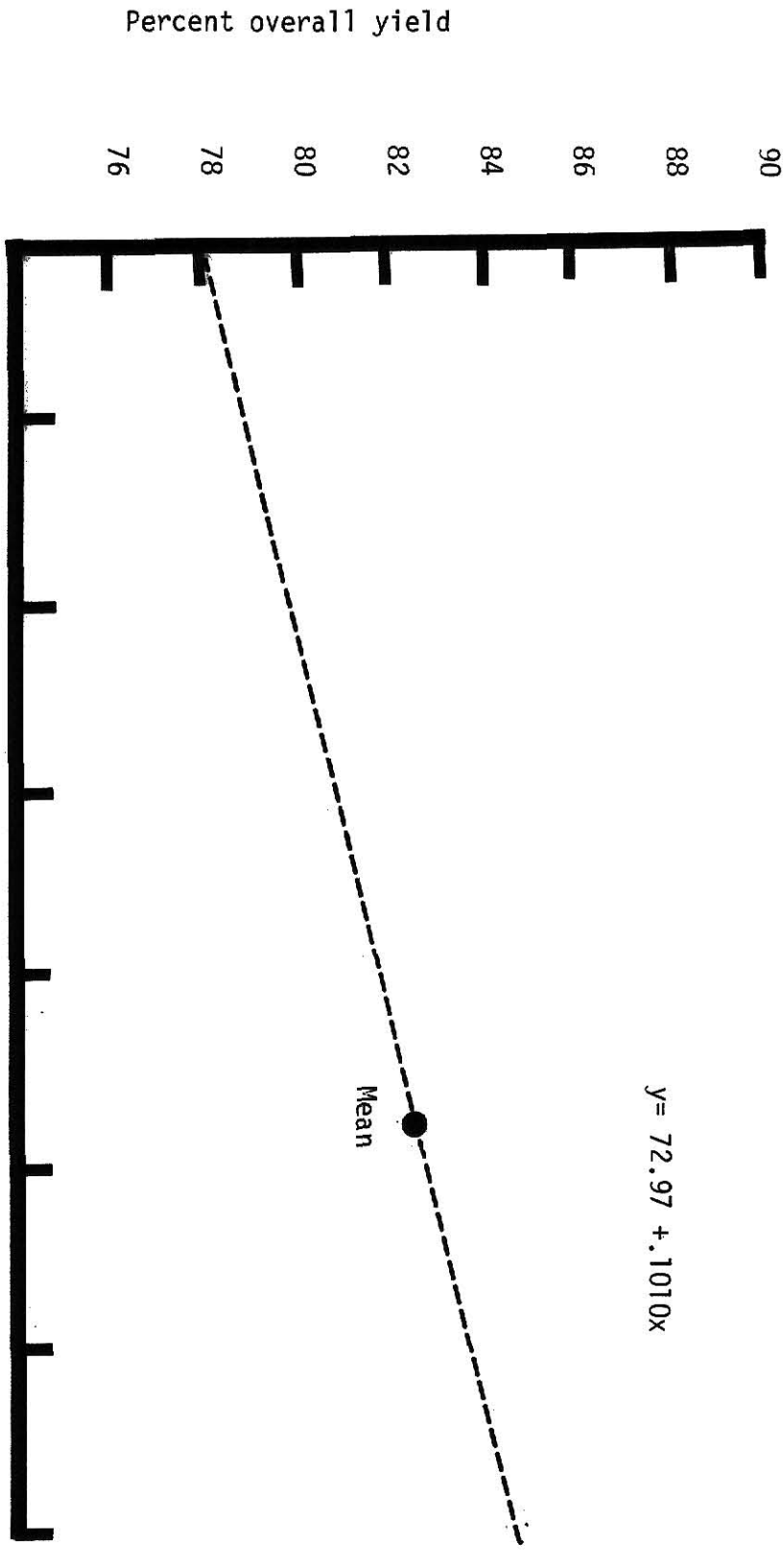

Figure 3: The relationship between percent overall yield and the original weight of the drumstick.

Paper 4

The Effect of Temperature on % Weight Gain of Broiler Drumsticks after Marinating and the Effect of Different Chemical Groups on Yield of Poultry Drumsticks

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ABSTRACT

The mean % weight gain of broiler drumsticks tempered to refrigerator temperature (4°C) was compared to those tempered to room temperature (23°C) after marinating the drumsticks in distilled water with agitation for 30 and 60 min. Those drumsticks marinated at 23°C had significantly greater absorption (P=.0001) with an average % absorption of 3.81%. Those marinated at 4°C had an average % weight gain of 1.75%.

Different chemical groups including acids, enzymes, salts, and emulsifiers and gums were studied in relation to % weight gain, % coating pickup, % cooking loss, % crumb loss and % overall yield of coated broiler drumsticks by soaking them in agitated solutions for 30 or 60 min., or by using the chemicals as batter substitutes during coating. Drumsticks treated with emulsifiers and gums used as a batter substitute had significantly higher coating pickup (12.25%) and the control drumsticks, using a milk batter had the lowest (5.34%). The % cooking loss was highest for drumsticks treated with acids (27.70%) and enzymes (27.70%) and lowest for control drumsticks (23.46%) that were soaked in distilled water. The % crumb loss was highest for drumsticks treated with emulsifiers and gums used as batter substitutes (4.14%) and lowest with milk batter control drumsticks. Drumsticks marinated in distilled water had the highest overall yield (86.67%) and the non-marinated drumsticks using a milk batter the lowest (79.30%). Those non-marinated drumsticks coated with emulsifiers and gums as a batter substitute had a high overall yield of 83.12.%.

A 12 member experienced semi-trained taste panel was used to determine differences in the flavor of drumsticks treated with the different additives. The taste panel preferred drumsticks soaked in a 2% NaCl solution and scored low the skinless drumsticks soaked in a 4% Kena solution (90% tripolyphosphate and

10% hexametaphosphate blend made by Stauffer Chemical Co.). The taste panel found little difference in drumsticks treated with the other additives used in this study.

INTRODUCTION

The batter and breading industry is a billion dollar industry (Anonymous, 1981). Commercial batters and breadings provide processors with their greatest value-added opportunity at the lowest cost (Jessup, 1981).

Batters and breadings add flavor and improve appearance (Elston, 1975), remove monotony (Jessup, 1981), contribute to the nutritional value of a food product (Elston, 1975), prevent oxidation and reinforce food structure (Morgan, 1971), and add crispness and browning to a food product.

Many factors that affect batter and breadings involve ingredient manipulation. Cunningham and Tiede (1981) found increased batter viscosity to cause increased breading pickup and decreased cooking losses. A 1:2 water:solids ratio was found to be best for breading adhesion. Suderman et al. (1981) studied the effect of protein and gum sources in relationship to coating adhesion. Protein sources that were studied included whey, soy, nonfat dry milk, egg albumen, and gelatin. Gelatin and egg albumen were the most effective in improving adhesion. Gums studied were sodium carboxymethyl cellulose (CMC), guar, tragacanth, and xanthan. CMC was the only one to significantly improve adhesion. Increased levels of gums and proteins in the coating did not affect adhesion significantly. Baker et al. (1972) compared 15 predust materials and found proteins improved adhesion of batter and breaded coatings more than starches or gums. Hale and Goodwin (1968) combined gums and proteins, incorporating egg white and hydroxypropyl methyl-1-cellulose (HMC) with batters and reported no significant adhesion differences.

Suderman and Cunningham (1979) used water, whole milk, and evaporated milk to determine their effect on breading pickup, baking loss, volume loss, evaporative and drip loss, tenderness, and water holding capacity using broiler drumsticks and thighs. Poultry parts had decreased baking loss and improved tenderness values when coated with a breading mix ($P<0.05$). Volume loss and losses due to baking were reduced as breading predip usage progressed from water to whole milk, to evaporated milk. Soy, nonfat dry milk, and egg albumen proteins were used to determine what effect protein sources at levels of 5, 10, and 15% had on breading pickup, baking loss, volume loss, tenderness, and water holding capacity. Soy protein improved meat tenderness ($P<0.05$) and decreased baking loss ($P<0.05$). Single-cell protein (Schnell, 1976) and comminuted fish flesh (King et al., 1974) have also been used to improve coating adhesion.

Phosphates have been used in the meat industry for moisture retention, tenderization, to preserve color and flavor, and delay rancidity and spoilage (Cassidy, 1977). Being salts, phosphates and NaCl, increase the solubility of proteins and cause more protein to be in the fluids on the surface of the meat (Vadehra and Baker, 1970) increasing binding. Bendall (1954) said the swelling effect on meat of inorganic pyrophosphate or tripolyphosphate can be traced to their ability to split actomyosin into its component proteins, actin and myosin, resulting in the uptake of water, resembling the action of adenosine triphosphate.

Tenderness was increased in broiler breast muscle within 1 hr. after slaughter by injecting the muscle with sodium polyphosphates, 20 min. postmorten (Peterson, 1977). The tenderness effect may be due to a slowing down of the pH. After ageing, pH of polyphosphate treated muscles averaged 6.15 compared with 5.81 for untreated muscles.

Seeley (1981) studied chemical predips in relation to coating adhesion. Phosphates significantly decreased crumb loss as the concentration increased. A linear relationship was found in this respect to curafos tripolyphosphate, and curafos sodium tripolyphosphate and sodium hexmetaphosphate blend. Kena (90% sodium tripolyphosphate and 10% sodium hexametaphosphate) did not show a linear relationship. Acids were also studied in relation to batter and breading adhesion. Citric and tartaric acid were used and no significant difference was found between drumsticks soaked in acid and the controls. Acids have been shown to increase the shelflife of poultry by decreasing the microbial load, and their use in industry is well known.

Landes (1972) found percent cooked yield of broiler quarters increased with increased polyphosphate content. Phosphorous content of the cooked tissue increased as the polyphosphate content of the marinade increased, with light meat absorbing more phosphate than dark meat. Organoleptic evaluations of the quarters indicated that chicken and meaty flavors decreased through the storage period with increased polyphosphate levels in the marinade. Warmed over flavor decreased with increased phosphate level, but an objectionable baking soda like flavor was present which increased in intensity with increased polyphosphate treatment. Overall flavor ratings decreased with increased phosphate levels after 0 and 1 month, but after 3 and 6 months frozen storage the decrease was not as pronounced. The polyphosphate treated samples were more tender and juicy.

The use of enzymes, including papain, to tenderize meat has been studied (Prusa et al., 1981; Fry et al., 1966), but no one has looked at the effect of enzymes on batter and breading adhesion. Prusa et al. (1981) found no difference in the roast chicken flavor of samples with and without papain, but off-flavor

increased when papain was added (.001 and .002% solutions). Off-flavor could be due to the enzyme present or to the additional free amino acids liberated in the chicken muscle.

Gums have mostly been used for their rheological properties, for emulsion stability, high viscosity, cling ability, and for controlling water migration. They have been used in batters and breadings to increase breading pickup; however, little work has been done on their effect on coating adhesion. Emulsifiers work to lower the interfacial tension between two immiscible substances and are often called surface active agents (Hart, 1983). Possibly emulsifiers could increase breading adhesion.

The purpose of this experiment was to determine the effect of NaCl, a phosphate blend, acids, emulsifiers, gums, and enzymes on cooking loss, batter and breading adhesion and flavor of broiler drumsticks. The difference in the amount of marinade absorbed by broiler drumsticks at room (23°C) and refrigerator temperatures (4°C) will also be studied.

MATERIALS AND METHODS

The first part of this study compared the % water absorption of broiler drumsticks at room (23°C) and refrigerator (4°C) temperature. Twenty-four broiler drumsticks where tempered in a refrigerator at 4°C for 48 hrs. Two gallon jars with 1900ml. of distilled water were also chilled to 4°C. Twelve drumsticks were placed in each jar and one jar was agitated for 30 min., and the other for 60 min. in an temperature controlled water bath shaker (American Optical) set on the fastest speed of 10. The drumsticks were towel-dried and weighed before agitation, allowed to drain for 15 min. after agitation, and towel-dried again to determine the amount of water absorbed.

Other broiler drumsticks (48) were tempered at room (23°C) temperature along with four gallon jars containing 1900ml. of distilled water each. Twenty-four drumsticks were agitated for 30 min. and 24 for 60 min. Drumsticks were weighed before and after agitation, data were recorded, and analysis of variance was calculated (Snedecor and Cochran, 1976).

Additive absorption.

Broiler drumsticks, purchased from a local supermarket, were thawed overnight, towel-dried, and weighed individually. Solutions of additives were made and checked for initial pH. The additives and amounts used are as follows: The additive solution and 12 drumsticks were placed in a gallon jar and covered. The solution completely covered the drumsticks. Two identical jars were placed in a temperature controlled water bath shaker (American Optical), for 30 min. and 60 min., to measure differences in the time allowed for the additive to penetrate the drumsticks. After shaking for the allotted time on the fastest speed of 10, the drumsticks were allowed to drain for 15 min. on wire racks over a cookie sheet, and a sample of solution was taken to measure pH. The drumsticks were towel-dried and reweighed to determine the amount of additive solution absorbed, then battered and breaded. To coat, the drumsticks were immersed in a whole milk predip for 10 seconds; drained for 10 seconds; placed in a 10" by 10" plastic bag containing 70 grams of breading mix and shaken for 10 seconds. The drumsticks were reweighed to determine coating pickup. The breading mix was composed of the following ingredients: wheat flour, partially hydrogenated soybean, cottonseed and palm oils, salt, malted barley, sugar, spices, paprika, yeast, cornstarch, dried garlic, monosodium glutamate (flavor enhancer), natural hickory smoke flavor, artificial color, and dried onion. The coated drumsticks were baked for 40 min. in a commercial sized Partlow oven

(National Mfg. Co., Lincoln, Nebraska) at 204.5°C. After a 20 min. cooling period, the drumsticks were reweighed and shaken for 1 min. on a portable sieve shaker on a 1/4" grid (Suderman and Cunninghan, 1979). After the pieces were shaken, they were reweighed to determine crumb loss. Determinations were made of the solution uptake, coating pickup, cooking loss, crumb loss, and overall yield. Calculations were made as follows:

$$\% \text{ solution pickup} = \frac{\text{soaked wt. - towel dried wt.}}{\text{towel-dried wt.}} \times 100$$

$$\% \text{ coating pickup} = \frac{\text{coated wt. - soaked wt.}}{\text{towel-dried wt.}} \times 100.$$

$$\% \text{ cooking loss} = \frac{\text{coated wt. - cooked wt.}}{\text{towel-dried wt.}} \times 100.$$

$$\% \text{ crumb loss} = \frac{\text{cooked wt. - shaken wt.}}{\text{towel-dried wt.}} \times 100.$$

$$\% \text{ overall yield} = \frac{\text{shaken wt.}}{\text{towel-dried wt.}} \times 100.$$

Two way analysis of variance (Snedecor and Cochran, 1976) was performed between each treatment to determine the effect of soak time on each treatment. The additives and amounts used were:

1) 4% Kena (90% sodium tripolyphosphate, 10% sodium hexametaphosphate) provided by Stauffer Chemical Co., Westport, Connecticut.

2) 4% Kena on skinless drumsticks.

3) 2% NaCl.

4) .5% ascorbic acid.

5) .4% Emulsifier 76 (polysorbate 80 and propylene glycol), provided by Germantown, Broomall Pennsylvania.

6) .35% Synergy (mono and diglycerides, guar gum, polysorbate 60, and xanthan gum, standardized with salt), provided by Germantown.

7) 5% Seal n Save (cellulose gum, carrageenan, mono-diglycerides, in an aqueous solution containing glycerin and propylene glycol) provided by Germantown.

8) 1.5% Gold Medal (mono and diglycerides, cellulose gum and guar gum), provided by Germantown.

9) .002% papain.

10) .006% papain.

Some additives were used as a batter substitute, instead of milk during coating, rather than being used as a marianade. These included:

1) 2:1 water:Seal n Save.

2) 4:1 water:Seal n Save.

3) 2% Gold Medal, with a 20 second drain instead of a 10 second drain as used for other additives.

One additive was used for both soaking and as the milk replacement. This was a 5% solution of Seal n Save and 5:1 water:Seal n Save.

One way analysis of variance was performed on all data to compare treatments soaked and not soaked (Snedecor and Cochran, 1976).

Preliminary studies were done to determine the concentrations used in the experiment.

A 12-member experienced semi-trained taste panel was used to determine how the additive affected flavor. Although adhesive properties of the coating and effect on cooking loss were our main concerns, a taste panel was used to determine how additives effected flavor. The taste panel scored the drumsticks for flavor, juiciness, tenderness, coating appearance and flavor, and overall acceptability, on an eight point hedonic scale, 1 representing very undesireable, and 8 representing very desireable. Analysis of variance (Snedecor and Cochran,

1976) was calculated to indicate significant differences at the 5% level between treatments. Individual differences between taste panel members was removed by statistical procedures so as not to affect the final results.

RESULTS AND DISCUSSION

Percent absorption of distilled water at 4°C or 23°C

The mean % absorption at 4°C and 23°C was significantly different (P=.0001). More distilled water was absorbed by broiler drumsticks at 23°C than at 4°C. Table 1 gives the % mean absorption at both temperatures and at 30 and 60 min. The % absorption was also significantly affected by the time of marinating at 23°C but not at 4°C. Chen (1982) found rotary-marinating at room temperature in a hexagonal shaped drum rotated at 31.5 rpm increased the rate of penetration of a salt solution over still marinating at refrigerature temperatures. Equivalent salt marinade penetration into drumsticks was approximately 4 hrs. in still marinating to 25 min. of rotary-marinating. Marinade penetration at 4 hrs. of still marinating of breasts, thighs and wings could be accomplished by rotary-marinating in 10 min. Marinade solutions were agitiated in the automatic water bath shaker in this experiment to increase the rate of absorption of marinade into the drumsticks over still marinating. Preliminary results found agitating-marinade times of 30 or 60 min. to be adequate for marinade penetration. As Chen (1979) found little increase of marinade penetration in rotary-marinating after 10 min., there was little increase in marinade penetration after 60 min. of agitating-marinade. Depending on the type of additive used in the marinade the penetration time could be shortened. The wide variety of chemicals used called for two experimental times. Drumsticks were also allowed to temper overnight to room temperature

from the frozen state because of the increase in marinade absorption at 23°C over 4°C.

The mean % weight gain of broiler drumsticks after soaking in various additives for 30 or 60 min. is given in the Table 2. The addition of 4% Kena to the distilled water caused a lower % weight gain than the control. This was expected because one of the functions of polyphosphates in chill water of freshly killed eviscerated poultry is to reduce weepage during refrigerated storage or during thawing from frozen storage, and this is partly accomplished by reducing water absorption during chilling (Mahon, 1983). Polyphosphates reduce moisture absorption and reduce weepage possibly by the influence of pH, ionic strength effects, and specific phosphate anion interactions with divalent cations and myofibrillar proteins (Hamm, 1971).

The skinless drumsticks absorbed more because of the lack of skin which acts as a barrier to water absorption in the muscle. Addition of 2% NaCl also reduced weight gain, probably due to the ionic strength it gives to the poultry muscle. The uptake of 0.5% ascorbic acid solution was very similiar to that of the control. The amount of papain solutions absorbed was slightly lower than the control. The enzyme did not penetrate the skin very easily. Temperature effected the amount of enzyme solution absorbed into the drumsticks more than in other additives because of the increased enzyme activity with a warmer temperature. The drumsticks in solutions of emulsifiers and/or gums had less weight gain than the controls possibly because the large molecular structure of the gums inhibited them from penetrating the skin and muscle. The solution of 1 1/2% Gold Medal was very viscous. Drumsticks after soaking in 0.5% ascorbic acid were pale in color and the feather follicles had been denatured causing large goosebumps on the skin surface. The mean % weight gain of the broiler

drumsticks after 30 min. of soaking for all additives of 2.41% was significantly lower than those soaked for 60 min. with a mean of 3.54% (P=.0001).

Table 3 gives the mean % coating pickup of broiler drumsticks after agitation for 30 or 60 min. in different additive solution. 5% Seal n Save + 5:1 water:Seal n Save gave significantly higher ($P<0.05$) % coating pickup on drumsticks than other additives. The viscous nature of Seal n Save used not only for agitating-marinade but as a batter substitute replacing milk greatly increased coating pickup. Proctor and Cunningham (1983) found significantly increased coating pickup and decreased crumb loss of skinless drumsticks over those with the skin intact, but cooking losses were increased. It was thought that the addition of polyphates may reduce the cooking loss. The mean % coating pickup of skinless broiler drumsticks coated at 4°C without soaking was 8.08%. The coating pickup for broilers marinated in Kena was higher, 8.58% after 30 min. and 11.35% after 60 min. marinade.

Broilers soaked in papain had significantly lower % coating pickup than broilers marinated in other additives ($p<0.05$).

The average % coating pickup for all drumsticks soaked in various additives at 30 and 60 min. was not significantly different even though those soaked for 60 min. had a slightly higher mean.

The mean % cooking loss of coated broiler drumsticks agitated for 30 or 60 min. in different additive solutions before coating is seen in Table 4. The 4% Kena, skinless drumsticks had significantly more cooking loss ($P<0.05$) than many of the other drumsticks. The cooking time of meats with Kena in them can be reduced by 5-10% according to Stauffer Chemical who makes Kena (Mahon, 1983), and this would reduce cooking loss. No adjustment of cooking time was made in this study. More cooking loss was found for drumsticks that had been

soaked for 30 min. rather than 60 min. Increased penetration of Kena seemed to reduce some of the cooking loss.

Papain soaked drumsticks also had increased cooking loss compared to the control and drumsticks soaked in other additives. Seal n Save was reported by Germantown to decrease cooking loss, but that was not the case for meat that had been soaked in Kena. Using Seal n Save as a batter substitute did decrease some of the cooking loss. One and one-half percent Gold Medal caused lower cooking loss than the other additives and was approximately equivalent to the control. The average % cooking loss for all additives was not significantly different (P=.288), but the cooking loss was lower after 60 min. of soaking.

Table 5 is the mean % crumb loss of coated broiler drumsticks agitated for 30 and 60 min. in different additive solutions before coating. Significantly reduced crumb loss (P=.0001) was found for the skinless drumsticks soaked in 4% Kena. Papain treated drumsticks also had reduced crumb loss, but the % coating they picked up was small, still leaving the drumsticks sparsely coated. The drumsticks soaked in 0.5% ascorbic acid had a significantly higher % crumb loss (P=.0001) than the control. The additive, 5% Seal n Save + 5:1water:Seal n Save caused a high crumb loss, but a lot of breading had been picked up on the drumstick during coating. The difference between the mean crumb loss for all additives after 30 and 60 min. of soaking was not significant (P=.1982).

The mean % overall yield of coated broiler drumsticks agitated in different additive solutions for 30 or 60 min. prior to coating is in Table 6. The % overall yield average for the control was significantly higher ($P<0.05$) than all other drumsticks soaked in an additive solution. The 4% Kena, skinless drumsticks had an overall yield mean of 86.37% after 60 min. of soaking which was comparable to the control (86.92%). The drumsticks soaked in 5% Seal n

Save and Seal n Save + 5:1 water:Seal n Save also had a high overall yield mean after 60 min. of soaking (84.11%).

Table 7 is the averages of the variables studied where the additives were used as a batter substitute for coating broiler drumsticks. The control, where whole milk was used in the batter step had a lower % coating pickup (5.34%) than the control that was soaked (7.02%). Chen (1982) also found non-marinated poultry parts to have less coating pickup than marinated parts. It was postulated that the increased surface moisture of the marinated parts may be responsible for this difference. The % cooking loss and % crumb loss was approximately the same for the marianted and non-marinated control. The differences in the overall mean seem to stem from a low coating pickup in the non-marinated drumsticks.

The ratio of 2:1 water:Seal n Save gave less cooking loss and crumb loss and consequently a higher overall yield than the 4:1 ratio which was significant (P=.009). The combination of soaking the drumsticks in 5% Seal n Save and using Seal n Save as the batter substitute gave the highest overall yield (84.11%) which was significantly higher (P=.0008) than the non-marinated chicken using a 2:1 water:Seal n Save batter substitute, but not significatly different from the non-marinated 2% Gold Medal drumsticks. The crumb loss was high on the non-marinated 2% Gold Medal poultry pieces. The coating came off in large chunks on the non-marinated Gold Medal and Seal n Save broiler drumsticks, leaving an unattractive product. Cooling or freezing cooked drumsticks would eliminate some of this problem.

Within Table 8 the additives were grouped according to their composition to see if there were significant differences between them using the variables studied in this experiment. The non-marinated emulsifiers and gums caused

significantly higher coating pickup than the other groups. The non-marinated control had the least pickup. The acids, enzymes, and salts groups caused the greatest amount of cooking loss, and the marinated control the least. The drumsticks treated with emulsifiers and gums lost more crumb than the other groups, but they had the most coating to loose. The % overall yield was highest for the marinated control followed by the non-marinated drumsticks treated with emulsifiers and gums, acids, enzymes, and the lowest yield was obtained by the non-marinated control drumsticks.

pH

Table 9 gives the pH of the solutions of each additive in which broiler drumsticks were soaked. Dodge and Peters (1960) reported the pH of postmortem poultry to be around 5.8. The pH of distilled water (when 12 drumsticks were soaked for 30 and 60 min.) increased from 5.89 to 6.88 to 6.99 from 0, 30, and 60 min., respectively. Kena is alkaline and a 4% solution had a pH of 8.65. Little change in pH was observed after drumsticks were soaked for 30 and 60 min. The 0.5% ascorbic acid had a low initial pH of 3.05 and increased slightly after the poultry pieces had been soaked. The emulsifiers and enzymes had a pH very close to that of distilled water. The 1 1/2% Gold Medal was a little on the alkaline side with an initial pH of 7.55.

Taste panel results.

Table 10 shows taste panel scores for flavor of broiler drumsticks treated with various additives by soaking for 30 and 60 min. or used as batter substitute during coating. The lowest significantly different flavor scores were those for drumsticks soaked in papain and those skinned and soaked in 4% Kena. Prusa et

al. (1981) also found an off-flavor due to papain injection. Landes (1972) found an objectionable baking soda like flavor associated polyphosphates in broiler meat at increased levels. The lack of skin made it easier for the Kena to penetrate the muscle causing increased polyphosphate levels. Most of the other scores were not significantly different from each other. Drumsticks soaked in 2% NaCl for 60 min. had a flavor score (7.00) which was significantly higher than for those soaked in 5% Seal n Save solution (P=0.05).

Table 11 shows the taste panel mean scores for juiciness of broiler drumsticks treated by soaking for 30 and 60 min. in an additive solution or used as a batter substitute during coating. The drumsticks marinated in a solution of 1 1/2% Gold Medal were significantly juicier than drumsticks soaked in many of the other additives except the control. The significantly lowest scores were for the poultry parts that had been skinned and soaked in 4% Kena. Possibly a shorter cooking time would help to correct this problem. The other scores were very close to each other and not significantly different.

Table 12 shows the taste panel scores for tenderness of broiler drumsticks treated by soaking for 30 and 60 min. in different additive solutions or using the additive as a batter substitute during coating. Drumsticks skinned and soaked in a 4% Kena solution were significantly less tender than drumsticks treated with any other additive. Drumsticks marinated in 2% NaCl and 1 1/2% Gold Medal had higher tenderness scores than controls but the difference was not significant. The other scores given for drumsticks were not significantly different from the controls or other treatments.

Table 13 shows the taste panel mean scores for the flavor and texture of the coating on broiler drumsticks treated by soaking for 30 and 60 min. in various additive solutions or used as a batter substitute during coating.

Drumsticks skinned, and soaked in a 4% Kena solution had significantly lower scores for flavor and texture of coating than drumsticks from any other treatment. Poultry parts coated using a 2% Gold Medal solution as a batter substitute had a significantly lower score than drumsticks for many treatments. The breading used in the experiment had a high salt content, and was the heaviest on the drumsticks skinned and those treated using 2% Gold Medal. The objectionable taste was due to the high salt content. Flavor and texture of coating scores of drumsticks treated with other additives were not significantly different from on another.

The taste panel scores for the overall acceptability of broiler drumsticks treated by soaking for 30 and 60 min. in various additive solutions or used as a batter substitute during coating are shown in Table 14. The highest score for the overall acceptability of broiler drumsticks was found in those soaked 60 min. in a solution of 2% NaCl. The difference in the score was significant from the controls and many of the other treated drumstick scores. The score for drumsticks soaked in a solution of 1 1/2% Gold Medal was also high, but it was not significantly higher than the controls. The significantly lowest scores for overall acceptability were for the drumsticks that had been skinned and soaked in a 4% Kena solution.

CONCLUSION

The mean % absorption of distilled water into broiler drumsticks marinated for 30 and 60 min. under agitation at room temperature (23°C) was significantly higher (P=.0001) than at refrigerator temperature (4°C). The average % absorption for those drumsticks soaked for 30 and 60 min. was 3.81% at 23°C, and 1.75% at 4°C.

The % weight gain of broiler drumsticks after soaking for 30 and 60 min. in 4% Kena and 2% NaCl was lower than control drumsticks. Absorption of a 4% Kena solution into skinless drumsticks was higher than that into control drumsticks. The mean % weight gain of the broiler drumsticks after 30 min. of soaking for all additives of 2.41% was significaty lower than those soaked for 60 min. with a mean of 3.54% (P=.0001).

The % coating pickup was greatest on those drumsticks treated by using a gum-emulsifier combination as a batter substitute while coating, or by using skinless drumsticks. Broilers soaked in papain had significantly lower % coating pickup than broilers marinated in other additives ($P<0.05$).

The % cooking loss was greatest for those drumsticks treated with an acid, enzyme or a salt. Drumsticks skinned and soaked in 4% Kena solution had the highest cooking loss. The control drumsticks had the least cooking loss.

Crumb loss was significantly reduced (P=.0001) in skinned drumsticks (1.72%) soaked in a 4% Kena solution compared to control drumsticks (1.88%). Reduced crumb loss was also found in drumsticks treated with enzymes but less coating was picked up initially on these drumsticks. The largest crumb loss was from poultry parts treated with emulsifiers and gums as a batter substitute (4.14%).

The average % overall yield of coated, cooked, and shaken drumsticks agitated in different additive solutions for 30 or 60 min., or coated with a batter substitute was highest for marinated control drumsticks (86.67%). Four percent, skinless treated drumsticks and drumsticks soaked in 5% Seal n Save + 5:1 water:Seal n Save had high overall % yields of 86.37% and 84.11% respectively after 60 min. of soaking. The pH of distilled water was 5.89, and increased to 6.69 after 60 min. of soaking while agitating 12 drumsticks. Four

percent Kena solution had an initial pH of 8.65 and reduced very little after 60 min. of soaking while agitating with 12 drumsticks. The 0.5% ascorbic acid solution had an initial pH of 3.05, and the 1 1/2% Gold Medal had an initial pH of 7.55.

The taste panel preferred the drumsticks treated with 2% NaCl for overall acceptablity. They gave the lowest scores to skinless drumsticks soaked in 4% Kena, and found little difference in drumsticks treated with the other additives and the controls.

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Table 1. The % absorption of distilled water into broiler drumsticks while soaking at refrigerator temperature (4°C) or room temperature (23°C), for 30 or 60 min.

Temperature	Time	Mean % absorption	Avg/method	P>F
23°C	30 min.	3.17[b]	3.81	
	60 min.	4.45[a]		.0001
4°C	30 min.	1.59[d]	1.75	
	60 min.	1.91[c,d]		

Number of observations/time at 4°C = 12.

Number of observation/time at 23°C = 24.

alpha level = 0.05.

Those means with the same letter are not significantly different.

Table 2. The mean % weight gain of broiler drumsticks after soaking in various additives for 30 and 60 min.

Additive	30 min.	60 min.	Avg.
Distilled water (control)	3.17	4.45	3.81
4% Kena	1.63	2.23	1.93
4% Kena, skinless drumsticks	2.38	4.18	3.28
2% NaCl	2.46	2.97	2.71
.5% Ascorbic acid	3.17	4.29	3.73
.002% Papain	2.21	3.19	2.70
.006% Papain	1.94	3.06	2.50
.4% Emulsifier 76	2.05	2.53	2.29
.35% Synergy	1.22	1.84	1.53
5% Seal n Save	2.44	3.12	2.78
5% Seal n Save + 5:1 water:Seal n Save	1.30	2.02	1.66
1 1/2% Gold Medal	0.750	0.996	0.873

Number of samples/treatment/time = 12.

Table 3: The mean % coating pickup of broiler drumsticks after agitation for 30 and 60 min. in different additive solutions.

Additve	30 min.	60 min.	Avg.
Distilled water (control)	7.02	7.58	7.30
4% Kena	6.96	7.44	7.20
4% Kena, skinless drumsticks	8.58	11.35	9.96
2% NaCl	6.17	5.97	6.07
.5% Ascorbic acid	6.41	6.61	6.51
.002% Papain	5.99	6.52	6.26
.006% Papain	6.71	6.43	6.57
.4% Emulsifier 76	6.64	6.44	6.54
.35% Synergy	6.98	6.55	6.77
5% Seal n Save	7.09	7.58	7.33
5% Seal n Save + 5:1 Water:Seal n Save	11.15	10.99	11.07
1 1/2% Gold Medal	6.65	6.35	6.50

Number of samples/treatment/time = 12.

Table 4. The mean % cooking loss of coated broiler drumsticks agitated for 30 and 60 min. in different additive solutions before coating.

Additive	30 min.	60 min.	Avg.
Distilled water (control)	22.07	24.84	23.46
4% Kena	24.45	25.80	25.12
4% Kena, Skinless drumsticks	33.06	27.93	30.49
2% NaCl	25.21	24.46	24.84
.5% Ascorbic acid	27.98	27.42	27.70
.002% Papain	29.58	28.63	29.11
.006% Papain	25.47	26.96	26.21
.4% Emulsifier	26.56	26.86	26.71
.35% Synergy	29.23	25.71	27.47
5% Seal n Save	28.06	26.83	27.45
5% Seal n Save + 5:1 Water:Seal n Save	26.26	25.95	26.10
1 1/2% Gold Medal	23.84	24.00	23.92

Number of samples/treatment/time = 12.

Table 5. The mean % crumb loss of coated broiler drumsticks agitated for 30 and 60 min. in different additve solutions before coating.

Additive	30 min.	60 min.	Avg.
Distilled water (control)	2.16	1.59	1.88
4% Kena	1.72	2.02	1.87
4% Kena, skinless drumsticks	1.46	1.99	1.72
2% NaCl	1.95	1.91	1.93
.5% Ascorbic acid	2.33	2.49	2.41
.002% Papain	1.74	1.46	1.60
.006% Papain	1.54	2.04	1.76
.4% Emulsifier 76	1.93	2.20	2.06
.35% Synergy	2.06	2.34	2.20
5% Seal n Save	2.04	2.70	2.37
5% Seal n Save + 5:1 Water:Seal n Save	3.40	2.92	3.17
1 1/2% Gold Medal	2.33	1.87	2.10

Number of samples/treatment/time = 12.

Table 6. The mean % overall yield of coated broiler drumsticks agitated in different additive solutions for 30 and 60 min. prior to coating.

Additive	30 min.	60 min.	Avg.
Distilled water (control)	86.40	86.92	86.67
4% Kena	82.87	82.23	82.56
4% Kena, skinless drumsticks	76.09	86.37	81.23
2% NaCl	81.29	82.06	81.68
.5% Ascorbic acid	79.24	80.79	80.01
.002% Papain	76.78	79.84	78.30
.006% Papain	81.17	81.15	81.16
.4% Emulsifier 76	79.96	80.07	80.01
.35% Synergy	76.90	80.07	80.01
5% Seal n Save	81.98	82.73	80.97
5% Seal n Save + 5:1 Water:Seal n Save	32.73	84.11	83.42
1 1/2% Gold Medal	81.29	81.58	81.44

Number of samples/treatment/time = 12.

Table 7. Averages of the variables studied where the additives were used as a batter substitute for coating broiler drumsticks.

Additive	% Coating pickup	% Cooking loss	% Crumb loss	% Overall yield
Control (whole milk)	5.34	24.52	1.51	79.30
2:1 Water:Seal n Save	10.84	24.24	2.62	83.97
4:1 Water:Seal n Save	10.99	25.87	3.37	81.75
2% Gold Medal	14.94	24.87	6.43	83.64

Number of samples/treatment = 12.

Table 8. The means of the variables studied for each of the chemical groups.

Groups	Variables			
	% Coating pickup	% Cooking loss	% Crumb loss	% Overall yield
Control (water)	7.30 b	23.46 d	1.88 c	86.67 a
Control (milk batter)	5.34 d	24.52 c,d	1.51 d	79.30 e
Acids *1	6.51 c	27.70 a	2.41 b	80.01 d
Enzymes *2	6.41 c	27.70 a	1.61 d	79.74 d,e
Salts *3	7.74 b	26.82 a,b	1.84 c	81.82 c
Emulsifiers+gums, soaked *4	7.64 b	26.33 b	2.38 b	80.90 d
Emulsifers+gums (batter substitute) *5	12.25 a	24.99 c	4.14 a	83.12 b

alpha level = 0.05
*1 Acid group = .5% ascorbic acid.
*2 Enzyme group = .002% papain and .006% papain.
*3 Salts group = 2% NaCl, 4% Kena, 4% Kena, skinless drumsticks.
*4 Emulsifiers+gums group, soaked = .4% Emulsifier 76, .35% Synergy, 5% Seal n Save, 1 1/2% gold Medal.
*5 Emulsifiers + gums (batter substitute) group = 2:1 Water:Seal n Save, 4:1 Water :Seal n Save, 2% Gold Medal.

Means with the same letter are not significantly different.

Table 9. The pH of the solutions of each additive in which broiler drumsticks were soaked.

	Time		
	0 min.	30 min.	60 min.
Distilled Water	5.89	6.88	6.69
4% Kena	8.65	8.62	8.53
4% Kena, skinless drumsticks	8.65	8.57	8.46
2% NaCl	4.85	6.29	6.42
.5% Ascorbic acid	3.05	3.49	3.51
.4% Emulsifier 76	5.51	6.25	6.73
.35% Synergy	6.82	6.73	6.77
.002% Papain	5.72	6.50	6.54
.006% Papain	5.76	6.59	6.53
5% Seal n Save	5.67	6.35	6.44
1 1/2% Gold Medal	7.55	6.69	6.80

Table 10. The taste panel mean scores for flavor of broiler drumsticks treated with various additives by soaking for 30 and 60 min. or used as batter substitute during coating.

Additive	Batter Substitute	Soak time	
		30 min.	60 min.
Control (milk batter)	6.83		
Control (distilled water)		6.58	6.91
4% Kena		6.58	6.75
4% Kena, skinless drumsticks		5.24	5.25
2% NaCl		6.33	7.00
.5% Ascorbic acid		6.50	6.33
.002% Papain		6.25	5.75
.006% Papain		6.92	6.33
.4% Emulsifier 76		6.25	6.58
.35% Synergy		6.08	6.50
5% Seal n Save		6.50	6.25
5% Seal n Save + 5:1 Water:Seal n Save		6.33	6.25
2:1 Water:Seal n Save	6.58		
4:1 Water:Seal n Save	6.83		
1 1/2% Gold Medal		6.75	6.83
2% Gold Medal	6.42		

Number of taste panel scores per each mean = 12.

Taste panel scale = 8) very desireable; 7) desireable; 6) moderately desireable; 5) slightly desireable; 4) slightly undesireable; 3) moderately undesireable; 2) undesireable; 1) very undesireable.

All additives were diluted in distilled water.

Table 11. The taste panel mean scores for juiciness of broiler drumsticks treated by soaking for 30 and 60 min. in an additive solution or used as a batter substitute during coating.

Additive	Batter Substitute	Soak time 30 min.	Soak time 60 min.
Control (milk batter)	6.50		
Control (distilled water)		6.50	6.75
4% Kena		6.33	6.33
4% Kena, skinless drumsticks		4.73	5.08
2% NaCl		5.92	6.67
.5% Ascorbic acid		6.08	6.75
.002% Papain		6.00	6.00
.006% Papain		6.50	6.50
.4% Emulsifier 76		6.17	6.00
.35% Synergy		5.67	6.17
5% Seal n Save		6.42	5.83
5% Seal n Save + 5:1 Water:Seal n Save		6.33	6.00
2:1 Water:Seal n Save	6.75		
4:1 Water:Seal n Save	6.58		
1 1/2% Gold Medal		7.08	7.25
2% Gold Medal	5.67		

Number of taste panel scores per each mean = 12.

Taste panel scale = 8) very desireable; 7) desireable; 6) moderately desireable; 5) slightly desireable; 4) slightly undesireable; 3) moderately undesireable; 2) undesireable; 1) very undesireable.

All additives were diluted in distilled water.

Table 12. The tast panel mean scores for tenderness of broiler drumsticks treated by soaking for 30 and 60 min. in an additive solution or using the additive as a batter substitute during coating.

Additive	Batter Substitute	Soaking time 30 min.	Soaking time 60 min.
Control (milk batter)	6.92		
Control (distilled water)		6.92	6.75
4% Kena		6.58	6.33
4% Kena, skinless drumsticks		5.22	5.25
2% NaCl		6.33	7.25
.5% Ascorbic acid		6.58	6.83
.002% Papain		6.58	6.83
.006% Papain		6.83	6.75
.4% Emulsifier 76		6.25	6.50
.35% Synergy		6.17	6.58
5% Seal n Save		6.67	6.41
5% Seal n Save + 5:1 Water:Seal n Save		6.58	6.33
2:1 Water:Seal n Save	6.58		
4:1 Water:Seal n Save	6.75		
1 1/2% Gold Medal		6.83	7.17
2% Gold Medal	6.08		

Number of taste panel scores per mean = 12.

Taste panel scale = 8) very desireable; 7) desireable; 6) moderately desireable; 5) slightly desireable; 4) slightly undesireable; 3) moderately undesireable; 2) undersireable; 1) very undesireable.

All additives were diluted in distilled water.

Table 13. The taste panel mean scores for the flavor and texture of the coating on broiler drumsticks treated by soaking for 30 and 60 min. in various additive solutions or used as a batter substitute during coating.

Additive	Batter Substitute	Soaking time 30 min.	Soaking time 60 min.
Control (milk batter)	6.67		
Control (distilled water)		6.83	6.08
4% Kena		6.17	6.91
4% Kena, skinless drumsticks		5.02	4.92
2% NaCl		6.83	7.08
.5% Ascorbic acid		6.82	6.50
.002% Papain		6.50	6.83
.006% Papain		6.67	6.92
.4% Emulsifier 76		6.75	6.67
.35% Synergy		6.50	6.75
5% Seal n Save		6.50	6.75
5% Seal n Save + 5:1 Water:Seal n Save		6.42	6.50
2:1 Water:Seal n Save	6.33		
4:1 Water:Seal n Save	6.83		
1 1/2% Gold Medal		7.17	7.17
2% Gold Medal	5.92		

Number of taste panel scores per mean = 12.

Taste panel scale = 8) very desireable; 7) desireable; 6) moderately desireable; 5) slightly desireable; 4) slightly undesireable; 3) moderately undesireable; 2) undesireable; 1) very undesireable.

All additives were diluted in distilled water.

Table 14: The taste panel mean scores for the overall acceptability of broiler drumsticks treated by soaking for 30 and 60 min. in various additive solutions or used as a batter substitute during coating.

Additive	Batter Substitute	Soaking time	
		30 min.	60 min.
Control (milk batter)	6.83		
Control (distilled water)		6.67	6.42
4% Kena		6.50	6.50
4% Kena, skinless drumsticks		5.01	4.83
2% NaCl		6.33	7.33
.5% Ascorbic acid		6.58	6.58
.002% Papain		6.42	6.42
.006% Papain		6.92	6.67
.4% Emulsifier 76		6.42	6.67
.35% Synergy		6.17	6.42
5% Seal n Save		6.50	6.25
5% Seal n Save + 5:1 Water:Seal n Save		6.42	6.50
2:1 Water:Seal n Save	6.42		
4:1 Water:Seal n Save	6.75		
1 1/2% Gold Medal		6.92	7.08
2% Gold Medal	6.00		

Number of taste panel scores per mean = 12.

Taste panel scale = 8) very desireable; 7) desireable; 6) moderately desireable; 5) slightly desireable; 4) slightly undesireable; 3) moderately undesireable; 2) undesireable; 1) very undesireable.

All additives were diluted in distilled water.

COMPOSITION AND CHARACTERISTICS OF COATED BROILER PARTS

by

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AN ABSTRACT OF A MASTER'S THESIS

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Abstract

Cooking methods affected yield of poultry breasts and thighs. Cooking losses were observed as follows: baking < broiling < microwaving < panfrying < pressurized deepfat frying. The presence of a food coating greatly reduced moisture loss. More moisture was retained in poultry meat after broiling, baking, and panfrying than in microwaving and deepfat frying, and in thigh meat than breast meat. Higher concentrations of minerals were found in poultry muscle after microwaving and in uncoated rather than in coated meat. Those minerals affected by cooking method included Fe, Mg, Na, and Zn; those stable during cooking included Ca, P, K, S, Cu, and Mn.

Correlation between the original weight of a broiler drumstick and cooking loss was highly significant (P=.0001), and an regression equation $y = 32.58 = 0.1081x$ was calculated to describe the relation. Similarly, the relation between % crumb loss and original weight of a drumstick was highly significant (P=.0001) and the regression equation $y = -0.2196 + 0.0207x$ was calculated. The % overall yield was also dependent upon original weight (P=.0003). The regression equation $y = 72.97 + 0.1010x$ describes that relationship. The % coating pickup of drumsticks coated at room temperature (23°C) was not significantly different ($P< 0.05$) from those coated at refrigerator temperature (4°C), with means of 5.34%, and 5.05%, respectively. Those drumsticks coated at 110°C however, had a lower % coating pickup, possibly due to a drier skin surface and those coated at -15.5°C had the least coating pickup. Poultry parts frozen before coating had the highest cooking loss and those coated at 23°C and 4°C had significantly lower % cooking losses of 24.52% and 24.55%, repectively. The % crumb loss of broiler parts coated at 4°C, 23°C, and -15.5°C, of 1.72%, 1.52%, and 1.50% was significantly higher than drumsticks coated at 110°C with 1.13% crumb loss, but the drumsticks coated

while frozen had very little coating pickup in the first place. The % overall yield of drumsticks coated at 23°C (79.30%), and 4°C (78.78%) was significantly higher than those coated at 110°C (76.40%), and those had significantly higher yield than poultry drumsticks coated at -15.5°C. Broiler drumsticks coated without skin had significantly increased coating pickup and decreased crumb loss over drumsticks with the skin on, but the % overall yields of 77.97% for those without skin, and 78.78% for those with skin were not significantly different.

Drumsticks marinated at 23°C had a significantly higher % weight gain than drumsticks marinated at 4°C (P=.0001) for 30 and 60 min. Those marinated at 4°C had an average % absorption of 1.75%, while those drumsticks marinated at 23°C had average weight gains of 3.81%.

Different chemical groups including acids, enzymes, salts, and emulsifiers and gums were studied in relation to % weight gain, % coating pickup, % cooking loss, % crumb loss and % overall yield of coated broiler drumsticks by using them in agitated soak solutions for 30 or 60 min., or as a batter substitute during coating. Emulsifiers and gums used as a batter substitute had significantly higher coating pickup (12.25%) and the control drumsticks, using a milk batter had the lowest (5.34%). The % cooking loss was highest for control drumsticks (23.46%) that were soaked in distilled water. The % crumb loss was highest for drumsticks treated with emulsifiers and gums used as batter substitutes (4.14%) and lowest with milk batter control drumsticks. Drumsticks marinated in distilled water had the highest overall yield (86.67%) and the non-marinated drumsticks using a milk batter the lowest (79.30%). The non-marinated drumsticks coated with emulsifiers and gums as a batter substitute had a high overall yield of 83.12%. A taste panel preferred drumsticks soaked in a 2% NaCl solution and scored low, skinless drumsticks soaked in a 4% Kena solution (90% tripolyphosphate and 10%

hexametaphosphate blend made by Stauffer Chemical Co.). The taste panel found little difference in drumsticks treated with the other additives used in the study.