ADHESION OF COATING TO BROILER DRUMSTICKS

by

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INTRODUCTION

Deep-fat fried foods, and in particular chicken, are widely accepted among people of all ages. Fried chicken, furthermore, is very popular in commercial food-serving establishments due to the inconvenience of preparing fried chicken in the home; fried chicken is usually prepared by coating the chicken in a batter and/or a dry mix, such as breading and subsequently fat frying the coated chicken parts. The cooked product is then consumed immediately or the product may be packaged and quick frozen so that the consumer may finish preparing simply by reheating the chicken. Adhesion of the coating to the chicken then becomes important for both economic and aesthetic reasons.

Batters, in general, are liquid mixtures consisting primarily of water or milk (or a combination of the two), egg, flour, starch, and seasonings. Breadings, on the other hand, are dry mixtures containing such ingredients as flour, starch, bread crumbs, and seasonings; adding crispness to the final product. Coatings refer to the batter and/or breading adhering to the food product after cooking. In reading the literature, however, the terms batter and breading are often used interchangeably.

Coatings may contribute to the food product's appearance, taste, juiciness, crispness, texture, and overall acceptability (Suderman, 1979). Adhesion of the coating to the food product has been, and still is, under investigation. A commercial firm, makers of a coating mix, provided financial assistance for researchers at Kansas State University to further investigate the problem of coating adhesion to poultry. Specific areas of interest included:

1) The effect of temperature on adhesion of coating to broiler drumsticks.

2) Coating adhesion on broiler drumsticks prepared by microwave and conventional oven cooking.

3) The effect of chemical predips on adhesion of coating to broiler drumsticks.

4) The effect of cooking method on composition of broiler skin.

The results are presented in the following four papers.

LITERATURE REVIEW

For food processors who manufacture battered and breaded products, adhesion of coating is important. Coating losses create aesthetic problems to the consumer and economic losses to the food processor. Past studies involving the problem of coating adhesion to breaded products generally focused on cooking method and coating ingredients.

Smith and Vail (1962) compared skillet-frying, deep-fat frying, and oven-frying of flour-coated chicken. Although skillet-frying gave a higher yield than deep-fat or oven-frying the difference in yield due to cooking method was not statistically significant.

Hanson and Fletcher (1963) examined the possibility of precooking chicken as a means of improving coating adhesion. They believed that in typical deep-fat frying, the coating rapidly coagulates to the conformation of the original piece while the chicken itself shrinks away from the coating. In addition, the steam formed during heating forces the coagulated coating away from the meat resulting in a loose-fitting coating. Hanson and Fletcher, therefore, showed that coating adhesion could be improved by simmering the chicken parts in water so that the major cooking loss and shrinkage could occur before the batter was applied; resulting in a product with a tight coating that was less likely to peel.

Mostert and Stadelman (1964) studied cooking losses of breaded chicken cooked by deep-fat fry with zero pressure, deep-fat fry with 9 p.s.i. steam pressure, deep-fat fry with 30 p.s.i. steam pressure, pan-fry, and oven-fry. They concluded that pan-frying resulted in a cooking loss significantly higher than any of the other cooking methods while deep-fat frying in combination with 9 or 30 p.s.i. steam pressure resulted in significantly lower cooking losses.

Hale and Goodwin (1968) examined the effects of different precooking methods on coating adhesion after deep-fat frying. No significant differences in batter adhesion were observed for chicken prepared by conventional deep-fat frying and chicken prepared by microwave precooking followed by deep-fat frying. Sensory panel evaluation, however, indicated that precooking improved texture and hardness of the coating.

In addition, Hale and Goodwin (1968) compared conventional deep-fat frying, microwave precooking followed by deep-fat frying, and autoclave precooking followed by deep-fat frying. They found that adhesion of the batter coating was significantly greater when the chicken was precooked, by either method. Coating texture and hardness of the precooked chicken was judged better than the coating of the conventional deep-fat fried chicken although flavor of the conventional deep-fat fried product was better.

Baker _et al_. (1972) studied precooking by steaming, simmering, and boiling of chicken which was then predusted, battered, breaded, and deep-fat fried. These cooking methods produced an attractive product, with little problem of adhesion of the breading to the chicken.

Love and Goodwin (1974) examined the effect of cooking method and found that chicken breaded prior to steam cooking had better breading adhesion and breading pick-up then chicken breaded after water cooking.

Yang and Chen (1979) compared yield of chicken either battered and breaded or flour predusted, battered, and floured again before deep-fat frying. They found that fried chicken prepared with the flour predust-batter-flour method had higher yields than that prepared with the batter-breading method.

Suderman (1979) examined the effect of freezing and thawing of chicken parts on coating adhesion. He found that freezing and thawing chicken parts prior to breading only slightly improved coating adhesion as opposed to using fresh chicken.

With regard to coating ingredients, Hanson and Fletcher (1963) described some of the effects of formula variation of coatings applied after precooking chicken parts. They found that thick coatings peeled more readily than thin ones;

although a batter solids-moisture ratio of 1:0.70 produced a thicker coating with good adhesive properties it peeled more easily than a batter solids-moisture ratio of 1:0.85 which also had good adhesive properties. They also observed that coatings prepared from the waxy cereals 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 tended to peel off intact. Egg yolk content of the coating influenced color but had little effect on adhesion although there was a slight toughening of the coating as egg content increased.

Baker et al. (1972) compared various predust materials including starches, proteins, and gums to determine their effect on coating adhesion. They observed that protein materials produced crusts with better adhesion than starches or gums, eventhough the gums and starch materials had better predust pickup. Of the proteins tested, dried egg albumen produced the best coating adhesion followed by wheat gluten and soy concentrate.

Suderman (1979) studied the effect of various protein and gum sources and their increased levels on coating adhesion to broiler drumsticks. He found that protein source affected the adhesion of breading to poultry skin; gelatin was the best followed in order by egg albumen, NFDM, soy, and whey. The source of gum also affected the adhesion of breading to poultry skin; CMC was significantly better than guar, tragacanth, and xanthan gums. Furthermore, increased levels of proteins and gums in the breading did not significantly affect adhesion.

Suderman (1979) also examined the effect of various predips and found that type of predip affected coating adhesion to broiler drumsticks; coating adhesion improved as predip usage progressed from water to whole milk and to evaporated milk.

Sison (1972) found that soaking raw chicken pieces overnight in a polyphosphate solution improved coating adhesion. Polyphosphate treatments also decreased cooking drip loss and increased moisture retention (Schermerhorn <u>et al</u>., 1963; Monk <u>et al</u>., 1964; Baker <u>et al</u>., 1972; and Sison, 1972).

A review of several patents suggests that starch modification may be of significance in improving adhesion of coatings to poultry. Ducharme <u>et al</u>. (1962) claimed to improve breading adhesion by using crosslinked starches; starches modified so that temperatures required for gelatinization of the starch molecules are greater than those temperatures required to gelatinize unmodified starch molecules. The higher gelatinization temperature may retard firming of the batter coating until the majority of shrinkage in the food has occurred (Davis, 1981).

Another starch modification approach involves oxidizing batter starches as a means of improving coating adhesion. Antinori et al. (1968) suggested exposing dry starch to a stream of oxidizing gas (i.e. ozone, chlorine, chlorine dioxide, nitrosyl chloride, nitrogen dioxide). Marotta et al. (1969) sprayed dry starch with an aqueous solution of sodium hypochlorite. Gabel et al. (1971) treated the aqueous starch slurry with sodium hypochlorite followed by hydrogen peroxide. Fruin (1973) mixed dry starch with calcium hypochlorite. Oxidizing portions of the starch molecule to hemiacetal or hemialdal groups which during cooking react with amine groups in the protein portion of the coated food results in a covalent bonding of the coating to the food surface (Davis, 1981). Campbell (1972) suggested adjusting the protein level of a commercial starch to about 0.7 percent or more by weight of starch before oxidizing to produce a batter starch having superior adhesion properties.

A third area of starch modification, described by Moore et al. (1976), involves a batter starch system comprised of unmodified granular starches which lose birefringency at 125 F and cold-water swelling granular starches which lose birefringency within the range of 40 F and 120 F. The cold-water swelling starches reportedly impart a stable viscosity, salt tolerance and exceptional properties to the batter system.

In measuring coating adhesion one of the most common approaches involved subjective methods of scoring adhesion using a rating system applied by a taste panel (Hanson and Fletcher, 1963; Hale and Goodwin, 1968; Wyche and Goodwin, 1971; Baker *et al*., 1972; and Sison, 1972). Another common method simply involved peeling or scraping of the coating from the food piece to see how much of the food adhered to the coating (Ducharme *et al*., 1962; Antinori *et al*., 1968; Marotta *et al*., 1969; Gabel *et al*., 1971; Campbell, 1972; and Fruin, 1973).

May *et al*. (1969) devised a method in which battered and breaded products were weighed, placed in a container with water and agitated with compressed air for a standard time (usually 15 minutes) to remove breading. The meat component was then blotted to remove excess moisture and reweighed. The breading percentage was calculated as follows:

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

The method gave highly significant correlations with breading content of several types of breaded products. The authors reported, however, that their method was unsuited for two types of products tested because of loss of product integrity or failure to solubilize breading.

A more recent method to measure coating adhesion was developed by Suderman and Cunningham (1979). They developed a rapid objective method for measuring breading adhesion to poultry skin with the advantage that it simulates crumb loss which can occur during packaging, transportation, and handling. The process consists of shaking a breaded product, such as a broiler drumstick, on a standard wire sieve in a portable sieve shaker for one minute. The percent breading loss can then be calculated as follows:

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

PAPER 1

THE EFFECT OF TEMPERATURE ON ADHESION OF COATING TO BROILER DRUMSTICKS

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ABSTRACT

Coating adhesion of breaded broiler drumsticks was examined at different temperatures. Broiler drumsticks were coated with a commercial seasoned coating mix, baked in a conventional oven, cooled to different temperatures, then shaken on a portable sieve shaker to measure the crumb loss. Coating adhesion improved as the temperature of the broiler drumsticks decreased. Better adhesion may result from firming of the starch gel during starch retrogradation.

MATERIALS AND METHODS

Commercially processed and frozen broiler drumsticks, 92.4 grams average weight, were thawed to room temperature, moistened with water and subsequently coated with a commercial seasoned coating mix by shaking the individual drumsticks in a bag of the commercial breading. Ingredients of the coating mix, as listed on the package label in decreasing order are, wheat flour; partially hydrogenated soybean, cottonseed and palm oils; salt; malted barley; sugar; spices; paprika; yeast; cornstarch; dried garlic; monosodium glutamate; natural hickory smoke flavor; artificial color; dried onion. The coated drumsticks were oven-baked for 40 minutes at 204.4 C and then cooled to different temperatures. The temperature of the muscle surface (i.e. just below the skin) was recorded one minute after the thermometer (Weston Instruments, Inc. Model #2261) had been placed between the epidermal and muscle layers. Duplicate drumsticks were used for the temperature readings taken every 20 minutes for the first 40 minutes after baking (i.e. held at room temperature for 0, 20, 40 minutes) and then at refrigerator and freezer temperatures for a total of five different temperature readings. Immediately after the temperature of the sample was recorded, the drumsticks were weighed, shaken on a portable sieve shaker and reweighed to calculate the percent crumb loss (Suderman and Cunningham, 1979). The percent crumb loss was calculated for each drumstick and from this data the mean percent crumb loss and standard deviation was calculated for each temperature average. The experiment was repeated six times; a total of 46 samples for each treatment.

RESULTS AND DISCUSSION

Temperatures between duplicate samples generally varied by 1-2 C and so temperature averages were used in compiling the crumb loss data. The average temperature for the drumsticks tested for crumb loss immediately after baking was 73.3 C while the temperature of the drumsticks tested for crumb loss 20 minutes and 40 minutes after baking were 45.0 C and 30.0 C respectively. The drumsticks which were refrigerated overnight before being tested for crumb loss had an average temperature of 15.2 C and the drumsticks frozen overnight had an average temperature of 10.4 C at the time of testing crumb loss.

It was observed that coating adhesion improved as the temperature of the drumsticks decreased; less crumb loss was found as the drumsticks cooled (Table 1). There was a slight progressive improvement in coating adhesion as the drumsticks cooled from 73.3 C to 45.0 C to 30.0 C and a significant improvement in coating adhesion for the drumsticks examined at 15.2 C and 10.4 C.

I speculate that the difference in crumb loss may be attributed to the starch fraction of the coating mix. Starch gelatinizes through the combination of heat and moisture, during baking, to form a paste. When the temperature decreases and the gelatinized starch cools the starch mixture thickens as intermolecular hydrogen bonds form creating a three-dimensional gel network (Hodge and Osman, 1976). 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 (Hodge and Osman, 1976). Therefore, I believe that as the starch fraction undergoes retrogradation the coating may shrink to the conformation of the drumstick and, thus, result in better adhesion. Retrogradation of starch, furthermore, occurs most rapidly at temperatures near 0 C (Hodge and Osman, 1976). I believe this phenomenon then explains the significant improvement in coating adhesion for the drumsticks examined at 15.2 C and 10.4 C as opposed to the drumsticks examined at 73.3 C, 45.0 C, and 30.0 C.

Although better adhesion of the coating was observed as the temperature of the drumsticks decreased time may also be an important factor. As such, additional research is needed to examine the effect of time on adhesion of coating to broiler drumsticks while temperature of the drumsticks is held constant.

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

PAPER 2

COATING ADHESION ON BROILER DRUMSTICKS PREPARED BY MICROWAVE AND CONVENTIONAL OVEN COOKING

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ABSTRACT

This study was done to compare breading adhesion of chicken prepared by microwave and conventional methods. Chicken was prepared by cooking broiler drumsticks, coated with a commercial seasoned coating mix, in a microwave oven or in a conventional oven. The drumsticks were weighed, shaken on a portable sieve shaker and reweighed to determine the percent crumb loss. It was found that baking the coated drumsticks in a conventional oven resulted in better coating adhesion and, thus, a more appealing product as opposed to cooking the drumsticks in a microwave oven.

MATERIALS AND METHODS

Commercially processed and frozen broiler drumsticks, 90.6 grams average weight, were thawed to room temperature, moistened with water and subsequently coated with a commercial seasoned coating mix by shaking the individual drumsticks in a bag of the commercial breading. Ingredients of the coating mix, as listed on the package label in decreasing order are, wheat flour; partially hydrogenated soybean, cottonseed and palm oils; salt; malted barley; sugar; spices; paprika; yeast; cornstarch; dried garlic; monosodium glutamate; natural hickory smoke flavor; artificial color;

dried onion. The coated drumsticks were cooked in a Sharp Carousel Browning Oven (R-8200, 2450 MHz) on full power; six minutes on the first side followed by four minutes on the second side or were oven-baked for 40 minutes at 204.4 C. Immediately after cooking the drumsticks were weighed, shaken on a portable sieve shaker, and reweighed to calculate the percent crumb loss (Suderman and Cunningham, 1979). The percent crumb loss was calculated for each drumstick and from this data the mean percent crumb loss and standard deviation was calculated for both the microwave and oven-baked chicken. The experiment was repeated six times; a total of 24 samples for each cooking method. In addition, I examined both taste and appearance of the drumsticks.

RESULTS AND DISCUSSION

It was observed that coating adhesion for the oven-baked broiler drumsticks was far better than the adhesion for the microwave-cooked chicken; as seen by the large difference in the mean percent crumb loss (Table 1). The difference in sample means was found to be statistically significant at a 95% confidence interval (Snedecor and Cochran, 1976).

With oven-baking, a temperature gradient is formed as heat is transferred from the exterior to the interior of the food product. The combination of a high surface temperature and low water content (i.e. due to evaporation) trigger sugar dehydration reactions, such as sugar carmelization and Maillard reactions, which produce a crisp crust on the coated broiler drumsticks. The oven-baked product, with its crisp crust, better withstands the mechanical agitation experienced in measuring coating adhesion.

Whereas with microwave cooking, microwaves penetrate food pieces (depth of penetration is a function of microwave frequency) uniformly to set all polar molecules (i.e. water molecules) in motion to create intermolecular friction and, hence, heat (Potter, 1973). Heat is, therefore, uniformly generated throughout the food piece and not passed by conduction from the surface inward. Steam that is produced from the internal boiling away of moisture also heats the food, but by conduction (Potter, 1973). As the free water of the food system is converted to steam, the temperature of the food piece does not exceed the boiling point of water and, as a result, there is no surface dehydration and no crisp crust is formed from excessive surface heat. Instead the coating only loosely adheres to the broiler skin and does not withstand the mechanical agitation experienced in measuring coating adhesion.

In addition, I evaluated the microwave and oven-baked drumsticks for differences in taste (Table 2) and appearance (Table 3).

When taste testing the samples I found the oven-baked broiler drumsticks to be less juicy and slightly less tender than the microwave-cooked chicken (Table 2). The decrease in juiciness of the oven-baked chicken could be attributed to the evaporation of moisture during the longer cooking times, which would then result in a drier and less tender product. In handling the samples, the microwave-cooked chicken felt more greasy than the oven-baked chicken. I suspect that the greasy feeling was due to a combination of fat and higher moisture (i.e. less evaporation during cooking); contributing to the limpness in the coating of the microwave-cooked chicken (Table 2). The crisp texture of the oven-baked chicken, however, was only temporary for as soon as the coating absorbed moisture (most probably from the hot drumsticks) the coating lost its crisp texture. To look at the samples, the coating of the oven-baked chicken had better coloring (a deeper brown more characteristic of fried chicken) and also adhered more uniformly (no thinly coated areas) to the chicken drumstick, thus adding to the overall visual appeal of the oven-baked chicken (Table 3). Therefore, I found the oven-baked chicken more desirable than the microwave-cooked chicken.

Table 1. Crumb loss as a function of cooking method.

	Microwave	Oven Bake
Mean	9.41*	3.24*
Std. Deviation	7.93	2.63

* = significant at a 95% confidence interval

Table 2. Taste of microwave and oven-baked chicken.

	Microwave	Oven Bake
Juiciness	Juicy	Slight Juicy
Tenderness	Tender	Medium Tender
Greasiness	Greasy	Not Greasy
Texture	Limp	Crisp

Table 3. Appearance of microwave and oven-baked chicken.

	Microwave	Oven Bake
Color	Golden Brown	Deep Brown
Visual Adhesion	Loose, not uniform	Tight, uniform
Overall Appearance	Undesirable	Desirable

PAPER 3

THE EFFECT OF CHEMICAL PREDIPS ON ADHESION OF COATING TO BROILER DRUMSTICKS

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ABSTRACT

Chicken was prepared by soaking broiler drumsticks in chemical predips prior to applying a commercial seasoned coating mix. The drumsticks were then oven-baked and evaluated for crumb loss. Phosphate solutions significantly affected crumb loss of the coated broiler drumsticks while acid solutions did not significantly affect crumb loss.

MATERIALS AND METHODS

Commercially processed and frozen broiler drumsticks, 97.2 grams average weight, were thawed to room temperature and soaked in various acid and phosphate solutions for 30 minutes. The drumsticks were then coated with a commercial seasoned coating mix by shaking the individual drumsticks in a bag of the commercial breading. Ingredients of the coating mix, as listed on the package label in decreasing order are, wheat flour; partially hydrogenated soybean, cottonseed and palm oils; salt; malted barley; sugar; spices; paprika; yeast; cornstarch; dried garlic; monosodium glutamate; natural hickory smoke flavor; artificial color; dried onion. The coated broiler drumsticks were oven-baked for 40 minutes at 204.4 C, weighed, shaken on a portable sieve shaker then reweighed to calculate the percent crumb loss (Suderman and Cunningham, 1979). The predips included 0%, 0.5%, 1.0%, 2.5%, and 5.0% solutions of Kena (Stauffer Chemical Co. Formula FP-28), Curafos Tripolyphosphate (Calgon Corp. Granular 00-22), Curafos Sodium Tripolyphosphate and Sodium Hexametaphosphate blend (Calgon Corp. Formula 22-4), citric acid, and tartaric acid. The data was analyzed by analysis of variance and by Duncan's multiple range test (Snedecor and Cochran, 1976) with the aid of SAS (Statistical Analysis System) computer programming.

RESULTS AND DISCUSSION

It was found that Curafos Tripolyphosphate (Table 1), Curafos Sodium Tripolyphosphate and Sodium Hexametaphosphate blend (Table 3), and Kena (Table 5) all significantly affected crumb loss of the coated broiler drumsticks. Furthermore, a linear relationship between crumb loss and phosphate solution was observed for both the Curafos Tripolyphosphate (Table 1) and the Curafos Sodium Tripolyphosphate and Sodium Hexametaphosphate blend (Table 3); less crumb loss as the concentration of the solution increased. However, a linear relationship between crumb loss and phosphate solution was not observed with Kena (Table 5). It was also observed that the 1.0% and 5.0% solutions were more effective at decreasing crumb loss (Tables 2, 4, 6).

Citric acid (Tables 7 & 8) and tartaric acid (Tables 9 & 10), in contrast, did not significantly affect crumb loss of the coated broiler drumsticks.

Tripolyphosphates are commonly used in the processed meat industry to improve stability of cured meat color in the case of cured hams; to reduce fluid loss during cooking, refrigeration, and thawing of red meats, poultry, and fish; and to stabilize cooked flavor, color, and odor because of the reduction in oxidative changes in uncured red meat and poultry products (Mahon et al., 1971).

Mahon et al. (1971) reported immersing whole poultry carcasses in a 6% polyphosphate solution for 6-18 hours at refrigerated temperature to impart an adequate level of phosphate to the flesh. The authors also reported that cooking in 2-4% polyphosphate solutions resulted in poultry that absorbed a reasonable level of polyphosphates. Cutting a broiler carcass into several individual pieces significantly reduced both the immersion time and the polyphosphate concentration required to impart an adequate level of polyphosphate; overnight marinating in 3% tripolyphosphate resulted in poultry parts absorbing adequate levels of phosphate (Mahon et al., 1971).

The broiler drumsticks in this experiment, however, were allowed to soak in the phosphate solutions for 30 minutes. Since the individual broiler drumsticks were immersed in the solutions, as opposed to a whole poultry carcass, less time was needed for the phosphate solutions to diffuse into or penetrate the poultry skin and muscle to have a significant affect on the broiler parts. Therefore, improved coating adhesion was observed for the broiler drumsticks soaked in the phosphate solutions.

Table 1. Analysis of Variance--Crumb loss of broiler drumsticks as influenced by Curafos Tripolyphosphate.

Source	d.f.	SS	MSS	F value
Tripol.	4	167.82	41.96	3.10*
Linear	1	130.65	130.65	9.67**
Lack of fit	3	37.17	12.39	0.92
ERROR	85	1148.83	13.52	

d.f. = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

* = significant at alpha level = 0.05

** = significant at alpha level = 0.01

Table 2. Duncan's Multiple Range Test--Effect of Curafos Tripolyphosphate concentration on crumb loss of broiler drumsticks.

Grouping	Mean	N	Concentration
a	6.01	10	0.5%
a	5.80	50	0% (control)
a,b	4.10	10	2.5%
a,b	3.19	10	1.0%
b	2.08	10	5.0%

N = number of samples

alpha level = 0.05

degrees of freedom = 85

mean square = 13.52

Means with the same letter are not significantly different.

Table 3. Analysis of Variance--Crumb loss of broiler drumsticks as influenced by Curafos Sodium Tripolyphosphate and Sodium Hexametaphosphate blend.

Source	d.f.	SS	MSS	F value
Blend	4	213.36	53.34	3.26*
Linear	1	80.69	80.69	4.94*
Lack of fit	3	132.67	44.22	2.70
ERROR	85	1390.12	16.35	

d.f. = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

* = significant at alpha level = 0.05

Table 4. Duncan's Multiple Range Test--Effect of Curafos Sodium Tripolyphosphate and Sodium Hexametaphosphate blend concentration on crumb loss of broiler drumsticks.

Grouping	Mean	N	Concentration
a	6.27	10	2.5%
a	5.80	50	0% (control)
a,b	4.62	10	0.5%
b	2.23	10	1.0%
b	2.03	10	5.0%

N = number of samples

alpha level = 0.05

degrees of freedom = 85

mean square = 16.35

Means with the same letter are not significantly different.

Table 5. Analysis of Variance--Crumb loss of broiler drumsticks as influenced by Kena.

Source	d.f.	SS	MSS	F value
Kena	4	179.21	44.80	2.53*
Linear	1	38.59	38.59	2.18
Lack of fit	3	140.62	46.87	2.65
ERROR	85	1504.41	17.70	

d.f. = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

* = significant at alpha level = 0.05

Table 6. Duncan's Multiple Range Test--Effect of Kena concentration on crumb loss of broiler drumsticks.

Grouping	Mean	N	Concentration
a	7.12	10	0.5%
a	6.62	10	2.5%
a	5.80	50	0% (control)
a,b	3.28	10	5.0%
b	2.54	10	1.0%

N = number of samples

alpha level = 0.05

degrees of freedom = 85

mean square = 17.70

Means with the same letter are not significantly different.

Table 7. Analysis of Variance--Crumb loss of broiler drumsticks as influenced by citric acid.

Source	d.f.	SS	MSS	F value
citric	4	128.71	32.18	1.22
Linear	1	0.06	0.06	0.00
Lack of fit	3	128.65	42.88	1.63
ERROR	85	2237.56	26.32	

d.f. = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

Table 8. Duncan's Multiple Range Test--Effect of citric acid concentration on crumb loss of broiler drumsticks.

Grouping	Mean	N	Concentration
a	8.77	10	2.5%
a	7.96	10	1.0%
a	7.40	10	0.5%
a	5.80	50	0% (control)
a	4.98	10	5.0%

N = number of samples

alpha level = 0.05

degrees of freedom = 85

mean square = 26.32

Means with the same letter are not significantly different.

Table 9. Analysis of Variance--Crumb loss of broiler drumsticks as influenced by tartaric acid.

Source	d.f.	SS	MSS	F value
tartaric	4	89.45	22.36	1.39
Linear	1	45.10	45.10	2.80
Lack of fit	3	44.35	14.78	0.92
ERROR	85	1368.76	16.10	

d.f. = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

Table 10. Duncan's Multiple Range Test--Effect of tartaric acid concentration on crumb loss of broiler drumsticks.

Grouping	Mean	N	Concentration
a	6.14	10	0.5%
a	5.80	10	2.5%
a	5.80	50	0% (control)
a	3.68	10	1.0%
a	3.26	10	5.0%

N = number of samples

alpha level = 0.05

degrees of freedom = 85

mean square = 16.10

Means with the same letter are not significantly different.

PAPER 4

THE EFFECT OF COOKING METHOD ON COMPOSITION OF BROILER SKIN

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ABSTRACT

Coated and uncoated commercially processed broiler drumsticks were cooked by five different methods. After cooking, the skins of the broiler drumsticks were removed and analyzed. The skin samples were also examined for elemental differences by energy dispersive X-ray analysis through the scanning electron microscope.

From the proximate analysis results, cooking method significantly affected the dry matter, protein, ether extract, and ash contents of cooked broiler skin. Broiler drumsticks cooked by deep-fat frying had high dry matter and ether extract contents. Protein content differed significantly only in the sample cooked by microwave/browning. The microwave and microwave/browning samples had a higher ash content than samples of other cooking methods.

Coating application significantly affected the dry matter, protein, ether extract, and ash contents of the cooked broiler skin. Broiler drumsticks that were coated prior to cooking resulted in skin samples with higher dry matter and ash contents but lower protein and ether extract contents than skin samples without coating.

With regard to elemental composition, oven-broil had the lowest sulfur content while oven-bake had the highest sulfur content. Oven-broil had the lowest potassium

content while deep-fat fried had the highest potassium content. Microwave/browning had the lowest phosphorous content while deep-fat fried had the highest phosphorous content. Deep-fat fried had the lowest chlorine content while microwave/-browning had the highest chlorine content.

MATERIALS AND METHODS

Commercially processed and frozen broiler drumsticks, 91.5 grams average weight, were thawed to room temperature, moistened with water and subsequently coated with a commercial seasoned coating mix by shaking the individual drumsticks in a bag of the commercial breading. Ingredients of the coating mix, as listed on the package label in decreasing order are, wheat flour; partially hydrogenated soybean, cottonseed and palm oils; salt; malted barley; sugar; spices; paprika; yeast; cornstarch; dried garlic; monosodium glutamate; natural hickory smoke flavor; artificial color; dried onion. The coated and uncoated broiler drumsticks were cooked by five different cooking methods: (1) Microwave Oven (Sharp Carousel Browning Oven R-8200, 2450 MHz)-with each trial four drumsticks placed side by side in a two quart square Corning Ware baking dish were cooked on full power for six minutes on the first side followed by four minutes on the second side; (2) Microwave Plus Browning Element (Sharp Carousel Browning Oven R-8200, 2450 MHz)-with each trial four drumsticks placed side by side in a two quart square Corning Ware baking dish were cooked on full power for four minutes followed by eight minutes of browning (browning element in its lowest position) before turning the drumsticks over and cooking on full power for two minutes followed by eight minutes of browning; (3) Low Pressure Deep-Fat Fry (Presto Electric Low Pressure Chicken Fryer)-four drumsticks were cooked per trial by first browning the drumsticks for two minutes followed by seven minutes of pressure cooking; (4) Oven-Broil-the drumsticks were broiled in a conventional oven for 20 minutes per side (broiling rack was positioned approximately seven inches from the broiling element); (5) Oven-Bake-the drumsticks were baked at 204.4 C for 40 minutes without turning.

After cooking, the skins of the broiler drumsticks were removed and analyzed by proximate analysis; dry matter, protein, ether extract, and ash. The coating was scraped off the coated samples before submitting the cooked skins for analysis. In the analysis, the protein, ether extract, and ash were based on the dry matter. Since the analysis was on a wet weight basis it was necessary to correct for this by dividing the values for protein, ether extract, and ash by the decimal percent of dry matter. Samples of raw broiler skin were analyzed by proximate analysis to be used as the control.

In addition, the skin samples were examined for elemental differences by energy dispersive X-ray analysis through the scanning electron microscope operating at 10 Kv acceleration voltage and 1.5 amps condensor current for 200 seconds. Specimens from the skin samples were frozen in liquid nitrogen (i.e. immediately after cooking) then freeze-dried for 48 hours before mounting on aluminum SEM mounting stubs with Pelco No. 93 colloidal silver paint and allowed to air dry at room temperature.

The raw data from the proximate analysis was analyzed by a two-way analysis of variance and by Duncan's multiple range test (Snedecor and Cochran, 1976) with the aid of SAS (Statistical Analysis System) computer programming.

RESULTS AND DISCUSSION

It was found that cooking method significantly affected the dry matter (Table 1), protein (Table 2), ether extract (Table 3), and ash contents (Table 4) of the cooked broiler skin.

There was a significant difference in dry matter content of the deep-fat fried sample compared to other cooking methods; dry matter content of the deep-fat fried sample was significantly greater (Table 5). The high dry matter content was probably due to a high evaporation of moisture during the cooking process. With regard to protein, the microwave/browning sample was significantly greater in protein content compared to the other methods of cooking (Table 6). Theoretically, the protein content of the broiler skin should not change from one cooking method to another. I can only speculate that the difference in protein content of the microwave/browning sample was due to sample variability. Ether extract content of the cooked broiler skins varied among themselves with the deep-fat fried sample having a high ether extract content (Table 7). As a result of a high loss of moisture and an appreciable absorption of fat during cooking, deep-fat frying affected the ether extract content of the cooked broiler skin. As far as ash content of the cooked broiler skins, the microwave and microwave/browning samples were significantly greater in ash content than the samples cooked by other methods (Table 8). As with protein, ash content should not vary as a result of cooking method. The difference in ash content, therefore, may be due to sample variability.

Although the coating was removed from the coated samples prior to analysis, coating the broiler drumsticks significantly affected the dry matter (Table 1), the protein (Table 2), the ether extract (Table 3), and the ash contents of the cooked broiler skin. With the presence of coating, the dry matter content was significantly higher (Table 9), the protein content was significantly lower (Table 10), the ether extract content was significantly lower (Table 11), and the ash content was significantly higher (Table 12) than the samples cooked without a coating.

Lastly, interaction between cooking method and coating application was found to be significant on dry matter (Table 1), protein (Table 2), and ether extract content (Table 3) but not on ash content (Table 4) of the skin samples. It cannot be concluded, however, that the interaction of cooking method and coating application is additive of the two variables.

To calculate the elemental composition of the broiler skins examined by energy dispersive X-ray analysis, the peak height for each element was measured (i.e. to the nearest centimeter) then converted to a ratio based on the least variable element of the skin samples. For example, phosphorous, sulfur, chlorine, and potassium were the four elements observed in each of the samples. Phosphorous exhibited the least variability (i.e. more consistant peak heights) and was, therefore, used as the reference (i.e. amount of phosphorous was set to 1.000). The other three elements were then converted to ratios based on the amount of phosphorous. With each skin sample, three different areas were examined and as such, averages of the three areas were used to compare elemental composition with regard to cooking method.

To compare the levels of sulfur, chlorine, and potassium to phosphorous among the different cooking methods the relationship of one treatment (i.e. cooking method) to the relationship of the fresh, uncooked skin sample was examined (Table 13).

With the microwave/browning sample the sulfur to phosphorous level was significantly lower and the chlorine to phosphorous level was significantly higher than those of the fresh, uncooked skin sample (Table 13). The potassium to phosphorous level of the microwave/browning and the fresh, uncooked sample was relatively unchanged (Table 13).

With the microwave sample the sulfur to phosphorous level significantly decreased while the chlorine to phosphorous level and the potassium to phosphorous level were relatively unchanged from the fresh, uncooked sample (Table 13).

With the oven-baked sample the potassium to phosphorous level significantly increased while both the sulfur to phosphorous and the chlorine to phosphorous levels were relatively unchanged from the fresh, uncooked sample (Table 13).

With the deep-fat fried sample the potassium to phosphorous level significantly increased and the sulfur to phosphorous level significantly decreased while the chlorine to phosphorous level was relatively unchanged from the fresh, uncooked sample (Table 13).

With the oven-broiled sample both the sulfur to phosphorous and the potassium to phosphorous levels significantly decreased while the chlorine to phosphorous level was relatively unchanged from the fresh, uncooked sample (Tabke 13).

To evaluate phosphorous the elements had to be converted to new ratios based on the amount of chlorine (i.e. the second least variable element). The levels of phosphorous, sulfur, and potassium to chlorine among the different cooking methods were then examined (Table 14).

With the microwave/browning sample both the phosphorous to chlorine and the sulfur to chlorine levels significantly decreased while the potassium to chlorine level was relatively unchanged from the fresh, uncooked sample (Table 14).

With the microwave sample the sulfur to chlorine level significantly decreased while both the phosphorous to chlorine and the potassium to chlorine levels were relatively unchanged from the fresh, uncooked sample (Table 14).

With the oven-baked sample the potassium to chlorine level significantly increased while both the phosphorous to chlorine and the sulfur to chlorine levels were relatively unchanged from the fresh, uncooked sample (Table 14).

With the deep-fat fried sample both the phosphorous to chlorine and the potassium to chlorine levels significantly increased while the sulfur to chlorine level was relatively unchanged from the fresh, uncooked sample (Table 14).

With the oven-broiled sample both the sulfur to chlorine and the potassium to chlorine levels significantly decreased while the phosphorous to chlorine level was relatively unchanged from the fresh, uncooked sample (Table 14).

In summary, oven-broil had the lowest sulfur content while oven-bake had the highest sulfur content. Oven-broil had the lowest potassium content while deep-fat fried had the highest potassium content. Microwave/browning had the lowest phosphorous content while deep-fat fried had the highest phosphorous content. Deep-fat fried had the lowest chlorine content while microwave/browning had the highest chlorine content.

Table 1. Two-Way Analysis of Variance--Dry matter content of broiler skin as influenced by cooking and coating.

Source	d.f.	SS	MSS	F value
cook	5	10811.89	2162.38	45.46**
coat	1	236.05	236.05	4.96*
cook*coat	4	683.07	170.77	3.59**
ERROR	99	4709.05	47.57	
TOTAL	109	16440.06		

d.f. = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

* = significant at alpha level = 0.05

** = significant at alpha level = 0.01

Table 2. Two-Way Analysis of Variance--Protein content of broiler skin as influenced by cooking and coating.

Source	d.f.	SS	MSS	F value
cook	5	1465.59	293.12	3.83**
coat	1	1828.07	1828.07	23.91**
cook*coat	4	884.74	221.19	2.89*
ERROR	99	7568.48	76.45	
TOTAL	109	11746.89		

d.f. = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

* = significant at alpha level = 0.05

** = significant at alpha level = 0.01

Table 3. Two-Way Analysis of Variance--Ether extract content of broiler skin as influenced by cooking and coating.

Source	d.f.	SS	MSS	F value
cook	5	3039.58	607.92	4.80**
coat	1	529.15	529.15	4.18*
cook*coat	4	1631.82	407.96	3.22*
ERROR	99	12545.81	126.73	
TOTAL	109	17746.37		

d.f. = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

* = significant at alpha level = 0.05

** = significant at alpha level = 0.01

Table 4. Two-Way Analysis of Variance--Ash content of broiler skin as influenced by cooking and coating.

Source	d.f.	SS	MSS	F value
cook	5	37.61	7.52	26.75**
coat	1	9.55	9.55	33.95**
cook*coat	4	0.81	0.20	0.72
ERROR	99	27.83	0.28	
TOTAL	109	75.80		

d.f. = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

* = significant at alpha level = 0.05

** = significant at alpha level = 0.01

Table 5. Duncan's Multiple Range Test--Dry matter content of broiler skin as influenced by cooking method.

Grouping	Mean	N	Cook
a	80.76	20	deep-fat fried
b	66.65	20	microwave/browning
b	64.85	20	oven-broil
c	56.66	20	oven-bake
c,d	54.28	20	microwave
d	49.40	10	fresh, uncooked

N = number of samples

alpha level = 0.05

degrees of freedom = 99

mean square = 47.57

Means with the same letter are not significantly different.

Table 6. Duncan's Multiple Range Test--Protein content of broiler skin as influenced by cooking method.

Grouping	Mean	N	Cook
a	45.90	20	microwave/browning
b	37.58	20	microwave
b	37.27	20	oven-bake
b	36.96	20	oven-broil
b	35.60	10	fresh, uncooked
b	35.37	20	deep-fat fried

N = number of samples

alpha level = 0.05

degrees of freedom = 99

mean square = 76.45

Means with the same letter are not significantly different.

Table 7. Duncan's Multiple Range Test--Ether extract content of broiler skin as influenced by cooking method.

Grouping	Mean	N	Cook
a	66.94	10	fresh, uncooked
a,b	59.63	20	deep-fat fried
a,b,c	58.67	20	microwave/browning
b,c,d	53.51	20	microwave
c,d	51.90	20	oven-broil
d	48.96	20	oven-bake

N = number of samples

alpha level = 0.05

degrees of freedom = 99

mean square = 126.73

Means with the same letter are not significantly different.

Table 8. Duncan's Multiple Range Test--Ash content of broiler skin as influenced by cooking method.

Grouping	Mean	N	Cook
a	3.06	20	microwave
a	3.00	20	microwave/browning
b	2.50	20	oven-broil
b	2.32	20	deep-fat fried
c	1.79	20	oven-bake
d	1.23	10	fresh, uncooked

N = number of samples

alpha level = 0.05

degrees of freedom = 99

mean square = 0.21

Means with the same letter are not significantly different.

Table 9. Duncan's Multiple Range Test--Dry matter content of broiler skin as influenced by coating.

Grouping	Mean	N	Coating
a	66.18	50	with
b	60.82	60	without

N = number of samples

alpha level = 0.05

degrees of freedom = 99

mean square = 47.57

Means with the same letter are not significantly different.

Table 10. Duncan's Multiple Range Test--Protein content of broiler skin as influenced by coating.

Grouping	Mean	N	Coating
a	41.68	60	without
b	34.34	50	with

N = number of samples

alpha level = 0.05

degrees of freedom = 99

mean square = 76.45

Means with the same letter are not significantly different.

Table 11. Duncan's Multiple Range Test--Ether extract content of broiler skin as influenced by coating.

Grouping	Mean	N	Coating
a	58.52	60	without
b	52.23	50	with

N = number of samples

alpha level = 0.05

degrees of freedom = 99

mean square = 126.73

Means with the same letter are not significantly different.

Table 12. Duncan's Multiple Range Test--Ash content of broiler skin as influenced by coating.

Grouping	Mean	N	Coating
a	2.84	50	with
b	2.06	60	without

N = number of samples

alpha level = 0.05

degrees of freedom = 99

mean square = 0.28

Means with the same letter are not significantly different.

Table 13. Effect of cooking method on elemental composition of broiler skin--Phosphorous standard.

Cook	P	S	Cl	K
microwave/browning	1.000	0.763	1.337	0.952
microwave	1.000	0.649	1.172	0.981
oven-bake	1.000	1.133	0.978	1.057
deep-fat fried	1.000	0.821	0.866	2.398
oven-broil	1.000	0.369	1.058	0.348
fresh, uncooked	1.000	1.133	1.000	0.790

P = phosphorous

S = sulfur

Cl = chlorine

K = potassium

Table 14. Effect of cooking method on elemental composition of broiler skin--Chlorine standard.

Cook	Cl	S	P	K
microwave/browning	1.000	0.613	0.777	0.721
microwave	1.000	0.645	0.979	0.836
oven-bake	1.000	1.248	1.098	1.068
deep-fat fried	1.000	0.953	1.206	2.581
oven-broil	1.000	0.403	0.984	0.362
fresh, uncooked	1.000	1.144	1.002	0.795

Cl = chlorine

S = sulfur

P = phosphorous

K = potassium

CONCLUSION

In summary, I found coating adhesion of breaded broiler drumsticks improved as the temperature of the broiler drumsticks decreased. I believe better adhesion may result from firming of the starch fraction of the coating mix as the starch undergoes gelatinization and retrogradation (which favors cooler temperatures); producing a gel that becomes firmer as hydrogen bonding increases between the starch molecules.

I also found that coating adhesion for oven-baked broiler drumsticks was better than adhesion for microwave-cooked chicken. I believe better adhesion may be attributed to the crisp crust formed on the oven-baked chicken as a result of the high surface temperature and subsequent dehydration of the coating. Microwave cooking, in contrast, does not produce a crisp crust since there is no dehydration of the surface.

Presoaking broiler drumsticks in phosphate solutions affected coating adhesion while acid solutions did not affect coating adhesion. There was a linear relationship between crumb loss of the coated drumsticks and concentration of phosphate solution for both Curafos Tripolyphosphate and Curafos Sodium Tripolyphosphate and Sodium Hexametaphosphate blend. Yet there was no linear relationship between crumb loss and concentration of Kena phosphate solution.

Although the problem of adhesion of batters and/or breadings to poultry has been investigated for some time there is still much research that needs to be done; primarily on the chemical mechanism of coating adhesion. In reviewing the literature, past research was fairly limited in scope and relied on subjective observations; researchers simply reported observable changes in coating adhesion as influenced by cooking method or coating ingredients. Hanson and Fletcher (1963), however, did formulate a theory on what physically occurred to the coating in typical deep-fat frying. They believed that in deep-fat frying chicken, the coating rapidly coagulated to the conformation of the original piece while the chicken itself shrank away from the coating. Steam formed during heating then forced the coagulated coating away from the meat resulting in a loose-fitting coating. Later, Suderman (1979) hypothesized that adhesion of batters and breadings to poultry skin could be affected by poultry skin ultra-structure. He theorized that improved adhesion could result from batters and breadings applied to poultry skin without the cuticle (stratum corneum); speculating that the coating particles could lodge between skin protrusions extending up from the stratum germinativum (i.e. the layer just below the cuticle).

Still the chemical binding of coating to poultry skin has not been investigated. To fully understand the mechanism of coating adhesion and, therefore, solve the problem, I recommend future research to focus on examining the chemical bonding forces involved with respect to such factors as cooking method and coating ingredients.

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ADHESION OF COATING TO BROILER DRUMSTICKS

by

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ABSTRACT

Coating adhesion of breaded broiler drumsticks was examined at different temperatures. Broiler drumsticks were coated with a commercial seasoned coating mix, baked in a conventional oven, cooled to different temperatures, then evaluated for crumb loss. Coating adhesion improved as the temperature of the broiler drumsticks decreased. Better adhesion may result from firming of the starch fraction of the coating mix upon starch retrogradation.

Coating adhesion was examined for breaded broiler drumsticks prepared by microwave and conventional oven cooking. Baking the coated drumsticks in a conventional oven resulted in a product that had less crumb loss, was less juicy and less tender in taste, was more crisp in texture, had better coloring, and was more uniformly coated than the broiler drumsticks cooked in a microwave oven. The key to improved coating adhesion with the oven-baked drumsticks is that oven baking results in surface dehydration due to high surface temperatures to produce a crisp crust.

Coating adhesion was examined for broiler drumsticks which were soaked in chemical predips prior to applying a commercial coating mix and baked in a conventional oven. Various tripolyphosphate solutions significantly affected crumb loss of the coated broiler drumsticks. Although there

was no positive correlation between increased concentration of allthe phosphate solutions and improved coating adhesion the 1.0% and 5.0% solutions seemed to be more effective at decreasing crumb loss. Solutions of citric acid and tartaric acid did not significantly affect crumb loss of the coated broiler drumsticks.

Coated and uncoated broiler drumsticks were cooked by five different methods. After cooking, the skins of the broiler drumsticks were removed and analyzed. The skin samples were also examined for elemental differences by energy dispersive X-ray analysis through the scanning electron microscope.

From the proximate analysis results, cooking method significantly affected the dry matter, protein, ether extract, and ash contents of cooked broiler skin. Broiler drumsticks cooked by deep-fat frying had high dry matter and ether extract contents. Protein content differed significantly only in the sample cooked by microwave/browning. The microwave and microwave/browning samples had a higher ash content than samples of other cooking methods.

Coating application significantly affected the dry matter, protein, ether extract, and ash contents of the cooked broiler skin. Broiler drumsticks that were coated prior to cooking resulted in skin samples with higher dry matter and ash contents but lower protein and ether extract contents than skin samples without coating.

With regard to elemental composition, oven-broil had the lowest sulfur content while oven-bake had the highest sulfur content. Oven-broil had the lowest potassium content while deep-fat fried had the highest potassium content. Microwave/browning had the lowest phosphorous content while deep-fat fried had the highest phosphorous content. Deep-fat fried had the lowest chlorine content while microwave/browning had the highest chlorine content.