ABSTRACT

CENTRALIZED PROCESSING OF FROZEN PRECOOKED CHICKEN

By

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The feasibility of centralized processing of frozen precooked chicken and the influence of processing variables on the eating quality of microwave reheated products were evaluated. Cut-up chicken pieces were coated with breadings or batters; cooked by pressure frying (PF) or by microwave-steam (MWS) precooking in combination with pressure frying or deep-fat-frying (DFF); frozen by air blast, liquid nitrogen, or liquid freon; packaged in polyethylene bags, laminated pouches, or aluminum foil trays with or without acetylated monoglyceride coating; stored at constant -18^{o}C or under simulated distribution condition; and then reheated in a microwave oven and evaluated by taste panels.

It was demonstrated that chicken can be breaded, fried, and frozen at a central place, and distributed in a frozen condition or stored up to 3 months at constant -18^{o}C

and then reheated in a microwave oven and still have an eating quality comparable to that of newly cooked controls. The eating quality of microwave reheated fried chicken was influenced by coating procedure, cooking method, packaging and storage conditions, microwave reheating time, and reheating methods, but not by soaking in polyphosphate solution nor by freezing methods.

Soaking raw chicken pieces overnight in polyphosphate solution resulted in more juicy and tender products than untreated pieces when served soon after cooking, but not after freezing and microwave reheating. Polyphosphate treatment also resulted in higher cooked and reheated yields due to absorption of moisture during soaking and to adhesion of more coating.

It was found that breadings have better adhesion and are therefore more suitable for coating fried chicken than batters. However, more studies are needed to develop coatings which are more suitable for frozen fried chicken meant to be reheated in microwave ovens.

Among the cooking methods, pressure frying was found to produce the most tender freshly cooked products, but the combination of microwave and steam precooking and deep-fat-frying is recommended for the centralized preparation of frozen fried chicken. MWS-DFF yielded microwave reheated frozen products which have comparable eating quality and yield as those of pressure frying, but with lower reheating losses.

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The packaging requirement for frozen fried chicken was shown to be dependent upon the storage conditions. Under constant -18^{O}C, most commercially practical packaging materials may be used. However, under normal distribution condition (fluctuating temperature), packaging materials with good oxygen and water vapor barrier properties are necessary to retard flavor deterioration. The results also indicated the need for constant low temperature distribution condition to prolong the eating quality of the fried chicken. The potential use of suitable edible coating for minimizing moisture losses during frozen storage and microwave reheating was demonstrated.

Taste panel members did not differentiate the acceptability of chicken reheated by different methods. However, microwave reheating was the most rapid method and could be used satisfactorily, provided the chicken pieces are heated for only the minimum time needed to bring them to serving temperature, and that reheating time be based on weight rather than on the number of pieces. Prolonged heating in a microwave oven resulted in excessive loss of weight and in decrease in juiciness and tenderness scores.

It was generally observed that chicken pieces vary widely in sizes and shapes, and thus require different processing times. As such, it is recommended that the size and cutting procedure should be made more uniform and that different pieces should be processed separately. A commercial process consisting of soaking raw cut-up chicken pieces overnight in polyphosphate solution; precooking by microwave and steam; coating with breading; browning by deep-fat-frying; freezing with any economical but reasonably fast method; and packaging in any commercially practical package with good protective properties, can be used in the centralized preparation of frozen precooked chicken.

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INTRODUCTION

The integration of nearly all phases of production and the concentration of operation in areas where labor and other production costs are lower have enabled the broiler industry to attain remarkable efficiency in the production of meat. However, over production and obsolete practices of marketing unbranded perishable commodities have resulted in very low and variable earnings in the industry. In the face of ever-increasing costs of production coupled with consumer resistance to rising food prices, the broiler industry must find means of realizing more profits from its products. One important approach is to add more value to the product by centralized processing of branded items and distributing them through retail outlets.

The National Commission on Food Marketing (1966) showed that margins or profits increase as value is added to the product or as the product is brought closer to ultimate consumption. Processing into more stable products would minimize the problem of perishability and branding could create product differentiation or brand-loyalty which could command higher prices. A less perishable product and a recognized brand name can stabilize prices against fluctuation in supply or demand. Centralized processing near or at the chicken dressing plants would allow more efficient and economical operation.

Other factors favor centralized processing for increasing the profitability of the broiler industry. Broiler meat is a widely acceptable and very economical source of high quality protein for the diet. In a consumer survey in 1956 (Weidenhamer 1958), the USDA found that broilers were being consumed by nearly all families in all regions, and most of the families ate chicken once a week or more regardless of the season of the year. Frying was the most predominant method of cooking by 94% of the families. The major reasons cited for the popularity of chicken were taste, preference, economy and ease of preparation. However, the general deterrent to the greater use of chicken was the lack of variety in its preparation. These results indicate that processing into a variety of products may enhance greater consumption of chicken. Centralized operations could justify expenditure for consumer research to determine which forms or manner of preparation would be acceptable.

The growing affluence of American society has brought about a change in the eating patterns of the people, which in turn leads to greater demand for convenience foods. There is a definite trend towards kitchen-ready, oven-ready, table-ready, quick-service, and carry out types of food items (Atkins 1965). This trend is responsible for the phenomenal growth of the fast food stores or take-out restaurants. In 1970, the fast food business accounted for 20 to 25% of the total broiler production (Loberg 1971), whereas in a large eastern chain of food stores, the fried chicken variety alone accounted for 27% of the total movement of all products from its grocery frozen food cases (Gavries 1971). A prediction was made that many food stores will add new departments to handle increasing lines of convenience food items (Progressive Grocers 1971). With the continued growth of the convenience food or fast food business, greater demand for further-processed broiler products may very well follow.

Centralized processing may improve efficiency in the distribution of broiler products as well as in the operation of the chicken take-out restaurants. The distribution of packaged retail broiler products would eliminate the cutting up and packaging operations in retail stores and the cooking operations in the chicken restaurants. These operations, when conducted in a small scale, are inefficient in the use of labor and equipment, are space-consuming, and sometimes cause sanitation problems. Elimination of these inefficient operations could result in savings which may accrue as an additional profit to the industry.

Since frying is the most popular method of chicken preparation, frozen fried chicken would be a very important product for centralized processing. Consumer acceptance of frozen fried chicken would be influenced, among other things, by price, desirable eating qualities, and convenience in preparation for serving. A reheating method which is simple, rapid, and which will result in a highly acceptable product is essential. The commercially available oven units which utilize microwave energy to heat foods rapidly and uniformly may satisfy such reheating requirements for both store and home use.

The lack of technical publications on the centralized preparation of frozen fried chicken and on the use of microwave ovens for its reheating has hampered the development of centralized processing of this product. Hence, this project was initiated to study the problems associated with the large scale preparation of frozen fried chicken and to establish possible solutions.

Objectives

1. To evaluate the feasibility of utilizing microwave energy to thaw and heat frozen fried chicken for immediate consumption.
2. To study the factors which may affect the eating quality of microwave reheated frozen fried chicken in order to develop a better system of preparation.

3. To compare three methods of cooking to determine which one would be most suitable for centralized operation.

REVIEW OF LITERATURE

A. Microwave Heating

1. Principles

Microwaves are portions of the electromagnetic spectrum with wavelengths from 1 to 100 cm or frequencies in the hundreds or thousands of megahertz (MHz). Since this frequency range is used in radar communication, the Federal Communication Commission has allocated certain frequencies for industrial, scientific, and medical (ISM) uses. The two commonly used ISM frequencies for microwave heating are 915 and 2450 MHz with wavelengths of 32.8 and 12.25 cm respectively.

Microwaves are generated by special oscillator electron tubes such as magnetron and klystron, and are radiated by an antenna through a waveguide to the load in the oven chamber. Metals and insulators are not affected by microwaves because metals reflect microwaves like mirrors reflect light, and insulators are transparent to microwaves the way glasses are to light. However, dielectric substances such as foodstuffs are translu cent to and are therefore affected by microwaves.

Microwave heating is a radiation phenomenon (Copson 1962, Badger 1970) which is accomplished in a microwave oven. According to Copson and Decareau (1966), a complete microwave oven consists of eight major components: 1) the power supply which adapts line power to the generator requirement and to ancillary components; 2) the generator or power tube which converts the power supplied into microwave energy; 3) the transmission section for energy propagation to the oven proper; 4) coupling devices which permit the transfer of the energy to the load; 5) distributing devices which deliver the energy in a uniform interaction pattern; 6) the cavity or the oven itself which provides resonant structure for efficient energy transfer; 7) energy sealing and trapping structure to prevent stray radiation; and 8) operating controls and safety devices for selection of cooking condition and the protection of the operator. When microwaves are directed to or are reflected from the metal walls back and forth through a dielectric substance (load), the material absorbs energy from the electromagnetic field of the waves in proportion to its loss characteristics. The "loss" refers to the absorption of radiation within the dielectric material.

According to Goldblith (1966), the energy is absorbed by the charged assymetric molecules which compose the dielectric materials and store it as potential energy as they align themselves with the rapidly changing alternating current field. In this field, the molecules act as miniature dipoles, and while oscillating around their axis in an attempt to go to the proper positive and negative poles, intermolecular collision occurs and the stored potential energy is converted to heat. The materials that exhibit this intermolecular motion are considered "lossy". The greater the lossiness of the material, the greater the absorption of microwave energy and the greater the production of heat.

The rate of increase in temperature of the load is given in Equation 1:

$$\Delta T = 14.4 \text{ P/Cd} \qquad (^{\circ}\text{C/min}) \tag{1}$$

where C is the specific heat of the material (cal/$^{\circ}$C-gm), d is density (gm/cm^3), and P is the amount of power generated in the dielectric material by the electromagnetic field. Goldblith (1966) expressed P in Equation 2:

$$P = 55.61 \; E^2 f \varepsilon_r'' \times 10^{-14} \quad (\text{watts/cm}^3) \tag{2}$$

where E is the electric field strength (volts/cm), f is the frequency in hertz, and ε_r'' is the dielectric loss factor. Substituting Equation 2 into Equation 1,

$$\Delta T = \frac{8E^2 f \varepsilon_r'' \times 10^{-12}}{Cd} \qquad (^{\circ}\text{C/min}) \tag{3}$$

The dielectric loss factor ε_r'' is the overall measure of the ability of the material to respond when placed in an electromagnetic field:

$$\varepsilon_r'' = \varepsilon_r' \times \tan \delta \tag{4}$$

where ε_r' is the dielectric constant and tan δ is the dissipation factor or tangent loss. The dielectric constant relates the value of the electric field within the material to the value of the electric field externally applied to the material (Tinga 1970).

The literature is scant on the dielectric loss factor (ε_r'') properties of foods or on the factors affecting it. However, a number of authors (Bengstsson _et al_. 1963, Copson 1962, Decareau 1966a, Goldblith 1966, Van Dyke _et al_. 1969, and Tinga 1970) have reported that ε_r'' varies irregularly with frequency, temperature, and nature of the material. In studying the effects of frequency and temperature on the dielectric properties of different kinds of meat and fish, Bengtsson _et al_. (1963) found that: a) values for dielectric constant and loss tangent decreased at decreasing rates with increase in frequency; b) values for dielectric constant and loss tangent showed a sharp increase upon defrosting; and c) variation in dielectric properties were influenced by the proportion of moisture and fat in the material. In a related study on ground beef, Van Dyke _et al_. (1969) reported the following findings: a) below the critical moisture content (20%), water concentration had little effect on the dielectric loss factor; between 20 and 45%, ε_r'' increased dramatically with the increase in water concentration, the increase being greater at higher temperatures; and above 45%, the effect was negligible; b) the addition of salt to the sample caused an increase in the ε_r'' values; and c) at constant protein to ash ratios and at water contents above 45%, increasing the fat content resulted in a decrease in the ε_r'' values.

In general, microwave heating has some potential advantages over conventional methods of heating foodstuffs. These advantages include: a) rapid heating, b) uniform heating, c) degree of selectivity, and d) ease of control. An examination of Equation 3 would show that the rate of heating a foodstuff in a microwave oven is influenced by E, f, ε_r'', C, and d. Since ε_r'', C, and d are inherent characteristics of foodstuffs and f is restricted to the ISM frequencies, one can increase the rate of heating by increasing E.

The uniformity of heating is influenced by the distribution of assymetric molecules in the material and the penetration of microwave energy into the material. The penetration is described by half power depth or that thickness of the material which reduces the power at the surface to one half. Goldblith (1966) expressed HPD in Equation 5:

$$\mathrm{HPD} = \frac{.693}{55.61 \times 10^{-14}\ f \tan\delta \sqrt{\varepsilon_r'}} \qquad (5)$$

The greater the dielectric loss factor of the material, the lesser the penetration and the faster the heating near the surface as against the interior of the material. Thus, uniformity of heating can be achieved by heating thinner dimensions of materials in relation to its dielectric loss factor.

2. Application of Microwave Heating in Poultry Processing

Microwave heating has been used with varying measures of success in the precooking of broilers prior to freezing, and in the thawing and heating of frozen fried chicken dinners. Earlier attempts to precook chicken in continuous microwave ovens have resulted in dried-up products due to the tendency of the moisture at the surface to distill and condense over to the walls of the equipment. However, when steam was connected to the oven chamber, excessive dehydration was eliminated and better products were obtained. A number of authors (Anon. 1966a,b, Decareau 1966b, May 1969 and Thamer *et al*. 1971) have reported that the combination microwave-steam cooking, in comparison with other systems, shortens cooking time, reduces moisture loss, eliminates bone darkening, and is more economical in the long run. These benefits have prompted one firm to install a microwave-steam unit which cooks 1.5 tons of chicken per hour (Anon. 1970).

However, limited studies on the use of microwave ovens for the reheating of frozen fried chicken have shown discouraging results (Anon. 1969b, Co and Livingston 1969, and Goldblith 1966). The limitations on the use of microwave ovens for such a purpose can be summarized as follows: 1) the speed of heating depends upon the quantity of the load; 2) microwave heating causes excessive steaming which results in sogginess of the breading; 3) the uneven distribution of energy in the chamber results in non-uniform heating; 4) the preferential absorption of microwave energy by thawed portions, raising them to increasingly higher temperatures while the center cores remain frozen; and 5) microwave energy does not penetrate metals, which means that the frozen food must be in a special container when being heated. To solve these problems, a company developed a two-step process for reheating frozen precooked broilers (Anon. 1969a). The process consists of placing 95% precooked broilers in boxes into a microwave oven for 1.15 minutes, and then transferring the products (with the boxes open) to an infrared heater for surface crisping.

B. Factors Affecting the Eating Quality of Fried Chicken

1. Appearance

This visual property provides the initial appeal which induces consumers to sample the product for the first time. The appearance of fried chicken is influenced by the coating characteristics. Hanson and Fletcher (1963) studied the effect of cooking method, batter composition and formulation, and method of coating application on the characteristics of the coating. They reported that color is influenced by the composition of the batter: waxy rice flour and waxy cornstarch produced glossy brown coatings, wheat flour a grayish brown color, waxy cornstarch and cornstarch a very light brown color, potato flour a golden brown, and yellow cornflour a greenish yellow cast. Addition of egg yolk to the batter produced a darker color. They also reported that precooking to shrink the tissues before batter was applied resulted in better adhesion of the coating. Increasing the proportion of thickening agents and the number of coating layers resulted in thicker coatings. The thick coatings peeled off more readily than the thin ones. In another study, Hale and Goodwin (1968) found that precooking either in steam or with microwave before coating and deep-fat-frying improved batter adhesion as well as texture and hardness. Addition of skin was found to have no significant effects on the coating characteristics. However, Spencer and George (1962) showed that incorporating acetylated monoglyceride into the flour coating improved the appearance and durability of the coating.

In eating fried chicken, the presence of dark spots near or around the bones may detract from acceptability. These spots are coagulated blood pigments which oozed out of the bone marrow after freezing and slow thawing (Brant and Stewart 1949, Koonz and Ramsbottom (1947), Woodroof and Shelor 1948). Apparently, freezing and thawing alters the permeability of the bones of young chicken, thus allowing the leaching out of hemoglobin during thawing and subsequent cooking. Bone darkening can be prevented by cooking the birds immediately after rapid thawing, or by preheating the chicken pieces to 82°C before freezing (Brant and Stewart 1949, Ellis and Woodroof 1959, and Essary 1959).

2. Flavor

Once consumers taste a product, the satisfaction they derive from eating the product becomes the dominant factor which would influence their repeated purchase of that product. The eating experience can only be satisfying if the product has a desirable flavor. According to Moncrief (1967), flavor perception is the synchronous sensation of taste and odor, and can be modified by the simultaneous tactile responses in the mouth. Since this perception involves the interaction between the complex flavor characteristics (stimuli) and the response of the individual, a desirable flavor characteristic to one individual may not be considered as desirable by another individual. Hence, it is important for food processors to understand what constitutes a desirable flavor and what factors may influence it.

a. Nature of chicken flavor

Since flavor involves taste and odor stimuli, a typical chicken flavor must consist of volatiles, which can get into the olfactory chamber, and of smaller molecular weight non-volatiles, which can dissolve in the saliva in order to react with the taste buds. Bouthilet (1950) argued that chicken flavor is produced during cooking because raw chicken has no recognizable flavor. He suggested that the flavor components are reaction products of heat upon the tissues.

To date, over two hundred components have already been detected in cooked chicken volatiles and approximately 50 compounds have been identified (Crocker 1948, Bouthilet 1949, 1950, 1951a, b. Pippen et al. 1954, 1958, 1960, Pippen and Eyring 1957, Pippen and Nonaka 1963, Minor et al. 1965a, b, Shrimpton and Gray 1965, and Nonaka et al. 1967). The components already identified include: sulfur compounds, carbonyls, amines, aromatic benzene compounds, furans, esters, hydrocarbons, alcohols, and terpenes. However, information on the contribution or significance of these compounds to chicken flavor is still limited. While it is possible that all of these compounds blend or interact to produce the characteristic chicken flavor, Pippen (1967) suggested that the compounds which occur at significant concentrations at the time the poultry is eaten or smelled could have flavor significance.

1. Sulfur compounds

The sulfur compounds in cooked chicken flavor which have been isolated and identified include: hydrogen sulfide, carbonyl sulfide, methyl and ethyl mercaptans, carbon and methyl disulfides, 1,2-ethane dithiol and 2-methyl thiophene (Crocker 1948, Bouthilet 1949, 1950, Minor et al. 1965a, Shrimpton and Gray 1965, and Nonaka et al. 1967).

The presence of sulfur compounds in chicken flavor was first demonstrated by Crocker (1948). He distilled tissue from chicken, beef, and pork, and found hydrogen sulfide, ammonia and acetaldehyde in each of the three distillates. Crocker concluded that all meats possess identical fundamental flavor factors, and that differences in species may be due to low concentrations of compounds characteristic of the particular species.

During fractionation of chicken broth distillates, Bouthilet (1950, 1951a) observed separation of the extract into two flavor fractions: one was a sulfur-containing fraction which he considered "meaty" because it was not a typical flavor, and the other contributed the characteristic chicken flavor. Later, Minor et al. (1965a) demonstrated that removal of sulfur compounds caused nearly complete loss of "meaty" odor, indicating that the sulfur compounds contribute "meaty" character to the cooked chicken flavor.

Pippen and Eyring (1957) showed that nearly all the sulfur in the freshly cooked chicken volatile existed as hydrogen sulfide, and an insignificant amount as mercaptan. They also confirmed Bouthilet's (1951a) observation that desulfuration (hydrogen sulfide production) in broth continued as long as true chicken flavor existed. These results indicate that hydrogen sulfide is a direct contributor to the "meaty" flavor of chicken.

The role of hydrogen sulfide in the characteristic chicken broth aroma was also demonstrated by Klose et al. (1966) as follows: 1) when essentially all aroma constituents except hydrogen sulfide was removed by anhydrous calcium sulfate (or $CaCl_2$ or $CaCO_3$), the residual aroma was easily recognized as H_2S; 2) when H_2S was removed by any of a variety of heavy metal salts, a completely disagreeable aroma remained that indicated the blending or masking effect of the H_2S; and 3) when H_2S and other compounds were removed by magnesium oxide, an ammonical odor characteristic of ammonia and aliphalic amines was exposed.

Another evidence of the contribution of H_2S to chicken flavor was reported by Pippen and Mecchi (1969). Table 1 shows that 180-730 ppb H_2S in the meat of freshly simmered, roasted, and fried chicken are 18 to 73 times more than the 10 ppb H_2S odor threshold in water, which further proves that H_2S contributes directly to the aroma of these products.

Pippen and Mecchi (1969) also showed that hydrogen sulfide may contribute indirectly to cooked chicken flavor by forming secondary products when combined with carbonyl compounds. Results indicate the possibility of the formation of hydrogen sulfide-carbonyl esters with intense food-like odors, similar to those described by Barch (1952).

Table 1. Quantity of H_2S in cooked chicken[1]

Cooking Method	H_2S found[2], ppb	
	Leg Meat	Breast Meat
Boiled (1 hr at 100°C)	730	320
Roasted (to 85°C internal temp.)	596	180
Fried (to 85°C internal temp.)	580	180

[1]Pippen and Mecchi (1969)
[2]Analysis was started about 5 minutes after cooking.

2. Carbonyl compounds

The fraction which Bouthilet (1950) found to contribute the characteristic chicken flavor must have been composed of carbonyl compounds. Minor et al. (1965b) also demonstrated that removal of carbonyls from cooked chicken volatiles caused a loss of "chickeny flavor" and an intensification of "meaty" or "beefy" odor.

There are over 20 carbonyls identified in cooked chicken volatiles, but the major compounds are acetaldehyde, acetoin, diacetyl, decadienal and hexanal (Pippen et al. 1958, 1960, Minor et al. 1965b, Shrimpton and Gray 1965, and Nonaka et al. 1967). Pippen et al. (1960) conducted limited tests to ascertain whether diacetyl and acetoin contribute to the flavor of chicken broth. They found that normal concentrations of acetoin and diacetyl in chicken broth cannot be detected. However, if substantial amount of acetoin was oxidized to diacetyl, its presence was easily detected. They postulated that diacetyl contributes to the transient buttery-oily type aroma in freshly cooked chicken, and this was confirmed by Minor et al. (1966). Pippen and Nonaka (1960) obtained authentic samples of all the carbonyls which they have identified from cooked chicken volatiles and observed that none of the carbonyls had flavor characteristics like that of cooked chicken. However, they estimated that the average concentration in the chicken broth samples was 14×10^{-5} moles/liter which exceeded the reported threshold levels for these compounds in similar media (Lea and Swoboda 1958, and Patton et al. 1959). These results suggest that a blending of the carbonyl compounds is necessary to produce the distinctive "chicken" flavor.

Pippen and Nonaka (1963) showed that the carbonyl compounds in the volatiles of freshly cooked and rancid chicken are qualitatively the same, but the quantity is greater in rancid chicken. They also found that there is a narrow line between the characteristic freshly cooked chicken flavor and rancid chicken.

3. Amines

The presence of ammonia or amines in cooked chicken volatiles has been reported by Crocker (1948), Bouthilet (1951a), Pippen and Eyring (1957), Minor et al. (1965a) and

Klose _et al_. (1966). Pippen and Eyring (1957) found that ammonia accounts for nearly all the volatile nitrogen. Moreover, they showed that removal of ammonia resulted in more intense flavor, which explained the findings of Bouthilet (1950) that the lowering of pH, which minimizes the production of ammonia, raises the flavor level in chicken broth distillate. These results demonstrate that ammonia does not contribute directly to the characteristic chicken flavor but could exert a masking or suppressing effect on the other flavor components, and that the volatile chicken flavor is associated with the neutral or acid components.

4. Other compounds

The other compounds identified in cooked chicken volatiles have not yet been reported to be present in significant amounts nor shown to contribute directly to chicken flavor. However, the possibility that they could blend and interact with the other flavor components to give a distinctive desirable chicken flavor deserves further investigation.

5. Non-volatiles

A comprehensive study of the role of non-volatiles in chicken flavor was made by Kazeniac (1961). He proposed a possible flavor relation of various compounds in chicken broth, which indicates that non-volatiles are responsible for the taste, body, and mouth satisfaction characteristics of chicken broth flavor. Taste in chicken broth was attributed to several classes of compounds, including a mixture of amino acids, peptides, carbohydrates, inorganic salts, sulfides, carbonyls and non-amino nitrogen compounds, such as creatine/creatinine, carnitine, hypoxanthine, inosine, and inosinic acid. Kazeniac (1961), found that of the 17 or 18 amino acids in chicken broth, none had the taste characteristic of chicken. However, when certain amino acids, including lysine, arginine, alpha alanine, glutamic or aspartic acid, were added to chicken broth, the overall flavor was improved. Glutamic acid at levels between 0.02% and 0.05%, and lysine between 0.05% and 0.08%, gave chicken broth the highest amounts of mouth satisfaction and best overall flavor, and alanine imparted a sweet tasting broth and gave some mouth satisfaction. Lactic acid contributed to the sour, astringent taste in the broth, and improved mouth satisfaction at levels of 0.02-0.04% when combined with 0.06-0.08% lysine or arginine.

Kazeniac (1961) also reported that glucose, fructose, and ribose are the principal sugars present in chicken broth, and that inositol is suspected. These sugars are very low in concentration to make any substantial contribution to the sweet taste but might show increased taste intensity in combination with other compounds.

Kazeniac (1961) further found that inorganic salts and salts of amino acids contribute to the salty taste in chicken broth. Addition of inorganic phosphates led to some flavor improvements. Carnitine-enriched broth developed a strong fishy aroma. Hypoxanthine and inosine imparted a bitter taste, whereas inosinic acid made a major contribution to mouth satisfaction and intensified the effects of other compounds. Collagen and lipids gave more body to the flavor of the chicken broth. Kazeniac (1961) concluded that chicken flavor is a complex blend of different compounds, and that addition of precursors seem to hold more promise for improvement of the chicken flavor than the use of the flavorful compounds themselves.

b. Precursors of chicken flavor

1. Sulfur compounds

Mecchi et al. (1964) studied the origin of hydrogen sulfide in heated chicken muscle and found that about 90% of the hydrogen sulfide came from cystine and cysteine residues of the muscle proteins, and the rest came from glutathione of the non-protein fraction. Their findings nullified Bouthilet's (1951b) earlier conclusion that the true precursor of hydrogen sulfide is glutathione.

2. Carbonyl compounds

The presence of carbonyls in raw chicken meat was reported by Koehler and Jacobson (1967). However, studies by many researchers, including Crocker (1948), Bouthilet (1951b), Pippen et al. (1958, 1960), Pippen and Nonaka

(1963), Minor *et al*. (1965b, 1966), and Nonaka and Pippen (1965), showed that carbonyls were produced during heating. Pippen *et al*. (1958) observed that oxidative cooking, in which air stream was passed through simmering chicken, evolved four times as much carbonyls than did normal cooking when chicken was simmered with no air passing through, indicating that carbonyls were products of oxidative reactions. Pippen and Nonaka (1963) obtained more carbonyls, particularly n-hexanal and decadienal, from the skin and skin fat rather than from the leg and breast muscles, indicating that meat lipids were the source of carbonyls. Unsaturated C-18 fatty acids produced alkanals, alk-2-enals and alk-2-4-dienals upon oxidation (Ellis *et al*. 1961). Hence, it was concluded that carbonyls were formed from lipids (Lineweaver and Pippen 1961, Pippen and Nonaka 1963), particularly linoleic and arachidonic acids (Pippen 1967, Dimick and MacNeil 1970 and Thomas *et al*. 1971) by a lipid oxidation mechanism as discussed by Patton *et al*. (1959). Apparently, decadienal can also be formed merely by moist heating of linoleate (Patton *et al*. 1959).

3. Non-volatiles

Most of the significant non-volatiles in cooked chicken flavor are natural components of raw meat. Koehler and Jacobson (1967) reported that the chicken flavor-forming fractions extracted from raw muscle contained glucose, fructose, ribose, an unidentified sugar, lactic acid, amino acids, amines, inosine monophosphate, guanosine monophosphate, inosine, and sulfhydryls. The amino acids identified include: alanine, arginine, aspartic acid, cysteine, glutamic acid, glycine, histidine, isoleucine-leucine, lysine, methionine, serine, threonine, taurine, tryptophan, tyrosine, and valine. Other researchers (Minor et al. 1966, Miller and Dawson 1965, and Lillyblade and Peterson 1962) have likewise shown the presence of these compounds in raw chicken muscle.

c. Factors affecting characteristic chicken flavor

Flavor has been considered an elusive factor that may be influenced by production variables such as breed, sex, age, and diet, or by processing steps such as chilling, freezing, and cooking. This section summarizes the literature on the factors affecting the flavor of freshly cooked chicken.

1. Component parts of chicken

The "meaty" flavor in chicken has been reported to originate from the lean of the meat and not from the fat (Crocker 1948, Bouthilet 1950, Pippen et al. 1954, Pippen and Nonaka 1963, Pippen and Mecchi 1969, and Mecchi et al. 1964). In characterizing the chicken flavor-forming muscle extracts, Koehler and Jacobson (1967) found that the white meat extract had arginine, leucine-isoleucine, threonine, tyrosine, valine, two other amino compounds, and an unidentified sugar not found in the dark meat extract. They also found that heated white meat extract had a stronger chicken flavor than that of dark meat which had stronger meaty character.

On the other hand, Mecchi et al. (1964) observed faster liberation of H_2S from dark meat than from white meat under identical heating conditions. Pippen and Mecchi (1969) found greater amounts of H_2S in leg meat cooked by three different methods than breast meat cooked by those same methods (Table 1, page 18). Minor et al. (1965b) obtained 30 chromatogram peaks from leg meat but only 25 peaks from breast meat in the gas chromatography of cooked volatiles. They observed flavor differences between breast and leg meat similar to those noted by Koehler and Jacobson (1967). These results indicate that different flavor characteristics may arise from different parts of the chicken.

2. Production variables

There seems to be conflicting reports in the literature concerning the effects of production variables on flavor. Many authors, including Lineweaver and Pippen (1961), Morrison et al. (1954), Fry et al. (1958), Leong et al. (1958), and Kahlenberg et al. (1960), have concluded that chicken flavor is essentially independent of age, sex, genetics, and production conditions. However, Peterson et al. (1959) and Baker and Darfler (1968) found that older hens were more flavorful than 3-month-old pullets. While the volatile components were the same qualitatively between 20-month-old and 12-week-old hens, some of the volatiles were of higher concentration in the older birds (Minor et al. 1965b).

A notable difference in flavor between sexes was demonstrated by Gilpen et al. (1960) and MacNeil and Dimick (1970). Gilpen et al. (1960) showed that males yielded more meat and were tastier, while females had more fat and yielded a higher percentage of breast meat. MacNeil and Dimick (1970) observed differences in the production of carbonyls in the skin between sexes of turkeys. They found that the male birds had higher concentrations of total carbonyls than did the females (78 vs 50 µmoles per 10 gm lipid). Furthermore, the male birds had lower methylketone concentrations than the females but had 3 to 8 times more unsaturated aldehydes.

Lewis et al. (1956) demonstrated that birds raised on standard diets had more intense flavor than those raised on low-fat purified diets. When levels of 8% animal fat were fed to broilers for 10 weeks by Essary (1961), the tissue contained more fat than birds raised on a standard commercial diet. Marion and Woodroof (1963) reported that dietary fat alters the composition of lipids in chicken muscle. The feeding of fish meal or fish oil had also been reported to impart fishy flavor to chicken meat and accelerated deterioration during storage (Carlson et al. 1957, Darrow and Essary 1955, Carrick and Hauge 1926, Asmundson et al. 1938, and Edwards and May 1965).

3. Processing variables

The effect of chilling methods on flavor was studied by Pippen et al. (1954). They found that broth prepared from half carcasses immersed in ice water for as short as 3 hours had significantly less flavor than the broth from halves cooled in air. Leaching out of neutral ash or mineral content accounted partly for the loss of flavor during chilling in ice water (Pippen and Klose 1955). Hurly et al. (1958) also reported greater losses in flavor of poultry chilled in liquid than those chilled in air. Davidek and Khan (1967) indicated greater losses of inosine monophosphate during aging in slush ice as compared to drained crushed ice. Koehler and Jacobson (1967) showed that the flavor-containing fraction of chicken muscle was readily dialyzable in water. These results indicate that prolonged immersion of chicken in water may result in leaching out of flavor precursors/components and a loss of flavor.

Holding or aging of raw chicken at temperatures above freezing results in a number of biochemical changes. During a 6-day storage at $0^{o}C$, Lillyblade and Peterson

(1962) observed that glucose levels increased in white meat from 13-week-old pullets and also in both red and white meat from old hens, but decreased in red meat of pullets. Inositol, fructose, and ribose increased in the two muscles from both young and old birds. The changes in proteins during aging were studied by van den Berg et al. (1963). They observed appreciable proteolysis in both breast and leg muscles resulting in increase in extractable proteins, free amino acids and other breakdown products increased with storage time and temperature. However, the effects of the biochemical changes on the flavor after cooking have not yet been studied.

Stewart et al. (1945) reported that quick frozen broilers lost flavor during 51 days at -23^{o}C. Mountney et al. (1960) served cooked meat from fresh and frozen fryers to visitors at the Texas State Fair and found that more tasters preferred the fresh than the frozen ones. They concluded that there was enough flavor difference to create a slight resistance to frozen chicken stores for 3 to 9 months. To understand the causes of flavor deterioration during frozen storage, a series of studies were conducted at the National Research Council of Canada. Quantitative examination of chicken muscle proteins conducted by Khan et al. (1963) showed a decrease in protein extractability in both breast and leg muscles during frozen storage due to loss of solubility of actomyosin content.

They also observed an increase in free amino acids and other protein breakdown products which indicated continued proteolysis. They reported that the rate of these changes were directly related to the storage temperature and time. On further analysis of the non-protein fraction, Khan (1964) found a noticeable increase in acidic, aromatic, and sulfur-containing amino acids during storage for 45 weeks at temperatures between -5 and -40°C. Creatine/creatinine increased slightly while nucleic acid derivatives decreased. Davidkova and Khan (1967) studied the changes on lipid components and found that during storage at -10°C, the phospholipid content of muscles decreased owing to loss of lecithins and cephalins, while the fatty acids, triglycerides and lysolecithin content increased. These results suggest that lipolysis also occurs during frozen storage.

Khan and van den Berg (1967) found that freezing caused small but detectable changes in eating quality and that changes in muscle protein during freezing depended on the freezing rate. Slow freezing, on the other hand, caused larger loss of drip on thawing. Earlier, Khan and Lentz (1965) showed that loss of nitrogeneous constituents and ribose increased proportionately with the amount of drip.

The influence of cooking methods on chicken flavor has been mentioned earlier. Pippen et al. (1958) observed the production of larger quantities of carbonyls during oxidative cooking, which indicates that oxidative cooking conditions accelerates the production of volatiles. In studying the contribution of H_2S to cooked chicken aroma, Pippen and Mecchi (1969) found greater amounts of H_2S in meat of simmered chicken than in meat of roasted and fried birds (Table 1, page 18), indicating that water may be necessary in the production of hydrogen sulfide.

The influence of cooking temperature on chicken flavor was discussed by Kazeniac (1961). He showed that the amount of diacetyl, H_2S, and ammonia released from chicken meat increased as the cooking temperature was increased from 65°C to 100°C. Volatiles collected at 65°C had strong raw chicken aroma, but very little cooked chicken aroma; those collected at 85°C had detectable cooked chicken aroma; and those collected at 100°C had the cleanest overall chicken flavor.

In general, cooking treatment is the most important single factor which influences the flavor of cooked chicken. The addition of seasoning, spices, and flavor enhancers enable the modification and enhancement of the flavor to provide the particular taste and/or aroma desired by consumers. Also, the pH of the meat can be altered by precooking or cooking treatments such as marination. Pippen and Eyring (1957) showed that pH differences during cooking, as little as 0.14 to 0.48 pH units, influenced chicken broth flavor. Higher pH values during cooking favored the production of ammonia, diacetyl and H_2S (Kazeniac 1961, Mecchi et al. 1964). However, broth cooked at lower pH had more intense flavor (Pippen and Eyring (1957).

d. Factors affecting flavor deterioration in fried chicken

Hanson et al. (1959) reported that flavor changes in fried chicken involve first the loss of "freshly cooked" chicken flavor, followed by a slight staleness or a "warmed-over" flavor, and eventually, an objectionable flavor. Apparently, flavor deterioration in chicken involves cessation of desulfuration and progressive lipid oxidation. Hence, any factors which influence these reactions can affect the rate of flavor deterioration.

Pippen and Mecchi (1969) reported that freezing, thawing, and reheating reduced the H_2S in broth to subthreshold levels, indicating that freezing interfered with the mechanism of hydrogen sulfide production.

The stability of fried chicken flavor against oxidation during storage is affected by certain pre-cooking treatments, freezing, packaging, and storage conditions. Thompson (1964) showed that soaking carcasses in a phosphate solution (sodium tripolyphosphate + sodium pyrophosphate mixture) was effective in inhibiting oxidative deterioration during commercial production of frozen cooked chicken.

Throughout 1 week at 5^{o}C, phosphate-treated chicken showed none or very slight off-flavor and a 2-thiobarbituric acid (TBA) value of about 1, whereas untreated control chicken had a slightly strong to strong off-odor and a TBA value of about 6. A similar protective effect of phosphate on frozen pre-fried chicken was reported by Farr and May (1970).

Carlin et al. (1959) studied the effects of pre-cooking and packaging treatments, and noted faster development of off-flavor in partially and fully cooked broiler pieces than in similarly packaged uncooked pieces during storage at -18^{o}C for 15 weeks. Flavor deterioration was faster in the partially cooked pieces than in the fully cooked ones. Flavor changes occured to approximately the same extent whether the precooked broilers were packaged in cryovac bags, polyethylene bags, or aluminum freezer foil.

Berry and Cunningham (1970) reported that temperature and freezing rates influence the quality of cooked chicken. Sensory evaluation and TBA values indicated that liquid nitrogen freezing produced a better product than did blast freezing; however, a taste panel scored the flavor of products frozen in a household freezer better than those frozen by the two faster methods.

Studies on the stability of frozen fried chicken stored for periods from 2 weeks to one year at temperatures ranging from -23 to -66^{o}C were conducted by Hanson et al. (1959). The flavor stability was approximately the same for two commercial lots and one lot prepared in the laboratory. Off-flavor development was affected by temperature: at -18^{o}C, staleness developed in 4 months and rancid flavor in 9 months; at -12^{o}C, staleness developed in 2 months and rancidity in 6 months. Off-flavor occurred in the meat as well as in the skin, as also observed by Carlin et al. (1959). Fried chicken hermetically sealed in nitrogen in cans showed no detectable rancid flavor. Because the shape of chicken pieces prevents a "solid pack" and allows exposure of large surface areas of chicken to the atmosphere within the package, Palmer (1968) recommended the storage of fried chicken at low temperatures for a relatively short period of time.

3. Tenderness

Tenderness is another factor which could enhance the acceptability of poultry products. The sensation of tenderness is a complicated process, since chewing involves not only cutting and grinding, but also includes squeezing, sheering, and tearing (Pearson 1963). Like flavor, tenderness is considered by producers and processors as an elusive factor which may be influenced by production variables, certain post-mortem physico-chemical changes, and processing variables.

a. Production variables

Stadelman (1963) reviewed the influence of production variables on tenderness of poultry meat. On the basis of the studies of Morrison et al. (1954), Wesley et al. (1958), Gilpen et al. (1960) and Shrimpton and Miller (1960), Stadelman concluded that breed and sex have no significant effect on tenderness. However, he indicated that age and certain feeding practices definitely influence tenderness.

Peterson et al. (1959), observed that tenderness decreases with age. They also found that breast muscles of young birds were significantly tougher than the dark muscles, but in older birds, the dark muscles were slightly tougher than the breast muscles. May et al. (1962) observed that breast meat from 72-week-old chickens were less tender than those from 10-week-old birds, both initially and throughout aging. A contradictory finding was reported by Baker and Darfler (1968), who showed both by shear press and sensory evaluations that breast meat from fowl was more tender than the breast meat from fryers.

Shrimpton and Miller (1960) observed that when birds were kept on full feed, the meat was more tender than when birds were on a restricted diet.

b. Post-mortem physico-chemical changes

Within one to two hours after slaughter, chicken normally passes into a state of "rigor mortis" or muscle stiffening. Resolution of rigor takes place later and the muscles become pliable again and normal aging proceeds (Dawson et al. 1958). Chicken when cooked rapidly before the onset of "rigor mortis" gave tender meat (de Fremery 1966). However, chicken cooked at the state of rigor gave tough, rubbery or stringy meat (Lowe and Stewart 1946, Carlin et al. 1949), whereas chicken cooked after resolution of rigor gave meat which became progressively more tender with aging (Dawson et al. 1958, May et al. 1962, Khan and van den Berg 1964 and van den Berg et al. 1964).

The phenomenon of "rigor mortis" is normally accompanied by breakdown of ATP, glycolysis and a decrease in muscle pH (de Fremery and Pool, 1958, 1959, and de Fremery 1963). Klose et al. (1959), Pool et al. (1959), and de Femery and Pool (1958, 1959, 1960) observed that accelerated development of rigor mortis was accompanied by rapid loss of ATP and glycogen and an increased drop of pH, which induced toughness in cooked meat. De Fremery and Pool (1960, 1963, and De Fremery (1966) showed that minimization of post-mortem glycolysis by 1) subcutaneous injection of adrenalin (epinephrine) 16 hours ante-mortem; 2) intravenous injection of sodium bromocetate or iodoacetate 3-6 minutes before slaughter; or 3) rapid cooking, resulted in poultry meat that was tender without being aged. However, accelerated post-mortem glycolysis as a result of death struggle or epinephrine administration 1-2 hr before slaughter caused toughness (Khan and Nakamura 1970). De Fremery (1966) concluded that it is the acceleration of post-mortem glycolysis, not the acceleration of rigor mortis, which induces toughness, whereas Khan and Nakamura (1970) considered the rapid drop in pH, which may affect the activity of enzyme systems of solubility of proteins, as the cause of muscle toughness. Since post-mortem glycolysis and drop in pH are interrelated, factors which accelerate these changes during early post-mortem such as excessive scalding, beating, higher aging temperatures and freezing, can cause toughness in cooked chicken.

The adverse effect of overscalding due to high scalding temperature or longer scalding periods has been observed by Klose _et al_. (1956), Shannon _et al_. (1957), Pool _et al_. (1959) and Wise and Stadelman (1959, 1961). Wise and Stadelman (1961) showed variations in toughening effect depending upon the depth of the muscles and concluded that the toughening effect was a direct function of the tissue temperature during early post-mortem.

Klose _et al_. (1956) and Pool _et al_. (1959) observed that excessive beating action applied during feather removal caused muscle toughening, and the effect was greatest when applied immediately after slaughter. Klose _et al_. (1956) showed that toughness induced by excessive beating could not be resolved completely even by prolonged aging.

Investigations on the effect of post-mortem temperature on muscle toughness were reported by Dodge and Stadelman (1959), de Fremery (1963) and Khan (1971). De Fremery and his co-workers found that cooked breast muscles became increasingly tough as the post-mortem temperature was increased from 10 to 40°C, which is similar to the finding of Dodge and Stadelman (1959). In studying the effect of temperature during post-mortem glycolysis and dephosphorylation of high energy phosphates on poultry tenderness, Khan (1971) found that holding poultry meat at 30 and 37°C during the onset of rigor mortis caused toughness. He also found that the toughening effect of high temperature occurred when pH dropped from 6.3 to its ultimate level. Moreover, holding poultry at 10, 15, and 25°C during onset of rigor, or cooling it to 15°C before pH dropped to about 6.3 produced more tender meat. He concluded that after post-mortem glycolysis and dephosphorylation of high energy phosphates, holding at high temperatures has no deleterious effect.

De Fremery (1963) reported that freezing and thawing pre-rigor muscle induced very rapid "thaw rigor" and faster disappearance of glycogen, and also caused a highly significant increase in toughness of cooked meat. Freezing chicken while in the state of rigor arrests the aging process and requires longer holding to complete tenderization (Koonz _et al_. 1954, Klose _et al_. 1956, and Dawson _et al_. 1958). Hence, it is desirable to age the birds at least 6 to 12 hours before freezing to prevent toughening and to permit immediate cooking after freezing (Klose et al. 1956 and Dawson et al. 1958).

c. Processing variables

Lowe and Stewart (1946) found that cutting chicken breast muscle one hour after slaughter induced toughening which persisted even after 24 hours of aging and subsequent cooking, while cutting after rigor had no toughening effect (Lowe 1948). Koonz et al. (1954) cut into warm excised chicken breast muscle, subsequently aged for successive times up to 24 hours before cooking, and observed that the cut muscle was always tougher than the uncut control. Pool et al. (1959) found that fryers sawed hot into 10 pieces and aged for 21 hours were twice as tough in the breast muscle as controls similarly sawed cold after 21 hours aging. Klose et al. (1971) showed that knife cutting the wings at the shoulder joints and flattening the breast at 20 minutes, 60 minutes, and 2 hours post-mortem gave shear values for the outer breast muscle about twice that for muscles from birds after the same operation carried out 22 hours post-mortem. Sawing the wing off at the point beyond the breast muscle insertion eliminated the pre-rigor toughening effect. Holding the parts in chilled state for as long as 5 days before cooking did not eliminate tenderness differences due to hot cutting and flattening. These studies indicated that the post-mortem time of cutting and manner of cutting influenced the tenderness of cooked chicken.

The freezing of raw chicken, per se, has been reported to cause small losses of tenderness and juiciness (Khan and van den Berg 1967). However, different freezing rates appear to have similar effects on tenderness (Marion and Stadelman 1958, Stewart et al. 1945 and Miller and May 1965).

Certain processing variables which affect the overall cooking losses also influence the tenderness and juiciness in chicken meat. These factors include soaking birds in phosphate solution, precooking, and cooking methods. Mountney and Arganosa (1962), May et al. (1963) and Katz and Dawson (1964) showed that adding food grade phosphate in the chilling water for carcasses reduced moisture losses during refrigerated storage and cooking of broilers. Similar effects of polyphosphates on the reduction of cooking losses were reported for leghorns and heavy hens by Schermerhorn and Stadelman (1964) and Baker and Darfler (1968), and for young poultry meats by Monk et al. (1964). Spencer and Smith (1962), May et al. (1963) and Baker and Darfler (1968) also showed that phosphate treatment resulted in greater tenderness and juiciness of chicken meat.

Carlin et al. (1959) reported that precooking treatments increased total weight losses of broilers from raw to ready-to-eat stage, and indicated that there was a correlation between weight losses and juiciness. Mickelberry and Stadelman (1962) also reported that cooking chicken before freezing resulted in significantly less tender products and greater total loss than freezing raw and cooking after slow thawing.

Mostert and Stadelman (1964) found that frying methods affected shrinkage, moisture, and fat content of cooked broilers, indicating possible effects of cooking methods on juiciness and perhaps on tenderness. Pressurized deep-fat-frying resulted in minimum cooking losses and maximum moisture retention. They also found that breading minimized weight loss in every frying method. In a related study, Hale and Goodwin (1968) observed that cooking methods significantly affected the moisture and fat content and shear press values of breast and thigh muscles.

Cooking yield values in the literature are summarized in Appendix I.

Butts and Cunningham (1971) reported that methods of freezing, but not methods of reheating significantly altered the shear press values of meat. Shear press values were: 1.85 kgm/gm for chicken frozen in liquid nitrogen; 2.28 kgm/gm for chicken frozen in air blast; and 2.81 kgm/gm for chicken frozen in household freezer.

C. Packaging Requirements for frozen fried chicken

The package for frozen fried chicken for retail sale should have the properties of a typical consumer product package. The package must satisfy one or more of the following basic needs: protection, convenience or utility, motivation, and profitability (Modern Packaging Encyclopedia 1971).

1. Protection

The package must protect its contents from the expected environment for the expected period of use. Likewise, it must protect the environment from its contents. A package for frozen fried chicken should protect against: 1) loss of moisture; 2) atmospheric oxygen; 3) flavor contamination; 4) entry of microorganisms; 5) exposure to light; 6) mechanical damage; and 7) oil seepage to the surroundings. It should also 8) withstand very low temperatures, and preferably be 9) flexible enough to fit the contours of the chicken in order to exclude air spaces.

2. Convenience and/ or utility

The package must identify its contents and should indicate quantity. It should provide instructions for proper handling of its contents. It must facilitate distribution and be convenient to use. Hence, the package should have the following properties: 1) collapsibility or stackability for ease in transport and storage; 2) ease in filling; 3) ease of closure; 4) legibility of information; 5) Suitability to various heating methods; 6) ease in getting out the contents; and 7) disposability.

3. Motivation

The package should contribute to the selling efficiency by attracting customers to buy the product the first time and must be convenient enough to induce repeat purchase. A properly designed package could open new markets or new avenues of transportation and may even lower distribution cost. Hence, the package should have good printability so that it could be attractively designed, should permit viewing of its contents, and should be acceptable to the trade.

4. Profitability

Finally, the package must promote profitability of the product. This means that the package should be designed to produce the greatest number of sales at an acceptable level of production and selling costs.

D. Measurement of acceptability and eating quality

Many complex factors, such as those listed in Appendix II, combine to influence public acceptance of food (Harries 1953 and Amerine *et al*. 1965). Evidently, sensory properties are just a few of the factors which influence the selection and utilization of a certain kind of food. While consumer reactions are difficult to measure, the need for such studies continue to grow as competition for the consumer food dollar increases. In-depth study of consumer behavior might be the only way a food company can survive and grow as society enters the period of "over-choice" (Packard 1958 and Toffler 1971).

Consumer studies are conducted for at least one of the following purposes: 1) determination of market potential; 2) introduction of new products; 3) quality control of existing products; 4) establishment of specific factors of importance to the consumers; and 5) coordination of production and supply with consumption (Morse 1951 and Amerine et al. 1965). The objectives dictate the nature and procedure of the study, and for evaluation of eating quality, sensory measurements are necessary.

Preferably, consumer evaluation of eating quality should involve a large number of participants to represent the cross section of the population (Kotler 1967). However, high costs due to the amount of samples needed and the amount of time and assistance required in collecting and analyzing the data have limited the use of consumer panels and favored the use of laboratory-type panels (Pearson 1963).

The many factors interacting to influence individual food preference render the measurement of food preference very complicated. The need for a simplified but accurate method prompted the Quartermaster Corps to develop a scale with accompanying descriptive phrases (called the hedonic scale) for rating soldiers' food preferences (Jones *et al*. 1955 and Sheppard 1955, Peryam and Pilgrim 1957). Pilgrim and Wood (1955) compared the rating scale with paired comparison methods for measuring differences in consumer preferences for 12 pairs of food items and found that both methods were equally sensitive whether the difference in preference was small or large. Raffensperger *et al*. (1956) demonstrated that the hedonic scale was an appropriate and a logical approach for grading beef tenderness. In general, these workers agreed on the following features of the rating scale: 1) increasing the length of the scale up to 9 intervals marginally increases the time required for test completion; 2) test-retest reliability, within the range from 5 to 9 intervals, is constant; 3) longer scales, up to 9 intervals, tend to be more sensitive to differences among foods; 4) elimination of the "neutral" category is beneficial; and 5) a balance scale (equal number of positive and negative intervals) is not an essential feature of the rating scale. They are also agreed as to the following advantages: 1) judgment can be made on a number of samples; 2) a given item is rated in the light of a person's past experience, both immediate and remote, which enables comparison of data from one test to another; and 3) the descriptive categories of scales can be quantified or assigned numerical values.

Carlin et al. (1956) reported that the results obtained using 0-5, 0-10, 0-100 scales for sensory evaluation were linearly correlated, but 0-10 had the smallest standard deviation and coefficient of variation values.

Calvin and Sather (1959) compared student panels with household consumer panels in the determination of preferences for several types of food. They reported good agreement in the mean hedonic score and percentage preference from both panels, indicating that either method may be used to measure food preference. In an earlier study, Miller et al. (1955) reported a general agreement in the preference between household and laboratory-type panels. A consumer's bias for samples tasted first was noted.

While measuring preferences for various food combinations, Eindhoven and Peryam (1959) observed the occurrence of the following psychological errors of judgment: 1) position effect, similar to those observed by Miller et al. (1955), wherein the later samples tested are rated lower; 2) contrast effect in which serving good samples first lowered the rating for "poor samples"; and 3) convergence effect in which serving poor samples first lowered the rating for good samples. The latter two effects are independent of position effect.

Dawson (1963) and Petit (1958) reported that panel members tend to use all information available particularly that which has meaning to them in making their judgment. Dawson (1963) recommended that samples should be prepared and served as uniformly as possible, preferably in the conditions in which the food is normally consumed. Pearson (1963) also recommended that laboratory-type panels should consist of about 18 randomly selected members, the score card should be made simple, and the number of factors evaluated should be limited.

Tarver and Shenck (1958) and Pearson (1963) reported that the subjective nature of sensory measurements has a tendency to drift or to change in meaning with time, so they recommended that such measurements be anchored to a reproducible objective scale.

Peroxide values, carbonyl values, thiobarbituric acid values, and other chemical methods are used to follow the extent of oxidative flavor deterioration. However, Gaddis et al. (1959), Jacobson (1961) and Pippen (1967) have reported that these tests correlate only inconsistently with subjective estimates of staleness and rancidity. Nonaka and Pippen (1965) suggested the measurement of hexanal to indicate oxidative flavor deterioration in fried chicken, whereas Khan (1965) advocated the determination of the SH to tyrosine ratio to indicate the sensory quality of the product.

The difficulty of getting a good sample has made the Kramer shear press the only practical machine for the objective measurement of tenderness (Wells et al. 1962). This device measures the maximum pressure required to force a plunger through the material (Dodge and Stadelman 1960 and Pearson 1963). Shannon et al. (1957) reported a correlation of .86 between tenderness measurement of chicken meat by Kramer shear press and taste panel. Wise (1959) reported a .89 correlation between a chew panel and the Kramer shear press. These results indicate that the Kramer shear press can be used to estimate accurately the tenderness of chicken meat.

MATERIALS AND METHODS

A. General Procedures

The materials and cooking procedures in these experiments were similar to those used in commercial operation by a local chain of chicken take-out restaurants.

Chicken.--Ice-packed, cut-up chicken weighing from 900 to 1050 grams were obtained from commercial sources within one day before cooking. Each bird was cut into 9 pieces (2 drumsticks, 2 thighs, 2 wings, 2 breast-backs, and 1 breast tip).

Egg-milk dip.--Fresh mixture consisting of 8 large eggs blended for 1 minute in a Waring blender, two 14.5-oz cans evaporated milk, and 2 quarts cold water was prepared immediately before use.

Breading.--A basic mixture of 25 pounds all-purpose wheat flour (WF), 3.25 pounds salt, and 26 ounces commercial seasoning was used in most of these experiments. For comparison of breading materials, a 2:1 mixture of wheat flour and waxy corn (WF-WC) and a 2:1:1 mixture of wheat flour, corn meal and potato flour (WF-CM-PF) were also used in lieu of the all-purpose flour in the basic mixture.

Batter.--The different kinds of batter were prepared by mixing thoroughly equal weights of egg-milk dip and breading mixture in a Kitchen-Aid Model K5-A mixer immediately before use.

Phosphate treatment.--Cut-up chicken pieces were soaked overnight in 5% Kena*, a mixture of tripolyphosphate and pyrophosphate. *(Kena is a trademark of Calgon Corp., Pittsburgh, Pa.)

Pressure-frying (PF).--Chicken pieces were dipped in the egg-milk mixture for 10 seconds, drained, and breaded. The pieces were browned in oil preheated to 190-205°C in a pressure cooker for approximately 1 minute, and then cooked at 15 psi for 9.5 minutes. Immediately after cooking, the pressure was released and the pieces removed, placed on a wire rack, and then transferred to a warming oven set at 70°C to drain and darken in color. The pieces were held in the warming oven approximately 15 minutes. A Mies Commercial Pressure Fryer, Model C, was used in some trials and 4 Presto Model 7-B cooker-canners were used in other trials. The former cooked 4 birds per batch while the latter cooked only 2 birds per batch.

Microwave-steam (MWS) cooking.--Chicken pieces were precooked in a tunnel microwave cooker (Cryodry, 915 MHz, 25 kw maximum power) which was connected to a potable steam source. The pieces were placed in a single layer on the continuous belt, and cooked at 5 kw power for 10 minutes to approximately 85°C internal temperature. The pieces were coated and then browned for approximately 3 minutes either by pressure frying or by deep-fat-frying (DFF) at 177°C.

Freezing methods.--The fried chicken pieces were frozen to -18°C internal temperature, as recorded by a Honeywell Electronic multipoint potentiometer, by one of the following methods:

1. Blast freezing.--Chicken pieces arranged on wire racks were frozen in a walk-in convection freezer at -37°C.

2. Nitrogen-freezing.--Samples were frozen in an Air Product Cryogenic Freezer Model No. CT-1818-12F at -57°C. Nitrogen was forced by air at 5-8 psi pressure into the freezing chamber where the nitrogen vapor was circulated by a variable speed fan. Chamber temperature was controlled by varying the rate at which liquid nitrogen was forced into the chamber.

3. Freon freezing.--Products were frozen in a DuPont Laboratory type freezer (Figure 1) by dipping baskets of chicken pieces in Freon 12 for 8-10 minutes. The Freon 12 (Food grade, dichlorodiflouromethane) was maintained at -43°C by Freon 11 (trichloromonoflouromethane) and dry ice placed in the outer jacket.

Packaging.--The following packaging treatments were used in this study:

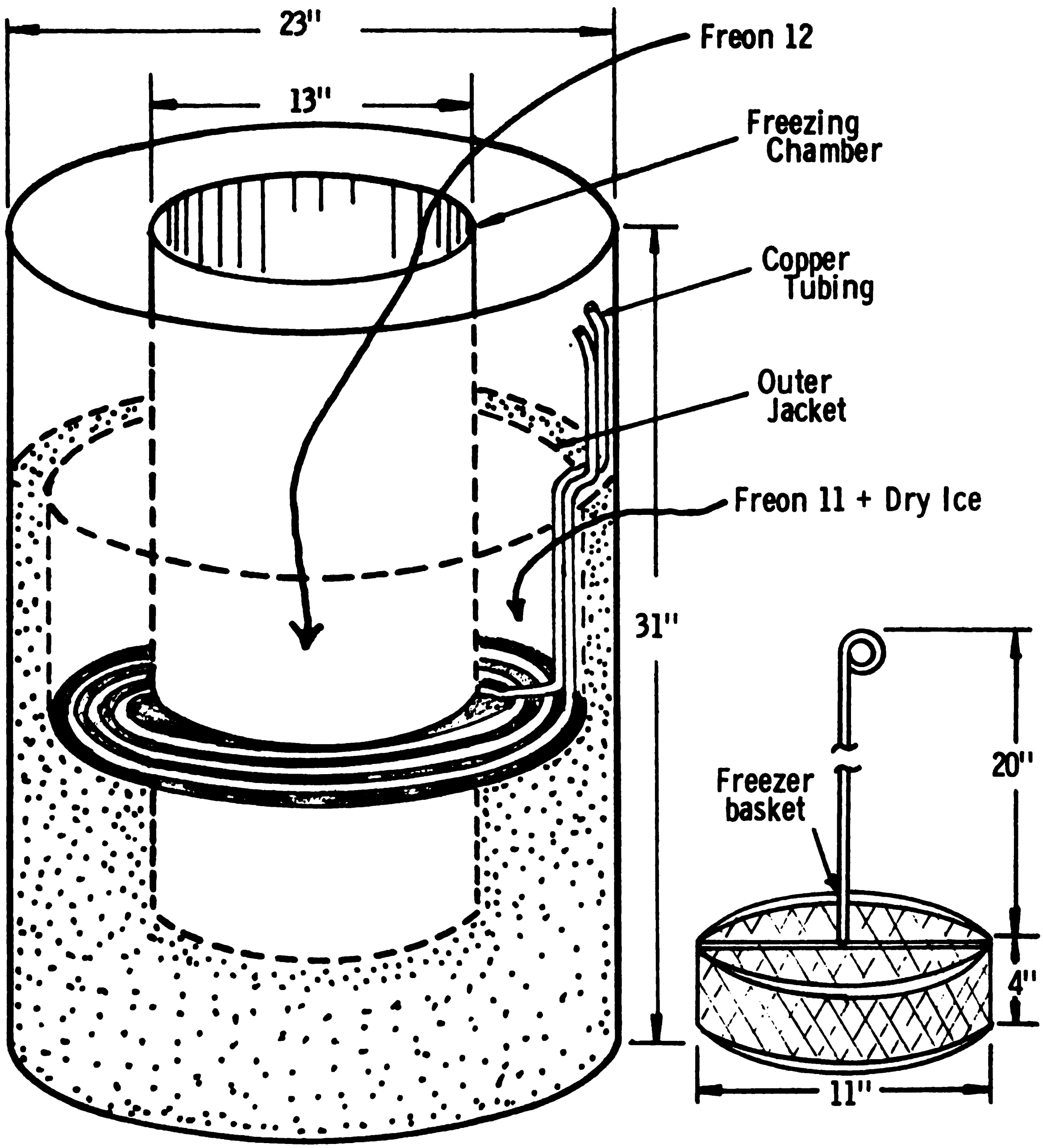

Fig. 1: Du Pont Laboratory Freon Freezer

1. Bulk-pack.--Individually quick frozen (IQF) chicken pieces were packaged in partially evacuated heat-sealed polyethylene (PE) bags, 4 birds per bag.

2. Vacuum-pack.--Pieces were individually vacuum-packed, using Kenfield vacuum sealer Model C-14, in saran-mylar-PE laminated pouches before or after freezing.

3. Air pack.--IQF pieces were packed in paperboard-covered aluminum foil trays, 4 to 6 similar pieces per tray.

4. AMG-coated.--IQF pieces were dipped for 30 seconds in the acetylated monoglyceride (AMG, Myvacet Type 7-00, Distillery Products, Inc., Rochester, N.Y.) which was heated to 93°C, and then air-packed as in No. 3.

Storage conditions.--All packages were placed in corrugated boxes, and stored in a freezer maintained at -18°C or subjected to a simulated distribution condition. In the simulated distribution condition, the boxes of chicken were transferred from the holding freezer to a walk-in cooler at 3-5°C for 16-24 hours every week during the storage period.

Reheating methods.--Frozen pieces at -18°C were thawed and heated to serving temperatures (65-70°C) by one of the following procedures:

1. Microwave (MW).--3 to 5 chicken pieces were placed on a paper plate, covered with a paper towel, and heated in a microwave oven (Litton Model 550, approximately 1 kw, 2450 MHz) for 1.5 to 2 minutes per piece or for 1 minute per 100 grams.

2. MW-DFF.--Frozen pieces were reheated in the microwave oven for half the usual time (30 seconds per 100 grams) and then placed in a deep-fat-fryer for 1 minute at 177°C to crisp.

3. Oven.--Frozen pieces were wrapped in heavy-duty aluminum foil and heated in an ordinary household oven at 205°C for 1 hour. In the last 15 minutes, the wrap was opened to allow the pieces to crisp.

4. Boil-in-bag.--Vacuum-packed pieces were placed in boiling water for 15 minutes.

Sensory Evaluation.--The chicken pieces were evaluated by taste panels consisting of 15 to 30 randomly selected graduate students and staff members of the Department of Food Science and Human Nutrition. Three pieces were served to each panel member each time for evaluation of appearance, flavor, juiciness, tenderness, and general acceptability according to an appropriate hedonic scale (Appendix III, IV and V). Thirty samples (6 pieces/part; 5 parts/bird) from each treatment were evaluated during each tasting. The samples were presented in a manner that the pieces from each treatment were equally served in the three positions and similar pieces from the different treatments were uniformly compared with each other. Panel evaluations were conducted from 9:30 to 11:00 a.m. or from 2:00 to 3:30 p.m. Data obtained were evaluated for each criterion by analysis of variance, and the Duncan's multiple range test was used whenever significant differences were detected.

Physical and Chemical Determinations

1. Shear press measurement.--An Allo-Kramer shear press, equipped with 1363.1 kgm ring and adjusted to 15 seconds downstroke, was used to measure objectively the maximum force required to shear 20-gram samples from the *Pectoralis major* muscle. Shear press values were calculated as follows:

$$\text{Shear press} = \frac{1363.1 \text{ x range x peak height}}{\text{weight of sample (gm)}}, \text{ (kgm/gm)}$$

2. Moisture.--About 500-gm samples of meat and skin were ground twice through a 3/16 inch grinder plate, then 10-gm samples were removed into tared aluminum drying pans and weighed to four significant places on a Mettler balance. The samples were dried to a constant weight in a convection oven at 106°C, and the average of the percentage loss in weight of duplicate samples were reported as the moisture content (AOAC, 1965).

3. Ether extract.--Moisture-free samples were weighed in tared extraction thimbles and extracted with petroleum ether for 24 hours in Soxhlet apparatus or 6 hours in Goldfisch apparatus. The loss in weight was reported as fat (AOAC, 1965).

4. Per cent breading.--The amount of breading on the fried chicken pieces was determined according to the procedure of May *et al.* (1969). Fried chicken pieces were tumbled for 45 minutes in a bucket of water in which

compressed air was bubbled through. The loss in weight after the pieces were blotted dry was reported as coating.

B. Experiments

This study consisted of seven experiments designed to evaluate the factors that may be relevant to the centralized processing of frozen fried chicken for retail distribution.

1. Acceptability of microwave reheated chicken.--Cut-up chicken pieces were breaded, pressure-fried, bulk-packed, and stored at -18^{o}C for periods up to 24 weeks. At certain intervals during storage, products in one bag were reheated in the microwave oven at 1.5 min/piece for the wings and 2 min/piece for the larger pieces, and were compared with newly cooked controls by a 20-member taste panel using the hedonic score card (Appendix III). The experiment was terminated after significant differences were detected between the controls and reheated chicken in two successive tastings.

2. Effect of freezing treatments on eating quality.--This experiment consisted of two trials. Trial 1 was similar to Experiment 1 but modified slightly to allow an evaluation of two methods of freezing fried chicken and to evaluate the eating quality of frozen uncooked chicken after subsequent pressure frying. Hence, the trial had two

control treatments (Treatment 1, newly cooked unfrozen control; Treatment 2, newly cooked frozen-thawed control) and two freezing treatments on fried chicken prior to storage and reheating (Treatment 3, blast freezing; Treatment 4, liquid nitrogen freezing). Evaluations were made using the hedonic score card in Appendix IV.

In Trial 2, chicken frozen by air-blast and liquid freon were evaluated. The frozen pieces were separately bulk-packed, stored at -18°C for 3 months, and then reheated in microwave oven and evaluated by a 20-member panel using the hedonic score card in Appendix IV.

In this experiment, the freezing rates of individual pieces frozen by the three methods were recorded. In addition, eight pieces of each part were labeled and weighed at various times during processing, and 8-16 representative samples were analyzed for moisture and fat content.

3. Effect of microwave reheating time on eating quality.--Chicken pieces were breaded, pressure-fried, bulk-packed and divided into two lots. Lot 1 was stored at constant -18°C while Lot 2 was subjected to a simulated distribution condition. After 3 months of storage, representative pieces of the same kind were reheated in a microwave oven until practically burned. The pieces were weighed at regular intervals during heating. Additional breast pieces from Lot 1 were heated for pre-determined times ranging from 1.0 to 2.25 min/100 gms, and 20-gm samples of the *Pectoralis*

major muscle were taken from each piece and served to a 15-member panel for tenderness and juiciness evaluation using a 9-point scale. Representative samples from each heating time were subjected to Allo-Kramer shear press determinations.

4. Effect of packaging and storage conditions on eating quality.--This experiment consisted of two trials. In Trial 1, a 3-way factorial experimental design was used to compare 2 freezing methods (blast and liquid freon); 3 packaging treatments (bulk-packed, vacuum-packed after IQF, vacuum-packed before IQF); and 2 storage conditions (constant $-18^{\circ}C$ and simulated distribution condition). The pieces of chicken were stored for 3 months, reheated in the microwave oven for 1 min/100 gms, and evaluated by a 30-member panel according to the hedonic scale shown in Appendix IV.

In Trial 2, a 2-way factorial experimental design was used to compare 3 packaging treatments (vacuum-packed after IQF, AMG-coated, and air-packed) and 2 storage conditions. The rest of the procedure was the same as in Trial 1.

5. Comparison of reheating methods.--In Trial 1, microwave oven, microwave oven and deep-fat-fryer and household ovens were used to reheat chicken pieces which had been stored for 6 months after they were processed as in Experiment 1. Evaluation was made by a 30-member panel using the hedonic score card shown in Appendix IV.

In Trial 2, individually vacuum-packed blast-frozen pressure fried pieces which had been stored for 3 months at $-18^{o}C$ were reheated in microwave oven or by boiling-in-bag, and compared with newly cooked controls by a 30-member panel using the hedonic score card shown in Appendix IV.

6. Evaluation of breading materials.--Chicken pieces were microwave-steam-cooked using the tunnel microwave oven, divided into 6 lots and coated according to the following schedule:

LOT NO.	Coating Treatment	
	Material	Method
1	WF	Dry breading (DB)
2	WF-WC	"
3	WF-CM-PF	"
4	WF	Wet batter (WB)
5	WF-WC	"
6	WF-CM-PF	"

Those pieces coated with dry breading were browned by pressure frying while those coated with wet batter were deep-fat-fried. One half of the pieces in each lot were evaluated immediately after browning by a 30-member panel using the hedonic score card shown in Appendix V. The other half of the pieces were blast-frozen, air-packed, stored under a simulated distribution condition for 3 months and then reheated in microwave oven and evaluated. Similar chicken pieces in each lot were bulk weighed after each stage of processing. The percentage breading was also determined for different pieces after browning.

7. Comparison of cooking methods.--Chicken pieces were randomly divided into 6 lots and treated as follows:

LOT NO.	Treatment	
	PO_4 treatment	cooking method
1	-	PF
2	-	MWS-PF
3	-	MWS-DFF
4	+	PF
5	+	MWS-PF
6	+	MWS-DFF

Immediately after cooking, one half of the pieces were evaluated by a 30-member panel using the hedonic score card shown in Appendix IV. The other one half of the pieces were also blast-frozen, air-packed, stored under simulated distribution condition, and then reheated in microwave oven and evaluated. Changes in weight of the different pieces during processing were recorded, and samples were taken for moisture, ether extract, and shear press determinations.

RESULTS AND DISCUSSION

Experiment 1. Acceptability of microwave reheated chicken. The taste panel scores for microwave reheated chicken pieces after frozen storage up to 6 months at -18°C are shown in Figure 2 (see Appendix VI for tabulated data). After 18 weeks of storage, the flavor of the frozen chicken pieces was less desirable ($P < .05$) than the flavor of freshly cooked pieces. The significant difference in flavor between the reheated pieces and the controls was detected after 4.5 months, which was about the same length of time that staleness was observed by Hanson *et al.* (1959) in fried chicken stored at the same temperature. The panel members did not indicate off-flavor, so the difference in flavor could be attributed simply to the loss of characteristic "freshly cooked" chicken flavor in the reheated frozen pieces possibly due to the reduction of H_2S to subthreshold levels (Pippen and Mecchi, 1969). After 6 months of storage, the frozen pieces were significantly less acceptable ($P < .05$) because of less desirable flavor. There were no significant differences in tenderness and juiciness between the reheated frozen chicken and the newly cooked controls. The results indicate that breaded fried

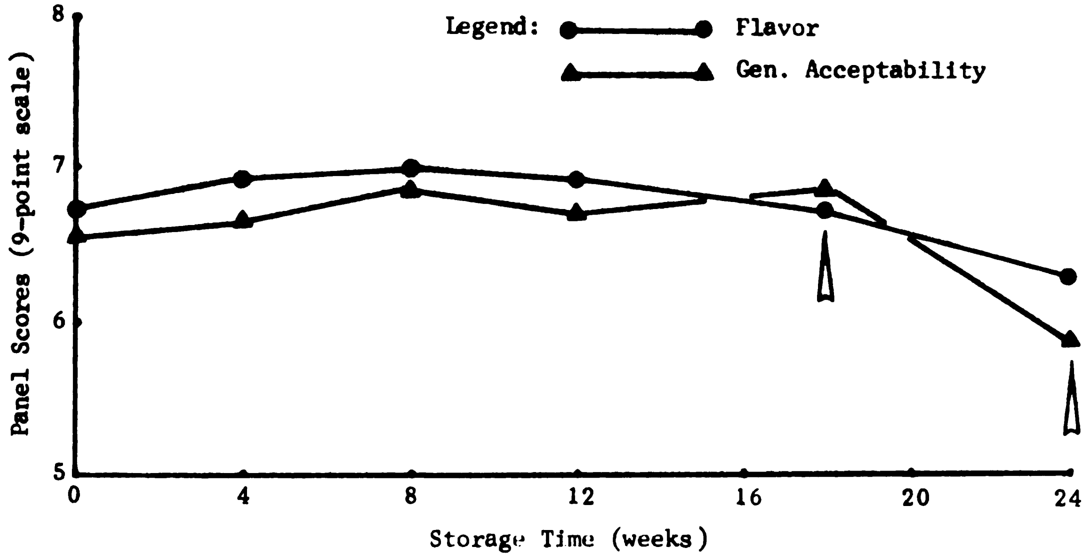

Fig. 2a. Flavor and general acceptability scores of microwave reheated frozen precooked chicken. (Arrows indicate the time at which significant differences from the controls were detected.)

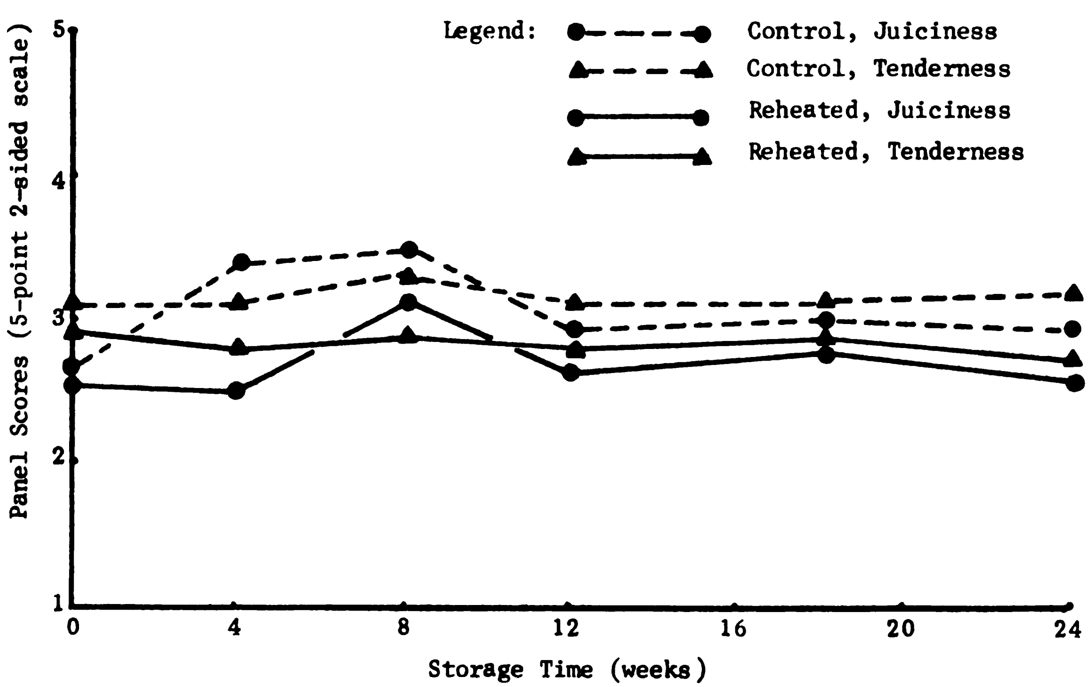

Fig. 2b. Juiciness and tenderness scores for microwave reheated frozen chicken and freshly cooked controls. (Points represent average of 30 samples.)

chicken can be stored up to 3 months at constant low temperature and then reheated in a microwave oven without substantial loss in eating quality.

Experiment 2. Effect of freezing treatments on eating quality. The taste panel scores of fried chicken subjected to different freezing treatments are summarized in Table 2a. In Trial 1, sensory evaluations after 0, 2, and 4 weeks storage periods (Appendix VII) all showed that the eating quality of frozen pieces was significantly lower ($P < .01$) than the controls. Hence, the trial was terminated after 1 month and only the aggregate scores of the 3 tastings are shown. Although these results do not agree with the results in Experiment 1, they are in general agreement with earlier findings of Hanson et al. (1959), Carlin et al. (1959) and Mickelberry and Stadelman (1962), which indicated that eating quality is at a maximum just after cooking and gradually declines after freezing and subsequent storage.

Apparently, the chicken pieces lost weight excessively and unevenly during microwave reheating. The fryers used in this experiment weighed about 150 gms less than those used in a preliminary trial upon which the reheating times were based. The different pieces varied widely in sizes (Table 3) and since most were reheated for the same length of time, the smaller pieces were in effect subjected to more microwave energy than the larger

Table 2a. Taste panel scores of microwave reheated fried chicken frozen by different methods.

Treatment	Average taste panel scores[1]			
	Juiciness	Tenderness	Flavor	Gen. Accept.
Trial 1 (Aggregate of tastings after 0, 2, and 4 weeks frozen storage)				
1. Control, unfrozen	7.4a[2]	7.5a	7.5a	7.4a
2. Control, frozen-thawed	7.4a	7.6a	7.7a	7.6a
3. Reheated, air-blast	5.5b	6.4b	6.6b	6.5b
4. Reheated, liquid N_2	5.3b	6.2b	6.7b	6.3b
Trial 2 (After 3 months frozen storage)				
1. Air-blast frozen	5.6	6.3	6.6	6.1
2. Liquid freon frozen	5.4	5.6	6.5	6.0

[1]Based on a 9-point hedonic scale, each score in Trial 1 is the average for 90 samples while each score in Trial 2 is the average for 60 samples.

[2]Within a column, scores followed by different letters differ significantly ($P < .01$) according to Duncan's multiple range test.

Table 2b. Analysis of variance of taste panel scores of microwave reheated fried chicken frozen by different methods.

Source of variance	Degrees of freedom	Mean Squares			
		Juiciness	Tenderness	Flavor	Gen. Accept.
<u>Trial 1</u>					
Treatment	3	72.8**	31.5**	11.27**	26.97**
Error	356	2.72	2.3	2.1	2.05
<u>Trial 2</u>					
Treatment	1	1.2	8.6	0.3	0.3
Error	118	3.08	2.48	1.9	2.42

**Significant at 1% level.

Table 3. Time required to lower the temperature of chicken pieces from approximately 50°C to -18°C internal temperature.

Chicken Parts	Average Weight and Standard Deviation[1]	Freezing Methods		
		Air-blast	Liq. N_2	Liq. freon
		-37°C	-57°C	-42°C
	gms		min	
Breast tip	104.2 ± 14.6	82[2]	15	8
Breast-back	98.2 ± 10.3	56	9	7
Thigh	114.8 ± 16.4	64	15	8
Drum	85.2 ± 15.1	55	14	6
Wing	56.1 ± 2.6	38	8	4

[1]Average of 8-16 pieces.

[2]Average of duplicate observations in 2 replications.

pieces and therefore lost relatively more weight. During reheating, each piece lost about 20 to 25% of the cooked weight (Appendix VIII). The loss in weight was accompanied by a decrease in moisture content since the meat in the reheated pieces had about 13% less moisture than that of cooked meat before freezing (Appendix IX). The excessive loss in moisture lowered the juiciness and tenderness scores and could have also affected the flavor and general acceptability ratings. Baker and Darfler (1968) reported, using subjective evaluation of chicken breast meat, that flavor and preference were significantly correlated with tenderness and juiciness.

No significant difference in the eating quality (flavor, juiciness, tenderness and general acceptability) of newly cooked unfrozen and frozen-thawed chickens was found, which was in agreement with the findings of Mostert and Stadelman (1964) and Baker and Darfler (1968), who reported that cut-up fryers can be frozen, stored for a limited time, thawed, and cooked without lowering the eating quality. However, frozen fryers should be stored at constant low temperature and cooked immediately after rapid thawing to prevent bone darkening (Brant and Stewart 1949).

No differences in the eating quality were found between products frozen by air-blast and liquid nitrogen, and between those frozen by air-blast and liquid freon

(Trial 2), which showed that reasonably fast freezing methods would have comparable effects on the eating quality of fried chicken. However, it was observed that products frozen in freon were paler in color even after reheating and that a layer of oil remained at the bottom of the freon freezing chamber after the Freon 12 had evaporated, indicating that the freezant was leaching out oil and perhaps other fat soluble components from the chicken pieces. It was thought necessary to investigate further the effect of freon freezing on fried chicken under more rigorous storage conditions.

The average times required to freeze various chicken pieces, starting at approximately 50°C to an internal temperature of -18°C by three freezing methods are shown in Table 3. The freezing rate of chicken pieces in liquid freon was twice as fast as those in liquid nitrogen and about 10 times as fast as those in air-blast under the conditions studied. The data also show great differences in the freezing rates between different pieces. The freezing rates for wings, for example, were twice as rapid as those for thighs and breasts. These results indicate that it may be advisable to feeeze chicken by individual cuts rather than all pieces of each bird together. There was also a difference in the freezing rates of the same piece from batch to batch arising mainly from the variations in the sizes of the chickens and in the manner in which they were cut. It is considered necessary that size of chicken and the manner of cutting must be more uniform when processed under commercial conditions. The loss in weight of chicken pieces during freezing was only 1 to 2% of the cooked weight (Appendix VIII), and this was mainly due to the flaking off of the coating. Carlin et al. (1959) reported no changes in weight in precooked broilers during 15 weeks storage at $-18^{o}C$.

Experiment 3. Effect of microwave reheating time on eating quality. This experiment was conducted to investigate more fully the effect of microwave reheating time on the quality of frozen fried chicken. The average weight losses of chicken pieces during reheating in microwave oven after 3 months under two storage conditions are shown in Figure 3, and the mathematical slope and x-intercept of the curve for each piece are shown in Table 4. The data indicate that it took 0.6 min (x-intercept) to reheat 100 gms of chicken pieces in the microwave oven to the boiling point of water and beyond that time, the excess microwave energy was utilized to vaporize the moisture content. However, the moisture near the surface started to steam off before the inside of the piece was thawed so that considerable moisture was lost even with the minimum heating time to bring the interior of the pieces to serving temperature. Although the average slopes of the weight loss curves of

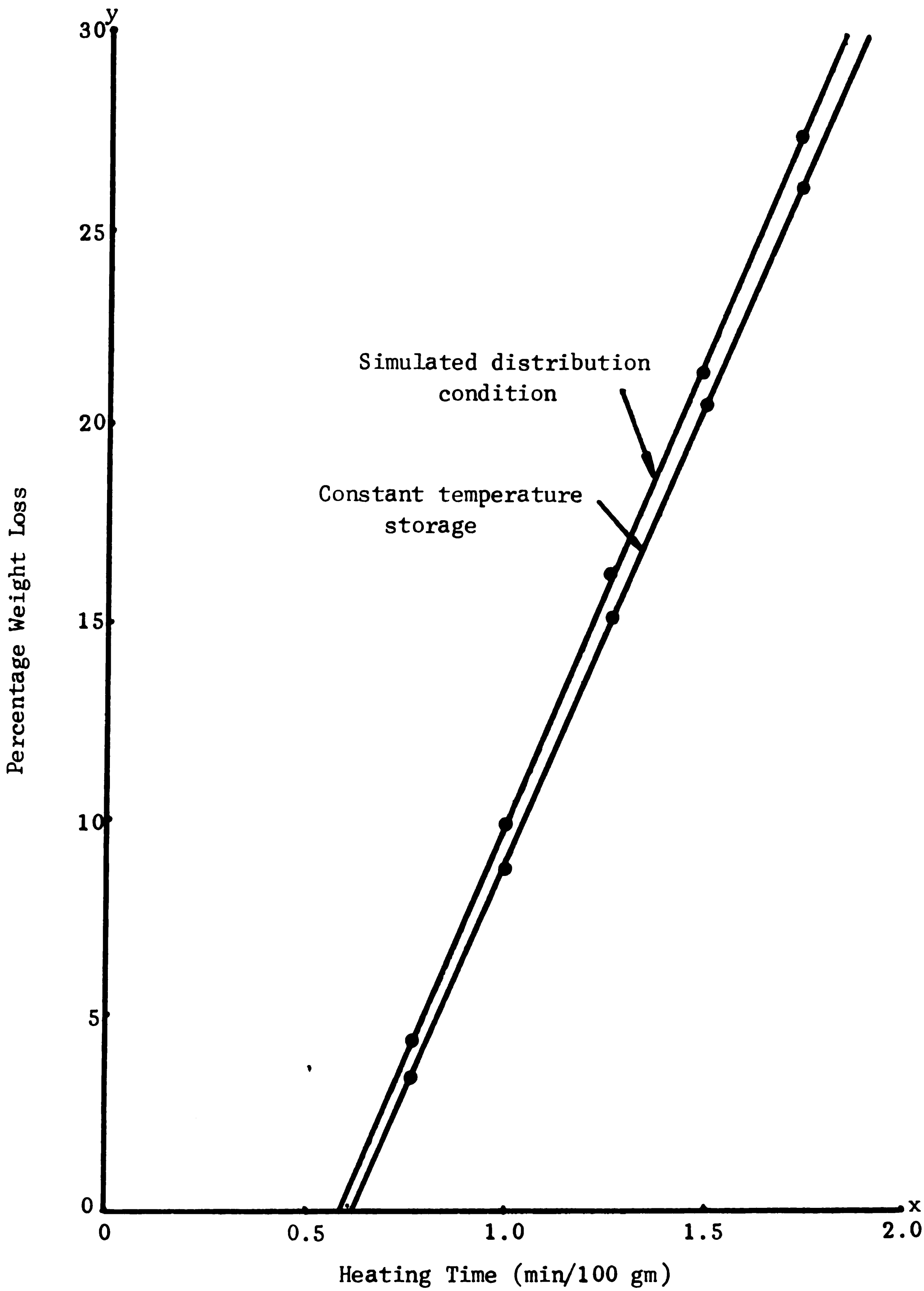

Fig. 3. Average weight loss of chicken pieces during reheating in microwave oven after 3 months under simulated distribution condition or constant -18°C storage.

Table 4. Mathematical x-intercept and slope of weight loss curves of various chicken parts.[1]

Parts	Constant -18°C storage		Simulated distribution condition	
	x-intercept	slope	x-intercept	slope
Breast tip	.78	21.5	.72	21.2
Breast-back	.50	20.3	.50	22.3
Thigh	.47	20.9	.58	25.4
Drum	.64	21.1	.66	21.7
Wing	.58	25.1	.56	26.5
Whole bird	.62	22.7	.60	23.3

[1]Average of 5-6 pieces.

the pieces subjected to a simulated distribution condition and those under constant temperature storage were the same, those under simulated distribution condition lost about 1% more weight at any given time due to a small difference in the x-intercepts. This may indicate that there was a slight moisture migration towards the surface of the piece during the fluctuating temperature storage. Variations in the x-intercepts and slopes of the weight loss curves of the different chicken pieces could have been due to differences in shape, surface area and/or moisture content. Beyond the x-intercept, the loss in weight was linearly related to the microwave reheating time. These results suggest that the loss in weight during reheating in a microwave oven is directly proportional to the heating time, which could be interpreted to mean that the weight loss is also a function of the power output of the microwave oven and the weight of the load.

The changes in juiciness and tenderness of breast meat with the increase in microwave reheating time per unit weight are shown in Figure 4. The data show that in the particular oven used in this study, increasing the reheating time of chicken breast beyond 1 min/100 gms resulted in highly significant ($P \leq .01$) decreases in juiciness and tenderness scores and increase in shear press values. Regression analysis (Table 5) showed a highly significant linear decrease in juiciness and tenderness scores

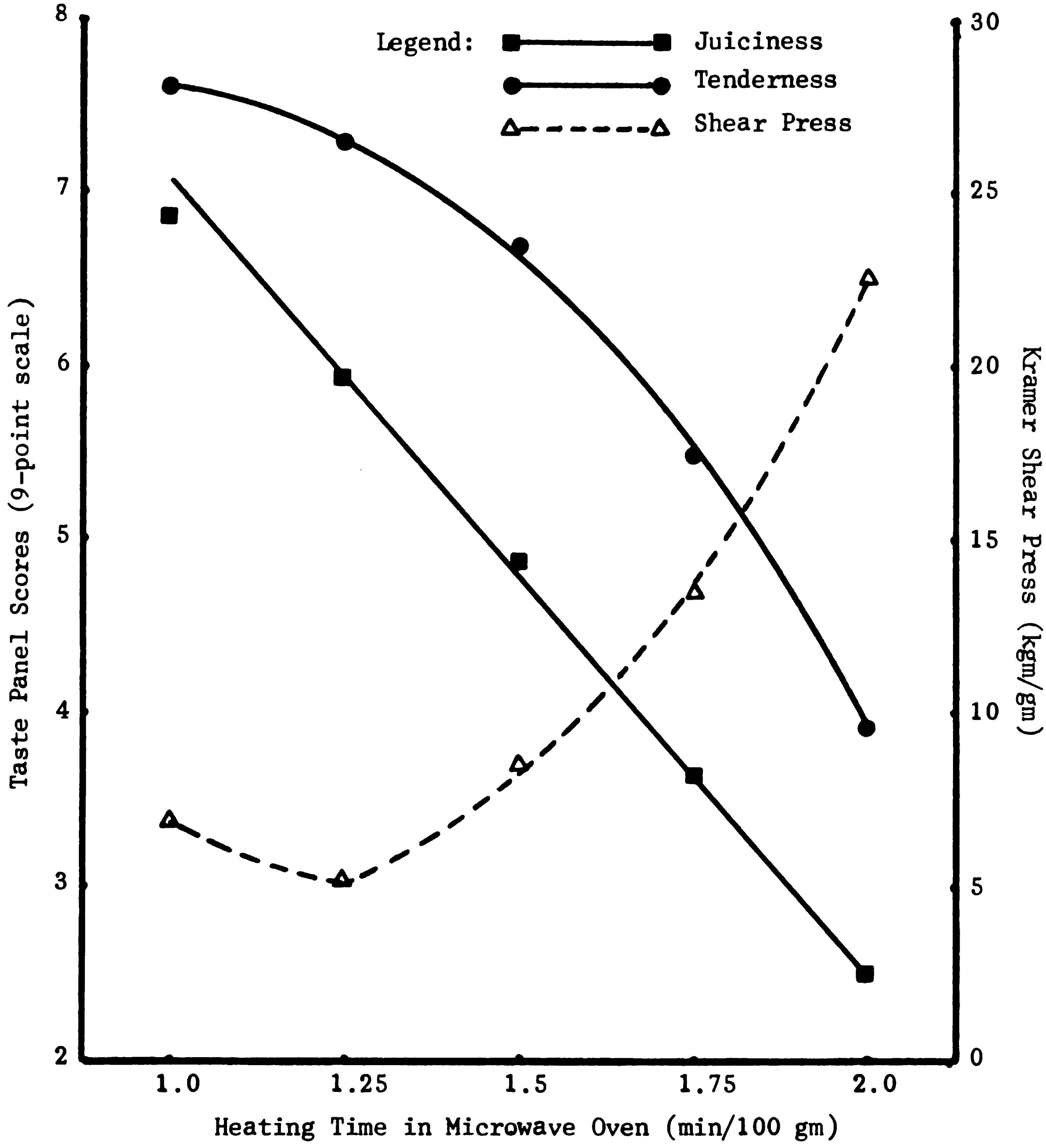

Fig. 4. Influence of microwave reheating time on juiciness and tenderness of Pectoralis major muscle.

Table 5. Regression analysis of the relationship of juiciness and tenderness scores and shear press values with microwave reheating time.

	Juiciness	Tenderness	Shear press values
b	-3.86	•-3.75	19.0
σ	+0.382	+0.50	+14.56
r	-0.980***	-0.964***	0.881**

**Significant at 1% level.

***Significant at .1% level.

b is the slope and σ is the variance of the least square fit curve.

r is correlation coefficient.

with the increase in reheating time, which indicates that excessive heating with microwave progressively decreases the eating quality of the fried chicken. There were also highly significant correlations between sensory tenderness scores and shear press values, and between juiciness scores and weight loss (Table 6). These results agree with earlier findings of Baker and Darfler (1968) on the relationship between tenderness and shear press values, and of Carlin *et al*. (1959) on juiciness and weight loss. These results further indicate that, in order to maintain the eating quality, chicken pieces should be reheated for only the minimum time required to bring them to serving temperature and that the time should be based accurately on weight rather than on the number of pieces. Since different models of microwave ovens vary in power output and the power output decreases with usage, individual oven units should be calibrated periodically to establish optimum heating time for the particular product.

Experiment 4. *Effect of packaging and storage conditions on eating quality*. The summary of the taste panel scores of microwave reheated chicken subjected to various freezing, packaging, and storage treatments (Trial 1) are shown in Table 7a, but the detailed scores are reported in Appendix X. Statistical analysis of the taste panel scores (Table 7b) showed that the freezing,

Table 6. Correlation coefficients for breast muscle measurements.

	Subjective		Objective	
	Juiciness	Tenderness	Weight loss	Shear press
Subjective:				
Tenderness	.978***			
Objective:				
Weight loss	-.987***	-.973**		
Shear press		-.962**	.895**	
Reheating time	-.980***	-.964**	.980***	.881**

**Significant at 1% level.

***Significant at .1% level.

Table 7a. Summary of taste panel scores of microwave reheated fried chicken subjected to various freezing, packaging, and storage treatments.

Factors	Average taste panel scores[1]			
	Juiciness	Tenderness	Flavor	Gen. Accept.
<u>Freezing method</u>				
Air-blast	6.3	6.9	7.1	6.9
Liquid freon	6.4	7.1	7.1	6.9
<u>Packaging</u>				
PE bag without vacuum	6.5	7.1	7.0	6.9
Vacuum-packed before IQF	6.2	6.9	7.3	6.9
Vacuum-packed after IQF	6.3	7.0	7.1	7.0
<u>Storage</u>				
Constant -18°C	6.4	7.1	7.1	6.9
Simulated distribution	6.3	6.9	7.1	6.9

[1]Based on a 9-point hedonic scale, each score under the freezing and storage treatments is the average for 180 samples while each score under the packaging treatment is the average for 120 samples.

Table 7b. Analysis of variance of taste panel scores of microwave reheated fried chicken subjected to various freezing, packaging, and storage treatments.

Source of variance	Degrees of freedom	Mean Squares			
		Juiciness	Tenderness	Flavor	Gen. Accept.
Freezing	1	0.7	1.8	0.1	0.3
Packaging	2	3.36	1.55	1.8	0.45
Storage	1	0.4	5.20	0.1	0.1
Error	354	2.48	1.75	1.53	1.74

packaging, and storage treatments did not significantly affect the eating quality of the product.

The results of the panel evaluation of chicken pieces receiving different freezing treatments are similar to the findings in Experiment 2, indicating that the freezing methods used in this study have comparable effects on the eating quality of fried chicken. Although Cunningham et al. (1971) reported differences in shear press and TBA values in fried chicken frozen by different methods, the differences were probably not significant to the consumers because they were with the so-called "just-not-noticeable-difference" (Baker and Darfler, 1968 and Palmer et al. 1965). The leaching out of fat when the pieces were immersed in Freon 12 appeared not to be a significant factor. It should be noted that the panel scores in this Trial were higher than those in Experiment 2, possibly because most of the pieces were vacuum-packed and because all of them were reheated for exactly 1 min/100 gms.

Since the polyethylene bag and the laminated pouch used in this Trial have both good oxygen and water vapor barrier properties, it can be inferred from the data that packaging materials which have good barrier properties would offer comparable protection with or without vacuum and under constant or fluctuating temperature storage. No significant differences were found in the panel scores of pieces vacuum-packed before and after freezing. The data also show that packaging in polyethylene bags in bulk offers adequate protection to the product during simulated distribution conditions.

Trial 2 was conducted to evaluate the effects on eating quality of 3 packaging treatments. The taste panel scores of the reheated chicken pieces after different packaging and storage treatments are reported in Table 8a. The results show that the panel scores of the frozen pieces which had been placed under constant temperature are significantly better ($P < .01$) than those subjected to a simulated distribution condition.

No differences were found in flavor, tenderness and general acceptability of products subjected to different packaging treatments and held under constant temperature storage. The results were similar to those of Carlin et al. (1959) indicating that packaging has a minor effect on the deterioration of eating quality under constant low temperature storage. The vacuum-packed pieces had lower juiciness scores; however, they were reheated first before serving.

Under simulated distribution condition, the vacuum-packed pieces had flavor scores comparable to those under constant temperature, and significantly higher ($P < .01$) than the flavor scores of the AMG-coated and the unprotected pieces. These results indicate

Table 8a. Taste panel scores of microwave reheated frozen fried chicken subjected to various packaging and storage treatments.

Treatment	Average taste panel scores[1]			
	Juiciness	Tenderness	Flavor	Gen. Accept.
Constant temperature				
A. Vacuum-packed	5.8bc[2]	7.0a	7.3a	7.1a
B. AMG-coated	7.0a	6.6a	6.7a	6.6a
C. Air-packed	6.6ab	6.8a	6.6a	6.7a
Simulated distribution condition				
A. Vacuum-packed	5.2c	6.3a	7.1a	6.4ab
B. AMG-coated	6.7a	6.4a	5.4b	5.6b
C. Air-packed	4.8c	5.9a	5.6b	5.4b
Average				
Constant temperature	6.5**	6.8**	6.9**	6.8**
Distribution condition	5.6	6.2	6.0	5.8

[1]Based on a 9-point hedonic scale, each score is the average for 30 samples.

[2]Within a column, scores followed by different letters differ significantly ($P < .05$) according to Duncan's multiple range test.

**Significant at 1% level.

Table 8b. Analysis of variance of taste panel scores of microwave reheated frozen fried chicken subjected to various packaging and storage treatments.

Source of variance	Degrees of freedom	Mean Squares			
		Juiciness	Tenderness	Flavor	Gen. Accept.
Package (P)	2	32.7**	1.4	26.05**	7.85*
Storage (S)	1	34.7**	16.8**	32.90**	38.0**
P x S	2	9.43**	1.8	4.25	3.7
Error	174	1.45	2.07	2.53	2.2

*Significant at 5% level.

**Significant at 1% level.

that materials with good oxygen properties should be used in packaging fried chicken in order to prevent flavor deterioration under adverse storage conditions. The AMG-coated pieces had the highest juiciness scores possibly because of higher yields (Table 9), suggesting the potential use of a suitable coating to prevent excessive moisture loss during storage and subsequent microwave reheating. Due to a strong vinegar flavor, the flavor and acceptability scores of the AMG-coated chicken pieces were similar to those of the controls. Apparently, acetic acid residues were released from the AMG during the fluctuating temperature storage. No significant differences were observed in tenderness and acceptability among the treatments.

This experiment demonstrated the need for a good protective package and constant low temperature in the distribution of frozen fried chicken to prolong its eating quality. It also showed that an edible coating which does not impart an undesirable flavor may be used to preserve the juiciness of the product even after microwave reheating.

Experiment 5. <u>Comparison of reheating methods</u>. Observations made in previous experiments indicated that microwave reheated pieces had soggy breading and were less juicy than newly cooked controls. Hence, this experiment was conducted to determine whether other

Table 9. Percentage change in weight at selected stages of processing of chicken subjected to different packaging and storage treatments (Experiment 4, Trial 2).

Treatment	Weight after freezing[1]	Stages of processing			
		after freezing	after AMG coating	after frozen storage	after micro-wave reheat-ing
	gms	% of weight after freezing			
<u>Constant temperature storage</u>					
A. Vacuum-packed	105.2	100	---	100.0	91.4
B. AMG-coated	104.0	100	110.5	111.3	91.8
C. Air-packed	107.1	100	---	99.4	90.1
<u>Simulated distribution condition</u>					
A. Vacuum-packed	116.6	100	---	100.0	89.4
B. AMG-coated	110.4	100	109.2	108.2	90.9
C. Air-packed	112.4	100	---	98.0	88.3

[1]Average of 90 pieces.

reheating methods could produce better products than those reheated by microwave. In Trial 1, chicken pieces reheated by microwave energy were compared with those receiving a combination of microwave energy and deep-fat-frying, which gave crispier products, and with those reheated in a household oven. Sensory evaluations (Table 10) showed that chicken pieces reheated in the household oven were significantly more juicy than products reheated by either methods using microwave energy. Since the juicier pieces did not lose as much weight during reheating (Table 11), it can be concluded that moisture loss was directly responsible for the decrease in juiciness of the microwave reheated pieces. There were no differences among treatments in flavor, tenderness, and general acceptability, which confirmed earlier conclusions of Cunningham et al. (1971) that the manner of reheating does not materially affect the flavor and tenderness of frozen fried chicken.

During the evaluations, each panel member was asked to indicate which sample was preferred most, and the reason for this preference. Chicken samples reheated by each method were preferred by an equal number of panel members. No consistent reasons were given for their preferences, which was similar to the observations of Baker et al. (1960) that in consumer acceptance testing, the direction of preference was not specific, and many

Table 10a. Taste panel scores of frozen fried chicken reheated by different methods.

Treatment	Average taste panel scores[1]			
	Juiciness	Tenderness	Flavor	Gen. Accept.
Trial 1				
Microwave	6.0a[2]	6.9a	7.3a	7.0a
MW-DFF	5.9a	6.8a	7.0a	6.8a
Ordinary oven	7.1b	7.4a	6.8a	6.9a
Trial 2				
Newly cooked control	7.3a	7.6a	7.3a	7.4a
Microwave	6.0b	6.5b	6.7a	6.6b
Boil-in-bags	6.7ab	7.1ab	6.6a	6.5b

[1]Based on a 9-point hedonic scale, each score is the average for 30 samples.

[2]In each trial, scores within a column followed by different letters differ significantly ($P < .05$) according to Duncan's multiple range test.

Table 10b. Analysis of variance of taste panel scores of frozen fried chicken reheated by different methods.

Source of variance	Degrees of freedom	Mean Squares			
		Juiciness	Tenderness	Flavor	Gen. Accept.
Trial 1					
Treatment	2	13.3**	3.4	1.5	.25
Error	87	2.21	1.55	2.2	1.4
Trial 2					
Treatment	2	11.2*	6.23*	2.40	4.9*
Error	87	2.35	2.2	2.04	1.5

*Significant at 5% level.

**Significant at 1% level.

Table 11. Percentage weight loss of chicken pieces during reheating.[1]

Reheating method	% Weight loss and standard deviation
Microwave	9.8 ± 2.3
MW-DFF	8.2 ± 2.0
Oven (household)	3.1 ± 1.2

[1]Average of 36 pieces.

consumers were indifferent to the characteristics being tested.

In Trial 2, vacuum-packed frozen chicken pieces reheated by microwave or by boiling-in-bag were compared with newly cooked controls. The taste panel evaluation showed that juiciness and tenderness scores were highest for the controls, intermediate for those boiled-in-bags, and lowest for the microwave reheated pieces. The differences in panel scores between the controls and microwave reheated pieces were significant at 5% level. These data show that freezing per se caused a slight decrease in juiciness and tenderness scores, and results were confounded by microwave reheating. No differences in flavor were observed among the treatments. However, the controls were significantly more acceptable ($P < .05$) than the reheated pieces. The low acceptability scores for the boiled-in-bag pieces were caused mainly by their greasy appearance.

The results of this experiment showed that a method which minimizes weight loss can be used to reheat frozen fried chicken without lowering the eating quality.

Experiment 6. Evaluation of breading materials. Preliminary trials were conducted to select satisfactory breading mixtures. Several combinations of flour from wheat, rice, potato, barley, oat and rye, and corn meal, cracker meal, and waxy cornstarches were applied to chicken pieces as dry breadings and as wet batters before deep-fat-frying. Fried chicken pieces were evaluated for color, adhesion, and texture after frying, and after freezing and microwave reheating. The all-purpose wheat flour, which was used in the preceding experiments, was found satisfactory for the batter, and was selected as the control. The wheat flour-corn meal-potato flour combination, which is the basic formula for some comercial breading mixtures, was found to be an excellent ingredient for the coating both as breading and as batter. The wheat flour-waxy cornstarch combination was also selected because it had good adhesion before and after freezing and microwave reheating.

The panel scores of the coating characteristics and eating quality of freshly cooked and microwave reheated chicken pieces subjected to various coating treatments are reported in Table 12a and summarized in Table 12b. The dry breaded coatings on the freshly cooked or microwave reheated chicken pieces had significantly better adhesion ($P \leq .01$) than those of the pieces coated with batter. Perhaps the breading may have shrunk with the tissues during processing and left a porous coating which allowed the gradual escape of volatiles during the cooking and microwave reheating processes, whereas the batter set at its original shape and formed a continuous crust which erupted or flaked off during cooking to allow

Table 12a. Taste panel scores of freshly cooked and microwave reheated frozen fried chicken subjected to various coating treatments.

Treatments	Coating Characteristics[1]				Eating Quality[2]			
	Color	Adhe-sion	Tex-ture	Hard-ness	Juici-ness	Tender-ness	Flavor	Gen. Accept.
Freshly Cooked:								
A. Dry Breading								
1. Wheat flour (WF)	3.1[3]	2.8	2.8	3.0	6.2	6.8	7.2	7.3
2. WF-Waxy corn (WC)	2.6	2.6	2.8	2.9	6.4	5.9	7.3	7.1
3. WF-CM-PF[4]	2.8	2.8	2.4	3.2	5.9	6.6	7.3	7.3
B. Wet Batter								
1. WF	3.5a	2.3	3.0a	3.4a	6.2	6.8	7.1	7.1
2. WF-WC	2.9b	2.1	2.9a	2.8b	6.6	6.8	7.5	7.3
3. WF-CM-PF	2.5c	2.2	3.4b	2.9b	5.7	6.1	7.0	6.6
Reheated in Microwave oven (after 3 months frozen storage):								
A. Dry Breading								
1. WF	3.0a	2.6	2.8	2.7	5.2	6.2	6.7	6.7
2. WF-WC	3.0a	3.0	3.1	2.8	5.8	6.0	6.4	6.5
3. WF-CM-PF	2.3b	2.8	2.8	2.6	5.5	6.4	6.3	6.1
B. Wet Batter								
1. WF	3.1	2.0b	3.3	2.4	5.8	6.3	6.2	6.0
2. WF-WC	3.0	2.5a	3.4	2.5	5.4	5.9	6.3	6.4
3. WF-CM-PF	3.1	1.8b	3.2	2.7	5.3	5.9	6.1	5.9

[1]Evaluated on a 5 point 2-sided scale: 3 being ideal.

[2]Based on a 9-point hedonic scale: 9, extremely desirable; 1, extremely undesirable.

[3]Each number is the average of 30 scores.

[4]CM = corn meal; PF = potato flour.

Table 12b. Summary of the taste panel scores of chicken subjected to various coating treatments.

Treatments	Coating Characteristics				Eating Quality			
	Color	Adhesion	Texture	Hardness	Juiciness	Tenderness	Flavor	Gen. Accept.
Coating Method								
Dry breading	2.8b[1]	2.8a	2.8a	2.8	5.8	6.6	6.9	6.8
Wet batter	3.1a	2.2b	3.2b	2.6	5.8	6.4	6.7	6.6
Coating Material								
WF	3.1a	2.4	3.0	2.9	6.0	6.5	6.8	6.8
WF-WC	2.9ab	2.5	3.1	2.8	6.1	6.4	6.9	6.8
WF-CM-PF	2.7b	2.4	3.1	2.8	5.6	6.3	6.7	6.5
Stage								
Freshly cooked	2.9	2.5	2.9a	3.0a	6.1a	6.7a	7.3a	7.1a
Reheated	2.9	2.4	3.1b	2.6b	5.5	6.2b	6.4b	6.2b
Freshly Cooked								
Dry breading	2.8	2.7a	2.7b	3.0	6.1	6.8	7.3	7.2
Wet batter	3.0	2.2b	3.1a	3.0	6.2	6.6	7.2	7.0
Reheated								
Dry breading	2.8b	2.8a	2.9b	2.7	5.5	6.2	6.5	6.4a
Wet batter	3.1a	2.1b	3.3a	2.5	5.5	6.1	6.3	6.1b

[1]Within a block, scores in the same column followed by different letters differ significantly at 5% level.

Table 12c. Analysis of variance of the taste panel scores of fried chicken subjected to various coating treatments.

Source of variance	Degrees of freedom	Mean Squares							
		Coating Characteristics				Eating Quality			
		Color	Adhesion	Texture	Hard-ness	Juici-ness	Tender-ness	Flavor	Gen. Accept.
Freshly Cooked									
Materials	2	6.5**	.7	.2	3.1*	7.4	4.1	1.1	1.0
Application	1	1.1	11.7**	8.5*	0	.2	2.0	.1	2.2
Error	176	.67	.68	.67	.74	2.5	1.8	1.1	1.5
Reheated									
Materials	2	2.4*	2.7*	.9	.15	.4	1.2	1.0	3.1
Application	1	3.8*	9.3**	6.8**	1.8	0	1.0	1.8	5.7*
Error	176	.73	.75	.89	.98	3.6	2.2	2.0	1.8
Combined									
Materials	2	7.3**	.7	.2	.8	5.5	6.5	2.2	2.0
Application	1	4.5*	23.0**	15.2**	.7	.1	2.8	1.4	4.6*
Stage	1	0	.8	4.0	16.9**	28.7**	27.8**	67.6**	12.5**
Error	355	.7	.67	.8	.86	3.0	2.0	1.5	1.6

*Significant at 5% level.

**Significant at 1% level.

the escape of volatiles (Hale and Goodwin 1968, Hanson and Fletcher 1963). These results indicate that dry breading is more desirable than wet batter for fried chicken. The significantly coarser texture ($P < .01$) of the dry breading can easily be altered by using finer ground ingredients, while the significantly lighter color ($P < .05$) can be made darker by increasing the time and/or temperature of frying.

No differences in the coating characteristics, except for color, were observed among the chicken pieces coated with different mixtures. The color was darkest in those coated with wheat flour, intermediate in those with wheat flour-waxy cornstarch, and lightest in those with wheat flour-corn meal-potato flour mixture. The difference in the color scores between wheat flour and wheat flour-corn meal-potato flour mixtures was significant at 1% level.

There were no differences in the eating quality of the chicken pieces regardless of the coating treatments, which was similar to the findings of Hale and Goodwin (1968), indicating that the coating only affects the appearance but not the eating quality of fried chicken.

The coatings on the reheated chicken pieces were significantly softer ($P < .01$) than those of the freshly cooked pieces, possibly due to the effect of moisture escaping as steam from the chicken tissues during microwave reheating (Anon. 1968), Co and Livingston 1969). The soft or "soggy" coatings and lower juiciness, tenderness, and flavor scores, combined to produce significantly less acceptable ($P < .01$) reheated products as compared with freshly cooked ones, which coincide with findings in Experiment 2. The coatings on the freshly cooked chicken pieces were significantly coarser ($P < 01$) than those on the reheated pieces, although the texture scores were almost ideal. No differences were observed in the color and adhesion of the coating on the freshly cooked and microwave reheated frozen chickens.

In spite of precooking the chicken pieces prior to coating application, as recommended by Hanson and Fletcher (1963) to insure better adhesion, the coating on the chicken pieces had generally poor adhesion with an overall average score of 2.5. More studies are needed to develop suitable coating methods and/or ingredients which would yield coatings with good adhesion for fried chicken, especially for those to be frozen and reheated in microwave ovens.

The percentage change in weight of breaded or battered chicken pieces at various stages of processing, based on the original raw weights, are shown in Table 13a. During the coating application, the pieces coated with batter increased 14% in weight, which was significantly higher ($P < .01$) than the 10% increase in weight of those

Table 13a. Percentage change in weight during processing of fried chicken subjected to various coating treatments.

Treatments	Original raw weight[1]	Stages of Processing[2]					
		After MWS cooking	After coating	After frying	After freezing	After storage	After reheating
	gms	percentage of original raw weight					
Dry Breading							
1. WF	876.6	93.0	101.0	86.2	84.3	79.0	74.4
2. WF-WC	875.8	91.4	101.2	88.8	86.4	81.6	77.0
3. WF-CM-PF	881.5	92.2	103.5	89.6	87.7	82.3	78.1
Wet Batter							
1. WF	855.4	92.3	105.7	88.6	86.7	85.6	80.8
2. WF-WC	850.8	92.1	106.6	86.6	84.8	83.7	78.4
3. WF-CM-PF	859.6	91.1	105.2	88.3	86.3	86.1	80.3

[1]Average weight of 10 birds used per treatment.

[2]Each figure is the weighted average of 90 pieces (20 pieces each for thigh, drum, wing, and breast-back; 10 pieces for breast tip).

Table 13b. Analysis of variance of breading content, percentage change in weight and yield data (Experiment 6).

Source of variance	Degrees of free- dom	Mean Squares						
		Breading content	Coating gains	Frying losses	Reheating losses	Coated yield	Cooked yield	Reheated yield
Material (M)	2	66.8**	2.9	61.2*	2.7	8.9	12.4	8.3
Application (A)	1	17.2	115.0**	133.1**	3.2	145.6*	0.3	0.1
M x A	2	6.2	19.0	19.0	0.1	3.0	0.1	0.3
Error	24	8.8	12.6	12.6	0.8	29.0	13.5	11.0

*Significant at 5% level.

**Significant at 1% level.

pieces coated with dry breading. However, during frying, the pieces coated with batter lost an average of 15% in weight which was also significantly higher ($P < .01$) than the 11% weight loss of the breaded pieces. Hence, the cooking yields for the pieces coated by both methods were the same (88%). Carlin et al. (1959) reported an average of 7% increase in weight of chicken pieces after breading with milk and flour, while Hanson and Fletcher (1963) and Hale and Goodwin (1968) reported gains ranging from 15 to 30% for pieces coated with batter depending upon the moisture:solid ratio of the batter and the number of applications. Carlin et al. (1959) and Hale and Goodwin (1968) also reported similar cooked yield values after deep-fat-frying of approximately 84%.

Analysis of variance (Table 13b) showed no differences in the yields, after coating and after cooking, among the pieces coated with different mixtures but by the same procedure, which was similar to the findings of Hale and Goodwin (1968). These results indicate that the amount of coating applied on the chicken pieces was affected more by the manner of application than by variation in the ingredients of the coating. However, the percentage of coating (Table 14) on fried chicken pieces coated with wheat flour-waxy cornstarch and wheat flour-corn meal-potato flour combinations were significantly greater ($P < .01$) than on those coated with wheat flour alone.

Table 14. Coating content of fried chicken subjected to various coating treatments.

Materials	Method of Application		
	Dry breading	Wet batter	Average
	%	%	%
WF	5.1[1]	9.0	7.0a[2]
WF-WC	10.7	11.4	11.0b
WF-CM-PF	10.9	12.8	11.9b
Average	8.9	11.1	

[1]Each figure is the average for the 5 different chicken pieces.

[2]Figures followed by different letters differ significantly ($P \leq .05$) according to Duncan's multiple range test.

These differences were partly due to differences in cooking losses (see Table 10a) which in turn may have been influenced by the differences in the proportion of starch in the coating. Perhaps the increased proportion of starch in the combination breadings may have increased fat absorption during frying which offset some of the moisture lost and therefore resulted in an apparently higher cooking yield. Hanson and Fletcher (1963) observed differences in both fat content in coating and in the amount of coating among fried chicken pieces coated with various materials. Mostert and Stadelman (1964) reported that breading increased fat absorption or retention. Further studies are needed to explain the differences in the percentage coating in fried products arising from the differences in the ingredients of the coating.

It can be concluded from the findings in this experiment, and in conjunction with the findings of Hanson and Fletcher (1963), Mostert and Stadelman (1964), and Hale and Goodwin (1968), that the coating of fried chicken is very important because of its influence on the yield, appearance, and on the distribution of the seasoning. A desirable coating should have a uniform golden-brown color, good adhesion, and optimum texture at the time the chicken is served. While these coating characteristics have been shown to be influenced by coating methods, ingredients, and microwave reheating, a great deal of art is still involved in producing fried chicken with a uniform and consistent color.

Experiment 7. Comparison of cooking methods. It was experienced in earlier experiments that pressure frying is essentially a batch operation and the data had shown that microwave reheated frozen chicken pieces were less tender or juicy than freshly cooked ones. Hence, this experiment was conducted to evaluate the suitability of three cooking methods for centralized processing and to investigate the efficacy of polyphosphates in improving the quality of reheated products. Pressure frying (PF) was selected as the control because it produces excellent products especially when served soon after cooking, whereas microwave-steam (MWS) precooking was selected for its speed and high yields. Although deep-fat-frying was the most convenient method, pressure frying was also considered for browning because it had not been used in combination with microwave-steam precooking before. A preliminary trial has shown that 5 kw was about the maximum microwave power output which could be used without causing bursting in the chicken pieces, and that a 10-minute processing at this power with the belt loaded was adequate to heat the pieces to 85°C internal temperature with an average shrinkage of 7-8%.

The panel scores and shear press values of freshly cooked and microwave reheated frozen chickens which have been cooked by different methods are shown in Table 15a. In the freshly cooked chicken, those soaked in phosphate were significantly more juicy and tender ($P < .01$) and therefore more acceptable than the untreated pieces. Shear press values were also significantly lower in the phosphate-soaked samples. These differences may be due to the significantly higher moisture content of the phosphate-treated pieces. Baker and Darfler (1968) observed differences in juiciness, tenderness, and preference between untreated and phosphate-soaked chicken pieces, but observed no differences in shear press values. Flavor was not affected by the phosphate treatment.

The chicken pieces cooked by MWS-DFF were significantly juicier ($P < .01$) than those cooked under pressure. However, there were no differences in flavor and general acceptability among the cooking methods, which was similar to the findings of Hale and Goodwin (1968). Conflicting results were obtained on the effect of cooking methods on tenderness. The sensory evaluation detected no significant differences whereas the shear press determination showed that the controls (PF) were significantly more tender ($P < .01$) than the precooked pieces. Anon. (1966) reported that chickens precooked in microwave-steam were as tender, if not more tender than, those cooked by DFF. Mickelberry and Stadelman (1962) observed no significant differences in the shear press values of pieces cooked by

Table 15a. Taste panel scores and shear press values of freshly cooked and microwave reheated chicken subjected to various treatments.

Treatment	Average taste panel scores[1]				Shear press values
	Juiciness	Tenderness	Flavor	Gen. Accept.	
	9-point hedonic scale				kgm/gm
FRESHLY COOKED					
A. Untreated					
1. PF	5.9a[2]	6.9	6.9	6.9	7.7b
2. MWS-PF	5.9a	6.4	7.2	6.6	10.0c
3. MWS-DFF	6.9b	6.8	7.2	7.2	11.4c
B. Soaked in phosphate					
1. PF	6.7b	7.5	7.2	7.1	6.4a
2. MWS-PF	6.8b	7.6	7.6	7.5	8.5b
3. MWS-DFF	7.3c	7.5	7.0	7.2	8.6b
Untreated	6.2	6.7	7.1	6.9	9.7**
Soaked in PO_4	6.9**	7.5**	7.3	7.3*	7.8
REHEATED IN MICROWAVE OVEN (After 3 months frozen storage)					
A. Untreated					
1. PF	6.0	6.5	6.9	6.8	11.4
2. MWS-PF	6.3	6.5	6.4	6.2	11.6
3. MWS-DFF	6.9	6.9	6.7	6.9	12.7
B. Soaked in phosphate					
1. PF	6.7	7.2	6.9	7.0	10.3
2. MWS-PF	6.5	7.0	6.7	6.6	10.8
3. MWS-DFF	6.4	6.5	6.4	6.3	9.9

Untreated	6.4	6.6	6.7	6.6	11.9
Soaked in PO_4	6.5	6.9	6.7	6.6	10.3
COMBINED					
A. Cooking method					
1. PF	6.3b	7.0	7.0	7.0	8.9a
2. MWS-PF	6.4b	6.8	7.0	6.7	10.3b
3. MWS-DFF	6.9a	6.9	6.8	6.9	10.6b
B. Marinate					
1. Untreated	6.3	6.7	6.9	6.7	10.8
2. Soaked in PO_4	6.7**	7.2**	7.0	6.9	9.0**
C. Stage					
1. Freshly cooked	6.7	7.1*	7.2**	7.1**	8.7**
2. Reheated	6.4	6.7	6.7	6.6	11.1

[1]Each score is the average for 30 samples.

[2]Within a block, scores in the same column followed by different letters differ significantly at 5% level.

*Significant at 5% level.

**Significant at 1% level.

Table 15b. Analysis of variance of taste panel scores of chicken subjected to various treatments.

Source of variance	Degrees of freedom	Mean Squares			
		Juiciness	Tenderness	Flavor	Gen. Accept.
Freshly cooked					
Cooking method	2	9.35**	.75	2.35	.55
Marinate	1	3.46**	31.3**	1.3	6.8*
Error	176	1.60	1.4	1.55	1.2
Reheated					
Cooking method	2	1.0	.6	2.3	4.1
Marinate	1	.5	2.5	0	0
Error	176	2.5	2.1	1.9	1.6
Combined					
Cooking method	2	8.4*	.8	.55	1.5
Marinate	1	23.5**	26.1**	.50	3.6
Stage	1	3.2	9.0*	24.5**	16.9**
Error	355	2.1	1.76	1.7	1.4

*Significant at 5% level.

**Significant at 1% level.

different methods. Hale and Goodwin (1968) inconsistently observed significant differences in sensory evaluation and in shear press determination of chicken samples cooked by different methods. These findings seem to substantiate the conclusion of Szczesniak (1968) that correlation between sensory evaluation and objective tenderness measurements is highly dependent upon the range of values covered. Apparently, the tenderness values observed in this experiment were within the range where shear press determination was more sensitive and could detect more differences below the threshold level for the panel tasters.

No significant differences in juiciness, tenderness, flavor and general acceptability scores were observed in the microwave reheated chicken, between the untreated and phosphate-soaked samples, and among those cooked by different methods. However, the reheated chicken pieces were less tender ($P < .05$) and had less desirable flavor ($P < .01$) and were therefore significantly less acceptable ($P < .01$) than the freshly cooked chicken pieces. The data show that the combined effect of freezing, storage, and microwave reheating on the eating quality of fried chicken is more pronounced than the effect of phosphate and/or cooking treatments. Soaking in phosphate improved juiciness and tenderness scores only in the freshly cooked chicken but not in the microwave reheated ones. The data also show that the 3 cooking methods produce products of comparable quality after frozen storage and microwave reheating.

The composition of meat and skin-coating complex of freshly cooked and reheated chicken pieces are presented in Table 16a. The moisture analysis concurred very well with the taste panel evaluation for juiciness. The moisture content was significantly higher in the flesh of the phosphate-soaked pieces which were found to be juicier than the untreated samples. Among the cooking methods, the MWS-DFF produced products which had significantly higher moisture than the products from the two other cooking methods. The flesh of the freshly cooked chicken had significantly higher ($P < .01$) moisture content than the reheated chicken, although no difference in juiciness was detected by sensory evaluation. The fat content of the meat was not affected by the phosphate treatment nor by cooking methods, so that the differences in solid content were due to the differences in moisture content.

The chemical composition of the skin-coating complex was affected by the cooking methods but not by the phosphate treatment (see Table 16b). Hence, only the summary of the composition for each cooking method are shown in Table 16a. The moisture content was significantly higher in the precooked pieces than in the controls, while the reverse was true for the fat content.

Table 16a. Proximate composition of meat and skin-breading complex from chicken subjected to various treatments.

Treatments	Moisture		Ether Extracts		Solids	
	Fresh	Reheated	Fresh	Reheated	Fresh	Reheated
	%	%	%	%	%	%
FLESH						
A. <u>Untreated</u>						
1. PF	61.0	56.9	6.4	8.7	36.6	34.4
2. MWS-PF	59.3	56.1	8.1	7.5	32.6	36.4
3. MWS-DFF	63.6	57.9	7.6	7.3	28.8	34.8
B. <u>Soaked in phosphate</u>						
1. PF	61.8	61.3	9.1	8.2	29.1	30.5
2. MWS-PF	61.3	58.9	11.4	6.2	27.3	34.9
3. MWS-DFF	64.0	62.2	7.6	6.5	28.4	30.9
Untreated	61.3	56.8	7.4	7.9	31.3	35.2
Soaked in Phosphate	62.3	60.9	9.4	6.9	28.3	32.2

PF	61.4	59.6	7.7	8.4	30.9	32.0
MWS-PF	60.3	57.5	9.7	6.8	30.0	35.8
MWS-DFF	63.8	59.8	7.6	6.9	28.6	32.3
Average	61.8	58.8	8.4	7.4	29.8	33.7
SKIN-BREADING COMPLEX						
PF	28.7	25.8	37.7	37.2	32.6	37.0
MWS-PF	32.5	27.0	30.8	32.8	36.7	40.2
MWS-DFF	32.4	30.0	32.6	33.5	35.0	36.5
Average	31.2	27.6	33.7	34.5	35.1	37.9

Note: Analyses were made in duplicates on samples taken from pieces constituting one bird per treatment.

Table 16b. Analysis of variance of shear press values and proximate composition data for chicken meat (Experiment 7).

Source of variance	Degrees of freedom	Mean Squares						
		Shear press	Flesh			Skin-breading		
			Moisture	Fat	Solid	Moisture	Fat	Solid
Marinate	1	18.0**	38.7**	1.1	52.6	8.9	15.5	.9
Cooking	2	6.2**	19.8**	3.9	8.0*	31.0**	71.6**	23.5**
Stage	1	32.6**	50.1**	4.0	82.6**	74.9**	2.7	49.0**
Error	19	1.0	.5	36.0	1.9	4.2	4.8	3.7

*Significant at 5% level.

**Significant at 1% level.

Table 17a shows the percentage change in weight of chicken pieces, based on the original weights, at various stages of processing. The chicken pieces soaked overnight in 5% phosphate solution increased 7% in weight. During precooking in microwave and steam (MWS), the phosphate-soaked pieces lost about 13% weight which was significantly greater ($P < .01$) than the 7.5% weight loss of the untreated pieces. A comparison was made on the percentage total cooking losses from the original weight for the untreated pieces and from the weight after soaking for the phosphate-treated pieces. The untreated pieces lost significantly more weight mainly due to the difference in gain during breading. The precooked phosphate-treated pieces gained twice as much breading as the untreated pieces, indicating that the phosphate treatment increased the affinity of the chicken pieces to breading materials. Probably, the surface of the phosphate-soaked pieces was more moist, which allowed better adhesion of the breading. The gain in weight of the phosphated pieces during soaking and the greater losses of the untreated pieces combined to give a significantly higher ($P < .01$) cooking yield for the treated pieces. Baker and Darfler (1968) reported that chicken pieces soaked in phosphate had significantly higher ($P < .05$) yields than pieces soaked only in water.

Table 17a. Percentage change in weight during processing of chicken cooked by different methods.

Treatments	Original weight[1]	Stages of Processing[2]						
		After PO_4 treatment	After MWS cooking	After breading	After frying	After freezing	After storage	After reheating
	gms	percentage of original weight						
No phosphate treatment:								
1. PF	729.0			111.9	82.7	79.5	78.9	70.0
2. MWS-PF	783.6		92.3	100.5	82.8	80.8	80.4	71.6
3. MWS-DFF	751.5		92.6	99.5	82.3	80.4	80.5	73.9
Soaked in phosphate:								
1. PF	787.2	105.2		116.5	85.9	83.7	83.0	75.3
2. MWS-PF	758.6	109.7	96.6	111.9	93.6	91.6	90.6	83.5
3. MWS-DFF	799.6	107.1	93.3	107.4	95.2	93.8	93.1	87.5

[1]Average weight of 10 birds.

[2]Each figure is the weighted average for 90 pieces (20 pieces each for thigh, drum, wing, and breast-back; 10 pieces for breast tip).

Table 17b. Analysis of variance of percentage change in weight and yield data (Experiment 7).

Source of variance	Degrees of freedom	Mean Squares				
		Breading gain	Cooking losses	Reheating losses	Cooked yield	Reheated yield
Marinate (M)	1	189.0**	182.1**	9.3	887.8**	1076.4**
Cooking (C)	2	5.6	27.8	29.3*	64.5	110.1
M x C	2	32.2	5.7	1.0	84.7	2.0
Error	24	18.1	18.5	8.2	25.9	58.3

*Significant at 5% level.

**Significant at 1% level.

No differences in total cooking losses nor in yields were observed among the cooking methods. Hale and Goodwin (1968) obtained comparable percentage yields among deep-fat-frying (DFF), microwave-DFF, and retort-DFF batches; however, Mostert and Stadelman (1964) showed that deep-fat-frying with pressure had significantly lesser percentage weight losses than ordinary deep-fat-frying, pan frying, or oven frying. These results indicate that pressure frying and microwave-steam precooking in combination with pressure frying or deep-fat-frying give the highest cooking yield among the probable commercial cooking methods.

There were no differences in weight losses during freezing and storage among the treatments. The losses were also small as was observed in Experiment 2.

The losses in weight during microwave reheating was affected more by the cooking methods than by the phosphate treatment. The chicken pieces which were subjected to pressure frying lost significantly more weight ($P < .05$) than those cooked by MWS-DFF. Apparently, pressure frying caused physical alterations in the chicken tissues which permitted faster escape of moisture during microwave reheating.

Because the phosphate-treated chicken had higher cooking yields, they also had higher yields after microwave reheating compared to the untreated pieces.

The fact that the pressure-fried chicken pieces were less juicy and had lower moisture contents than those cooked by MWS-DFF indicates that excessive moisture was being released from the tissues in the form of steam which produced the pressure during pressure frying. However, more fat was being absorbed by the skin-coating complex during pressure frying (see Table 15a), which compensated for the excessive moisture loss, so that the three cooking methods appeared to have comparable yields. Since MWS-DFF has been shown to produce products of comparable yield and eating quality as the pressure-fried ones but with lower reheating losses, it can be concluded that MWS-DFF is the best procedure for centralized processing of frozen fried chicken. It can be used in combination with phosphate treatment to obtain higher processing yields.

Miscellaneous Discussion

In spite of the identification and quantification of the influences of many processing variables on the quality of fried chicken, certain qualitative observations made during the conduct of this study indicate that a great deal of art is still involved in the production of appealing pressure fried products of consistent quality. In addition to the effects of coating ingredients and method of application, the appearance of the fried chicken pieces is also influenced by the length of time between the application of breading and frying, the age and number of times the oil has been used, and the frying temperature. Prolonged holding of chicken pieces between breading and frying resulted in darker and unevenly colored products, mainly due to the wetting of the breading. Cooking oil being used for the first time yielded products which were pale in color, whereas continued usage of the same oil resulted in progressively darker products. Breaded chicken pieces browned in oil preheated to 190-204°C were darker in color, crispier-looking and less greasy than those browned at 160-175°C. The operator's judgment determines how soon the pressure cooker could be sealed after the chicken pieces have been put in. Sealing the cooker sooner than optimum resulted in products which were greasy and very fragile to handle.

It appeared that the pressure cookers were designed to handle fixed capacities. Variations in loads due to variations in the sizes of chicken or the number of pieces being cooked may have caused some of the variations in cooking yields and juiciness scores from batch to batch. Cooking less than the desired load may have resulted in greater losses of moisture which produced the same amount of steam necessary to build the pressure.

Perhaps some of the art involved in the preparation of fried chicken may be minimized by using a continuous operation consisting of microwave-steam pre-cooking, breading, and deep-fat-frying. In a continuous operation, processing variables such as time and temperature for each process, time interval between different processing steps, and oil turnover rate, can easily be controlled to insure products of uniform quality. Continuous operations can also be adapted for the separate processing of different chicken pieces, necessary because of size variations.

Although this study has not provided all the pertinent information necessary for the success of centralized processing of fried chicken, it has demonstrated that the approach is technically feasible and worthy of further consideration by broiler processors.

Studies on the economics of the whole operation should be conducted to demonstrate that such an approach could be profitable. Furthermore, the results of this study should be used in conjunction with the findings of consumer studies on the preferences of target markets for specific seasoning, coating characteristics, and packaging systems in order to provide the products desired by the consumers.

SUMMARY AND CONCLUSIONS

In an effort to develop a suitable process for centralized preparation of broiler products, the acceptability of microwave reheated frozen fried chicken and the influence of various processing variables on its eating quality were evaluated.

Taste panel comparisons of microwave reheated chicken after frozen storage up to 6 months at -18°C and newly cooked controls, showed that breaded fried chicken can be frozen and stored at -18°C for 3 months and then reheated in a microwave oven without substantial loss in eating quality. However, prolonged storage or storage under fluctuating temperature results in less acceptable products due to undesirable flavor.

Soaking chicken pieces overnight in 5% polyphosphate solution resulted in about 7% gain in weight and in adhesion of more breading after microwave-steam precooking, which accounted for greater cooked and reheated yields as compared to untreated chicken pieces. Polyphosphate treatment produced products which were more juicy and tender when served immediately after frying, but not after freezing, storage, and microwave reheating.

It was shown that breadings have better adhesion and are therefore more suitable for coating fried chicken than batters. However, more studies are needed to develop coatings which are more suitable for frozen fried chicken meant to be reheated in microwave ovens.

Pressure frying was found to produce the most tender products when served immediately after cooking. However, a combination of microwave-steam precooking and deep-fat-frying was considered more practical for commercial processing of fried chicken because it is a rapid and continuous operation, and has processing yields and products as good as, and lower reheating losses than, pressure frying.

Freezing methods influenced the freezing rates but not the eating quality of fried chicken. The rate of freezing fried chicken from about 55°C to -18°C internal temperature in liquid freon (-42°C) was twice as fast as in liquid nitrogen (-57°C) and about ten times as fast as in air-blast (-37°C). Freezing raw chicken and cooking them immediately after rapid thawing resulted in products of comparable quality as the newly cooked controls.

Packaging materials with good barrier properties were found to offer the same protection to fried chicken under constant -18°C storage or under simulated distribution condition with or without vacuum. No differences were observed in the panel scores after storage and microwave reheating of chicken vacuum-packed before or after freon freezing. Packaging chicken pieces in aluminum foil trays, which did not offer good protection, resulted in significantly lower panel scores when subjected to simulated distribution condition than when stored under constant -18°C. The potential of using edible coating for minimizing moisture losses during frozen storage and microwave reheating was also demonstrated.

The taste panel members were divided on their preferences for products reheated by specific reheating methods. Reheating in a microwave oven was the most rapid among the methods used, but it resulted in substantial loss of moisture and less juicy products. However, microwave reheated products were still acceptable provided the reheating time was kept at the minimum time necessary to bring the frozen products to serving temperature. It was found desirable to base the reheating time on the weight of the load rather than on the number of pieces.

Chicken pieces vary widely in sizes and shapes and may require different processing times. As such, it is recommended that the size and the cutting procedure be made more uniform, and that different pieces be processed separately. A commercial process consisting of soaking raw cut-up chicken pieces overnight in polyphosphate solution; precooking by microwave and steam; coating with breading; browning by deep-fat-frying; freezing with any economical but reasonably fast method; and packaging in a commercially practical package with good barrier properties, can be used in the centralized preparation of frozen precooked chicken for distribution to the institutional or retail markets.

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APPENDICES

APPENDIX I

REPORTED COOKING YIELD VALUES FOR FRIED CHICKEN

Factor	Treatment	Yield	Reference
		%	
A. Frozen uncooked			
1. a) non-frozen	ave. of 5 cooking methods	71.8	Mostert & Stadelman (1964)
b) frozen	ave. of 5 cooking methods	70.2	
B. Breading			
1. a) breaded	ave. of 5 cooking methods	79.0	Mostert & Stadelman (1964)
b) non-breaded	ave. of 5 cooking methods	82.3	
C. Phosphate treatment			
1. a) control	simmered until tender	83.2	Baker & Darfler (1968)
b) phosphate-soaked	simmered until tender	84.4	
D. Cooking method			
1. a) microwave (MW)	13 min. in household-type oven	78.6	Mickeberry & Stadelman (1962)
b) deep-fat-frying (DFF)	10 min. in 325°F corn oil	76.6	
c) DFF-MW	3 min. DFF; 6 min. MW	75.5	
d) reel oven	170 min. at 325°F	83.2	
e) steam-DFF	20 min. at 250°F; 3 min. DFF	77.2	

2.	a) DFF	14 min. at 350°F	68.7	Mostert & Stadelman (1964)
	b) pressure frying (PF)	9 psi, 8 min.	76.2	
	c) PF	30 psi., 6 min.	75.2	
	d) pan frying	10 min. @ 360°F + 20 min. @ 260°F	63.0	
	e) oven frying	10 min. @ 375°F + 10 min. @ 425°F	72.2	
3.	a) MW	3.75 kw., 16 min.	82.0	Anon. (1966)
	b) MW-Steam (MWS)	3.75 kw., 8 min.	92.0	
	c) MWS	5.0 kw., 8 min.	92.5	
	d) MWS	2.5 k2., 10 min.	92.0	
4.	a) DFF	14 min. at 152°C	87.3	Hale & Goodwin (1968)
	b) MW-DFF	4 min. MW + 4 min. @ 177°C	91.6	
	c) Retort-DFF	10 min. at 5 psi + 5 min. at 182°F	85.0	
E.	<u>Frozen after cooking</u>			
1.	a) non-prefried	14 min. @ 375°F DFF after thawing	84.0	Carlin <u>et al</u>. (1959)
	b) prefried	3 min. and reheated	80.0	
	c) prefried	10 min. and reheated	74.0	
2.	a) cooked-frozen-thawed	average of 5 cooking methods	77.9	Mickelberry & Stadelman (1962)
	b) frozen-thawed-cooked	average of 5 cooking methods	80.0	

APPENDIX II

FACTORS AFFECTING CONSUMERS' ACCEPTANCE OF FOOD PRODUCTS[1]

Attributes of the food product	Attributes of the consumers
1. Availability	1. Regional preference
2. Utility	2. Nationality, race
3. Convenience	3. Age and sex
4. Price	4. Religion
5. Uniformity and dependability	5. Education, socio-economics
6. Stability, storage requirements	6. Psychological motivation
	a. symbolism of food
7. Safety and nutritional values	b. advertising
8. Sensory properties	7. Physiological motivation
a. appearance	a. thirst
b. aroma and taste (flavor)	b. hunger
	c. deficiencies
c. texture (juiciness, tenderness, etc.)	
d. temperature	

[1] Amerine _et al_. (1965).

APPENDIX III

TABLE PANEL SCORE CARD 1

CHICKEN EVALUATION

Name:________________________ Date:_________________________

Plate No. ________

INSTRUCTIONS: Evaluate appearance, flavor, juiciness, tenderness, and general acceptability of each sample according to the appropriate hedonic rating scale. Record results in the table below.

Appearance, flavor and General acceptability		Juiciness		Tenderness	
9	Like extremely	5	Too juicy	5	Too tender
8	Like very much	4	Slightly too juicy	4	Slightly too tender
7	Like moderately	3	Acceptably juicy (Ideal)	3	Acceptably tender (Ideal)
6	Like slightly	2	Slightly too dry	2	Slightly too tough
5	Neigher like nor dislike	1	Too dry	1	Too tough
4	Dislike slightly				
3	Dislike moderately				
2	Dislike very much				
1	Dislike extremely				

RESULTS:

Sample	Appearance score	Flavor score	Juiciness score	Tenderness score	General acceptability score
X					
Y					
Z					

Please provide additional comments about any or all samples.
LED:mmr 1/7/69

APPENDIX IV

TASTE PANEL SCORE CARD II

CHICKEN EVALUATION

Name:____________________________ Date:_________________________

Plate No: ___________

INSTRUCTIONS: Evaluate appearance, flavor, juiciness, tenderness, and general acceptability of each sample according to the appropriate hedonic rating scale. Record results in the table below.

Appearance, flavor, and general acceptability	Juiciness	Tenderness
9 Like extremely	9 Extremely juicy	9 Extremely tender
8 Like very much	8 Very juicy	8 Very tender
7 Like moderately	7 Moderately juicy	7 Moderately tender
6 Like slightly	6 Slightly juicy	6 Slightly tender
5 Neither like nor dislike	5 Neither juicy nor dry	5 Neither tender nor tough
4 Dislike slightly	4 Slightly dry	4 Slightly tough
3 Dislike moderately	3 Moderately dry	3 Moderately tough
2 Dislike very much	2 Too dry	2 Very tough
1 Dislike extremely	1 Extremely dry	1 Extremely tough

RESULTS:

Sample	Appearance score	Flavor score	Juiciness score	Tenderness score	General acceptability score

Please provide additional comments about any or all samples.

LED:mmr
7/28/69

APPENDIX V

TASTE PANEL SCORE CARD III

FRIED CHICKEN EVALUATION

Plate No.______ Name:______________________________Date:_____________

INSTRUCTIONS: Please evaluate the characteristics of the coating and the eating quality of each sample according to the appropriate scale. Record results in the table below.

COATING CHARACTERISTICS

CRITERIA \ SCORES	1	2	3	4	5
Color	Too light	Slightly light	Just right	Slightly dark	Too dark
Adhesion of coating	Too loose	Slightly loose	Just right	Slightly light	Too light
Texture of breading	Too coarse	Slightly coarse	Just right	Slightly smooth	Smooth
Hardness	Too soft	Slightly soft	Just right	Slightly hard	Hard

EATING QUALITY

JUICINESS	TENDERNESS	FLAVOR AND GENERAL ACCEPTABILITY
9 Extremely juicy	9 Extremely tender	9 Like extremely
8 Very juicy	8 Very tender	8 Like very much
7 Moderately juicy	7 Moderately tender	7 Like moderately
6 Slightly juicy	6 Slightly tender	6 Like slightly
5 Neither juicy nor dry	5 Neither tender nor tough	5 Neither like nor dislike
4 Slightly dry	4 Slightly tough	4 Dislike slightly
3 Moderately dry	3 Moderately tough	3 Dislike moderately
2 Too dry	2 Very tough	2 Dislike very much
1 Extremely dry	1 Extremely tough	1 Dislike extremely

APPENDIX V, Cont.

RESULTS:

COATING CHARACTERISTICS:

SAMPLE	Color	Adhesion	Texture	Hardness
X				
Y				
Z				

EATING QUALITY:

SAMPLE	Juiciness	Tenderness	Flavor	Gen. Accept.
X				
Y				
Z				

Please provide additional comments about any or all samples:

ECS:mmr
5/18/71

APPENDIX VIa

Taste panel scores of microwave reheated frozen precooked chicken and newly cooked controls, 0 to 24 weeks storage.

Storage Period	Taste panel scores[1]			
	Juiciness	Tender-ness	Flavor	Gen. Accept.
No storage				
Reheated	2.7	3.0	6.7	6.5
Control	2.7	3.1	6.5	6.1
4 weeks				
Reheated	2.6	2.8	6.9	6.6
Control	3.3**	3.1	7.3	7.3
8 weeks				
Reheated	3.1	2.9	6.9	6.8
Control	3.4	3.3	7.2	7.2
12 weeks				
Reheated	2.7	2.8	6.9	6.6
Control	3.0	3.0	7.2	7.2
18 weeks				
Reheated	2.9	3.0	6.7	6.8
Control	3.0	3.1	7.4*	6.8
24 weeks				
Reheated	2.7	2.8	6.3	5.9
Control	3.0	3.2	7.4**	6.9*

[1]Each score is the average for 30 samples. Evaluations for juiciness and tenderness were based on the 5-point 2-sided scale, 3 = ideal; while evaluations for flavor and general acceptability were based on the 9-point scale, 9 = like extremely; 1 = dislike extremely.

*Significant at 5% level.

**Significant at 1% level.

APPENDIX VIb

Analysis of variance of the taste panel score of microwave reheated frozen precooked chicken and newly cooked controls, 0 to 24 weeks storage.

Source of variance	Degrees of freedom	Mean squares			
		Juiciness	Tenderness	Flavor	Gen. Accept.
No storage					
Treatments	1	0	.2	.6	2.8
Error	58	.52	.29	1.63	2.30
4 weeks of storage					
Treatments	1	8.8**	1.4	2.4	6.6
Error	58	.59	.64	2.03	2.12
8 weeks of storage					
Treatments	1	1.4	2.0	1.4	2.0
Error	58	.91	.63	1.68	2.52
12 weeks of storage					
Treatments	1	.8	.5	3.7	4.2
Error	58	.43	.47	2.5	1.42
18 weeks of storage					
Treatments	1	.2	.2	8.0*	0
Error	58	.68	.88	1.75	2.10
24 weeks of storage					
Treatments	1	1.4	2.4	19.2**	14.0*
Error	58	.85	.68	1.82	3.05

*Significant at 5% level.

**Significant at 1% level.

APPENDIX VIIa

Taste panel scores of microwave reheated air-blast or liquid nitrogen frozen precooked chicken, and newly cooked unfrozen and frozen-thawed controls, 0 to 4 weeks of storage.

	Taste panel scores[1]			
	Juiciness	Tenderness	Flavor	Gen. Accept.
No storage				
1. Reheated, air-blast	4.9a[2]	6.1a	6.6a	6.5a
2. Reheated, liq. N_2	5.3a	6.3a	6.5a	6.4a
3. Control, unfrozen	7.1b	7.7b	7.7b	7.7b
4. Control, frozen-thawed	7.2b	7.6b	7.7b	7.7b
2 weeks of storage				
1. Reheated, air blast	5.9a	6.8a	6.8a	6.7a
2. Reheated, liq. N_2	6.2a	6.8a	7.2ab	7.1ab
3. Control, unfrozen	7.4b	7.5b	7.5b	7.5b
4. Control, frozen-thawed	7.4b	7.5b	7.6b	7.4b
4 weeks of storage				
1. Reheated, air blast	5.6b	6.2a	6.5a	6.3b
2. Reheated, liq. N_2	4.5a	5.6a	6.4a	5.6a
3. Control, unfrozen	7.6c	7.4b	7.2b	7.1c
4. Control, frozen-thawed	7.6c	7.8b	7.7b	7.7d

[1]Each score is the average for 30 samples.

[2]Within a storage period, scores followed by different letters in the same column differ significantly at 5% level.

APPENDIX VIIb

Analysis of variance of the taste panel scores of microwave reheated air-blast or liquid nitrogen frozen precooked chicken, and newly cooked unfrozen or frozen-thawed controls.

Source of variance	Degrees of freedom	Mean Squares			
		Juiciness	Tenderness	Flavor	Gen. Accept.
No storage					
Treatments	3	21.7**	11.0**	6.5**	8.5**
Sub-treatments	1	64.1**	32.3**	19.3**	25.4**
Error	115	2.33	1.28	1.29	1.74
2 weeks of storage					
Treatments	3	19.3**	5.6*	2.3	4.7**
Sub-treatments	1	56.1**	16.9**	5.7*	14.0**
Error	115	1.31	1.51	1.10	1.16
4 weeks of storage					
Treatments	3	72.8**	31.5**	11.3**	27.0**
Sub-treatments	1	200.2**	85.0**	30.0**	67.5**
Error	115	1.0	1.58	1.86	1.43

*Significant at 5% level.

**Significant at 1% level.

APPENDIX VIII

Percentage change in weight of various cooked chicken pieces at different stages of processing (Experiment 2).

Chicken piece	Average weight	Before freezing	After freezing	2-wk frozen storage	4-wk frozen storage	After microwave reheating
	gm	Percentage of weight before freezing				
Blast Frozen in air at -37°C						
Drum	65.0	100	98.2	98.4	98.8	82.7
Thigh	134.4	100	99.2	98.6	98.7	80.1
Breast	100.4	100	99.2	99.4	99.1	75.9
Shoulder	122.0	100	99.4	99.2	99.0	62.6
Wing	58.6	100	99.0	99.3	99.7	67.8
Frozen in Liquid Nitrogen at -57°C						
Drum	71.6	100	98.0	98.3	97.6	72.9
Thigh	128.9	100	97.2	96.8	96.6	71.8
Breast	118.4	100	99.0	99.5	98.8	74.4
Shoulder	117.6	100	97.8	97.8	97.8	76.8
Wing	56.2	100	98.1	98.3	95.6	58.8

NOTE: Each figure is the average for 8 pieces.

APPENDIX IX

Composition of cooked flesh of different chicken pieces at selected stages of processing following air-blast or liquid nitrogen freezing.

Chicken part	Moisture			Fat			Solids (fat-free)		
	Before freezing	After frozen storage	After microwave reheat	Before freezing	After frozen storage	After microwave reheat	Before freezing	After frozen storage	After microwave reheat
				Percent					
BLAST FROZEN -37°C									
Drum	69.1	61.9	62.3	4.4	8.7	8.0	26.6	29.4	29.7
Thigh	58.2	65.7	6.26	8.9	7.0	7.1	32.9	27.2	30.4
Breast	77.0	64.8	55.7	1.5	6.9	5.2	21.5	28.4	39.2
Shoulder	60.5	62.2	43.6	4.3	4.8	6.7	35.2	32.9	49.7
Wing	43.0	60.7	15.0	24.0	8.9	26.8	33.0	30.3	58.1
Mean	61.6	63.1	47.7	8.6	7.3	10.8	29.8	29.6	41.4
LIQUID NITROGEN FROZEN -57°C									
Drum	69.1	62.5	58.2	4.4	7.9	6.8	26.6	25.6	35.0
Thigh	58.2	60.6	55.5	8.9	9.9	9.4	32.9	29.5	35.2
Breast	77.0	64.8	33.9	4.5	6.9	4.5	21.5	28.4	61.5
Shoulder	60.5	65.4	57.6	4.3	4.4	8.0	35.2	30.1	34.4
Wing	43.0	65.2	37.8	24.0	7.9	13.4	33.0	28.9	48.9
Mean	61.6	63.7	48.6	8.6	7.4	8.4	29.8	28.5	43.0

NOTE: Analyses were made on samples taken from 8 pieces per part.

APPENDIX X

Taste panel scores of microwave reheated fried chicken subjected to various freezing, packaging, and storage treatments.[1]

Packaging	Constant -18°C		Simulated distrib. cond.	
	Air-blast	Liq. freon	Air-blast	Liq. freon
		Juiciness		
PE bag w/o vacuum	7.0	6.3	6.0	6.7
Vacuum-packed before IQF	6.6	6.1	6.2	6.4
Vacuum-packed after IQF	5.8	6.4	6.1	6.4
		Tenderness		
PE bag w/o vacuum	7.4	7.2	6.6	7.1
Vacuum-packed before IQF	7.2	7.0	6.9	6.9
Vacuum-packed after IQF	6.7	7.1	6.7	7.0
		Flavor		
PE bag w/o vacuum	7.0	6.9	7.1	7.1
Vacuum-packed before IQF	7.1	7.1	7.0	7.0
Vacuum-packed after IQF	7.1	7.4	7.4	7.1
		General Acceptability		
PE bag w/o vacuum	6.9	7.0	6.8	7.0
Vacuum-packed before IQF	7.0	6.8	6.9	6.7
Vacuum-packed after IQF	6.7	7.1	7.1	7.1

[1]Scores based on 9-point hedonic scale. Each score is the average for 30 samples.

APPENDIX XI

Proximate composition of skin-coating complex of chicken subjected to various cooking methods.

Treatment	Moisture		Ether Extract		Solids	
	Fresh	Reheated	Fresh	Reheated	Fresh	Reheated
	%	%	%	%	%	%
<u>Untreated</u>						
1. PF	30.2	23.3	33.4	38.0	36.4	38.7
2. MWS-PF	34.4	26.3	29.5	34.2	36.1	39.5
3. MWS-DFF	34.4	31.9	32.2	33.2	33.4	34.9
<u>Soaked in Phosphate</u>						
1. PF	27.3	28.4	42.1	36.4	30.6	35.2
2. MWS-PF	30.7	27.6	32.1	31.4	37.2	41.0
3. MWS-DFF	30.3	28.2	33.1	33.9	36.6	37.9

NOTE: Samples were taken from pieces constituting 1 bird.