

FACTORS AFFECTING THE COMPOSITION OF CHICKEN MEAT

by

JOE HOWARD DEMBY

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INTRODUCTION

In the past decade, a great deal of interest and emphasis has been placed on the nutritional value of food in both the raw and the processed state. Consumers are becoming more and more aware of nutritional values and many are buying food based on those values.

Chicken, an important item in the U.S. diet, as indicated by a record high 44 pounds per person consumed in 1977, (Anon., 1978), has traditionally been considered a good buy because of its nutritional value and relatively low cost.

Because of the importance of chicken in the human diet, this review will consider the nutritional changes that occur from initial processing of chicken, to preparation and consumption by the consumer.

This review is composed of three parts. Part I reports a composite of nutritional values for raw chicken from several different sources; Part II, concerns the changes in nutritional values occurring during commercial processing; and Part III deals with changes in nutritional values during storage, handling, and preparation.

Part I

Nutritional Values of Chicken

With more and more emphasis being placed on nutrition by the consumer, a trend reflected by governmental policies and programs, a great need exists for comprehensive information on nutritional composition of foods. Watt and Murphy (1970) stated that poultry, as an important item in the diet, needed much more attention than it has received. They believed current data were needed on mineral and vitamin content as well as on the effect of cooking and canning on the nutritional composition of chicken.

Some work has been reported but data on nutritional values and nutritional changes during processing and during different methods of cooking are lacking. The U.S.D.A. Research Service is currently updating and expanding existing data in U.S.D.A. Handbook #8.

Considerable variation exists when comparing published nutritional data on chickens (see Table 1). A large range exists for many values, such as protein with a low of 17.70% and a high of 23.3%, or ash from .70% to 3.63%. However, many variables such as breed, feed, age, method of production, sex, processing and type of meat which can affect nutritional values probably account for much of the large range in the data in Table 1.

Chicken is comparable to beef, lamb and pork in composition and nutritive value. The protein in chicken, approximately one fourth of the edible portion, is of high quality and readily digestible. It contains all the essential amino acids required for good human nutrition (Table 2).

Vitamins and Minerals. Chicken, like all lean meats, is a very good source of B-vitamins. It is also rich in iron and phosphorus (Charley, 1970). Mountney (1976) and Catellani (1970) both stated that chicken meat is a good source of niacin, and Mountney (1976) reported that it was a moderately good source of riboflavin, thiamin, and ascorbic acid. Table 3 on vitamins and Table 4 on minerals shows values from various reports which demonstrate that chicken is an outstanding source of these constituents.

Fats. Chicken is considered a low fat food. The majority of fat is located in the skin rather than in muscle tissue. Weihrauch (1976) found that broiler meat contained only 2.5 g of fat per 100 g edible portion of meat (the breast meat contained only 1.0 g per 100 g edible portion). He also reported that broiler fat contained a greater amount of unsaturated

than saturated fatty acids. Mountney (1976) stated poultry meat contained a higher portion of unsaturated fatty acids than fats from red meats but usually less than vegetable oils.

Lee and Dawson (1973) found that the major fatty acids in raw chicken muscle were oleic, linoleic, and palmitic. Those three comprised 79% of the total and had a total unsaturation of 70%. Fristiom and Weihrauch (1976) reported that oleic was the dominant fatty acid in broiler muscle. Katz et al. (1966) found that chicken muscle contained larger amounts of phospholipids than skin and depot fat (Table 5). They identified 18 different fatty acids in the neutral lipids and 22 fatty acids in the phospholipid fraction with arachidonic acid being the major component of the phospholipids. Chicken meat contains less cholesterol than many other foods of animal origin (Table 6).

Carbohydrates in chicken, as with most meats, are a very small portion of the total nutrients present. Most food composition reports do not list carbohydrate values for raw chicken. However, Lilyblade and Peterson (1962) did extensive work on identifying the carbohydrates in chicken muscle. Inositol, glucose, and fructose were the major carbohydrate constituents, with ribose and mannose minor constituents (see Table 7). Glucose was the principal free sugar in chicken meat.

Part II

Changes in Nutritional Value During Commercial Processing

Commercial processing of chickens to a ready-to-cook state can be broken down into several general steps. Those are 1) transportation, 2) unloading and hanging, 3) slaughter, 4) scalding, 5) defeathering, 6) washing, 7) evisceration, 8) inspection, 9) chilling, and 10) storage.

Broilers can then undergo other further processing steps such as canning, drying, curing and smoking.

Unfortunately, few reports exist on how different processing steps affect the nutritional value of chicken. Burger and Walters (1973) discussed the problem at the Nutritional Societies 1972 meeting when they stated "little information is available in the literature on the effect of processing on nutritional attributes of poultry meat". Harris and Von Loesecke (1971) believed that during processing of raw poultry, under accepted commercial practices, changes in the nutritional values of edible portions are minor and generally not detectable. They also noted that poultry meat was a good source of niacin and essential amino acids which are quite stable under most processing conditions. However, several authors, Froning et al. (1960), Pipen and Klose (1955), Landers (1972), Miller et al. (1965), Schaltyssek et al. (1970), Singh and Essary (1971), Terjung (1974), Khan and Lentz (1975), Wyche et al. (1972), Hale and Stadelman (1973) and others have noted significant changes or effects on the nutritional aspects of chickens during various steps of commercial processing.

Initial Composition. Nutritional composition of chicken is not only influenced by the type of feed and other production factors but also by the age, sex and breed of the bird. Very young broilers are marketed as Rock Cornish game hens, whereas most are 7-8 weeks old. Twining et al. (1978) found that 28 day old birds had significantly less protein and fat but higher moisture than 59 day old birds. Goodwin and Simpson (1973) found higher moisture and lower fat concentration in Rock Cornish hens than in older broilers. Amount of protein was approximately the same.

Singh and Essary (1971b), however, reported that 4 week old birds contained significantly higher levels of riboflavin than older birds and 6 week old birds were significantly higher in both niacin and thiamine than older birds (Table 8). Kravis and Morley's (1960) work disclosed that potassium and sodium levels increased in meat from birds up to five weeks of age but remained constant in older birds.

When comparing the effect of sex on nutritional values, Goodwin and Simpson (1973), Edwards and Denman (1975), and Twining *et al.* (1978) all reported male broiler carcasses were significantly higher in moisture and protein and lower in fat than female broilers. Ash values were approximately the same. Singh and Essary (1971) found that meat from broiler males was significantly higher in riboflavin than meat from females. However, meat from both sexes had approximately the same concentration of niacin and thiamine.

Edwards and Denman (1975), and other workers, have reported that body compositions varied greatly among breeds of chicken, with certain breeds having consistently higher nutritional values than others.

Stunning. Stunning is a common practice in poultry processing and usually is accomplished with an electrical shocker. Recently, work has been reported on the use of CO₂ as a stunning agent. Svettor and Guslyannikov (1970) revealed that CO₂ gas, (30 - 40 volume % concentration), when compared to electrical stunning, improved meat quality and stability during storage due to the lower pH caused by CO₂ penetration of the carcass. Stunning has not been found to significantly affected the nutritional value of broilers.

Scalding. Both the semi-scald, 50.6 - 54.4°C for 90-120 seconds and

the subscald can cause loss of the pigmented epidermal layer of skin, and possibly some nutrients, while the semi-scald leaves the skin intact, providing more protection from nutrient loss during chilling. Harris and Von Loesecke (1971) stated that there was no evidence or reason to believe that scalding at those temperatures caused any appreciable reduction in nutritive value. Scholtyssek et al. (1970) found that a scald temperature of 50-52°C resulted in lower drip losses, a lower pH value and better tenderness of broilers than when scald temperature of 57-58°C was used.

Plucking. Very little data is available in the literature on the effect of feather removal on nutritional value of chicken. In research on the physio-chemical changes during processing, Rassadkiva et al. (1970) compared mechanically plucked chickens to those plucked by hand. That research indicated that a combination of scalding and mechanical plucking caused partial denaturation of protein due to temperature increase in the meat. Those workers also found that glycogen levels dropped by 21.0% in the mechanically plucked light meat, compared to 4.2% in the hand plucked light meat. Free moisture was 41.5% in mechanically plucked birds. They felt that mechanical plucking had the greatest overall influence on physio-chemical changes in chicken muscle of all of the processing steps. From the data available it is evident that the technique of feather removal may affect nutritional value.

Chilling. U.S. Department of Agriculture regulations require that carcasses be chilled to 4.4°C internal temperature before they are stored. In the U.S. both dry chilling and ice slush are used to process broilers. Recent requirements allowing only imports of dry chilled birds by the common market countries in Europe have caused many processors in the U.S. to

convert to dry chilling.

In comparing the two types of chilling, generally, birds that are dry chilled have greater overall losses than ice chilled birds and reach the consumer containing less water. Froning et al. (1960) revealed that air chilling gave greater overall weight losses but much less thaw, drip loss, volatile and drip cooking losses than ice chilling. They also reported higher flavor scores for air chilled birds. Hale et al. (1973) attributed the flavor advantage of air chilled birds to the fact that more nutrients and flavor producing compounds are leached out during ice or wet chilling.

Wet chilling results in water absorption by the carcasses (possibly providing a weight gain for the processor); however, wet chilling adversely effects nutritional value of chicken. Hurley's et al. (1958) work on broilers wet chilled from 1-24 hours, indicated that solids, protein, and minerals were leached out of the carcasses at an increasing rate with no sign of leveling off up to 24 hours, (Table 9). Phippen and Klose (1955) also found that a high percentage of ash and total nitrogen was leached out of carcasses into the chill water. In addition, they revealed greater losses of solids, total nitrogen, and ash in the drip from 18 hour wet chilled broilers compared to drip from dry chilled broilers (6.5% as compared to 2.1%). Harris and Von Loesecke (1971) stated that wet chilling may leach out as much as 1% of the total solids into the chill water.

Froning et al. (1960) reported that a large amount of moisture absorbed in wet chilling was lost on thawing and cooking and that chilling time should be limited to reduce drip and volatile losses. Hale and Stadelman (1973) determined that even though wet chilled carcasses gained more weight

through water absorption, initially, the wet chilled broiler had an additional 20 gram net loss after cooking. They felt their results lent credence to the claim that wet chilling caused a considerable loss of fat and body tissue with water picked up in their place. Zenoble's et al. (1977) research work found that thiamine and mineral content was significantly higher in birds cooked immediately after slaughter compared with birds ice chilled for 20 hours. Most reports indicate that type of chilling can influence the nutritional value of the broiler carcass.

Phosphate During wet chilling of broilers, phosphates used in chill water reduce drip loss and help retard oxidative deterioration. Mountney and Arganosa (1963), Monk et al. (1964), Dawson and Sison (1973) and Shults and Wierbicki (1973) all found phosphate treatment reduced cooking losses. Little work has been done on the effect of phosphates on the nutritional value of chicken. Monk et al. (1964) found that phosphate treated broilers, after cooking, contained less protein than untreated birds due to dissolution of protein. Hamence and Kunwardia (1974) also reported that protein and fat was slightly reduced in phosphate treated raw chicken. Nutritional value of broilers may be reduced slightly when phosphates are used in the chilling process.

Post Mortem Aging. Broilers are normally aged or allowed to pass thru rigor before freezing to facilitate a more tender product. Broilers marketed fresh (not frozen) pass thru rigor with the advent of refrigerated storage; however, freezing stops aging if done before or during rigor. If rigor frozen birds are cooked without thawing from the frozen state or in a thawed state with the bird not having passed thru rigor, a tougher, dryer product will be the end result. Khan and Van

Den Berg (1964) determined the three stages of post-mortem aging to be prerigor (within 15 minutes of slaughter), rigor (after 4 hours of aging) and post-rigor (after 24 hours of aging). Khan and Lentz (1965) studied the effects of freezing broilers in prerigor, rigor, and postrigor. They found when broilers were thawed the greatest amount of thaw drip loss was from the carcasses frozen during rigor. Freezing during rigor produced the lowest protein solubility and greatest cooking losses. The loss of nitrogenous constituents and ribose was also more severe in the birds frozen during rigor. Freezing carcasses prerigor and postrigor, compared to freezing during rigor, gave less drip and nutrient losses. Khan and Van Den Berg (1964) reported that extractable nitrogen of broiler meat was at its maximum during postrigor aging and that proteolysis caused protein changes responsible for postrigor tenderization. Khan (1968) studied biochemical changes during aging and reported that free amino acid and peptide levels increased during postrigor aging. Hay et al (1973) studied lipid changes in postmortem aged chicken muscle and found that lysophosphatidyl choline, lysophosphatidyl ethanolamine, and free fatty acids increased with a corresponding reduction in phosphatidyl choline and phosphatidyl ethanolamine. Long chain polyunsaturated fatty acids were produced in aged muscle but were not found in unaged muscle.

Most research indicates that processing and freezing chickens during rigor may result in a somewhat tougher and less nutritious product.

Freeze-drying. Preserving chicken by freeze drying does not significantly affect its nutritional value. deGroot (1963) compared biological values and net protein utilization of cooked chicken with cooked, freeze dried chicken. His findings indicated insignificant

differences in biological values and true digestibility before and after dehydration (Table 10). In another study on freeze dried poultry, Rowe et al. (1963) found that freeze drying did not significantly affect levels of thiamine, niacin, or riboflavin in chicken muscle. Huber's (1968) work on protein solubility revealed that freeze-dried cooked muscle had greater solubility than frozen muscle, but raw freeze dried muscle had poorer solubility, though differences were not significant.

Curing and Smoking. Burger and Walters (1973) found some reduction in nutritional values in cured and smoked meats. Smoking caused the greatest reduction due to the heat lability of some vitamins. Rice et al. (1947) showed small losses of 1-5% of some vitamins during curing could be attributed to leaching into the curing pickle. However, smoking with temperatures high enough to cook the product produced overall vitamin reductions of 8-15%, with thiamine having the greatest loss. In another study on the effects of curing, smoking, and cooking, Beuk et al. (1950) reported significant reductions of thiamin (up to 16%) but riboflavin and niacin were not significantly affected. Another effect of smoking was noted by Hawley (1971) who reported a 12% reduction of available lysine due to cold smoking. Millares and Fellers (1949) compared the nutritional value of canned chicken meat to meat that was cured, smoked, and canned. They found that nicotinic acid was reduced significantly by curing and smoking; thiamine and protein was slightly reduced; but riboflavin was relatively stable (Table 11).

U.S. federal regulation have been proposed to restrict levels of nitrites which can be added in curing meats. There are no indications at this time that nitrates greatly affect the nutritional quality of the meat.

Hendrick et al. (1977) worked with cured beef shank muscle and found that added nitrites did not affect protein utilization.

Information presently available indicates that curing and smoking reduces nutritional value of chicken meat, but most nutritional losses are caused by thermal destruction which would occur during normal cooking.

Canning. In canning chicken, temperatures vary from 155.6°C or greater and times up to 2-3 hours. This high temperature for extended periods of time has been reported to affect the nutritional value of chicken. Burger and Walters (1973) found that heat processing reduced protein value as a result of destruction or unavailability of constituent amino acids.

The reduction was attributed to three reactions:

1. Maillard reaction in which the E-amino groups of lysine is rendered metabolically unavailable to the body.

2. Cross-linkage reactions of proteins forming [CH - N] links which are resistant to enzymatic hydrolysis in the intestine.

3. Damage to sulfur amino acids by oxidation or desulfhydration.

Lund (1973) felt that the amino acids, lysine and threonine, were most susceptible to heat destruction. However, Millares and Fellers (1949) found most amino acids were well retained during canning except for tryptophane where reductions as high as 50% occurred in chicken meat processed at 121°C for 70 minutes.

Canning significantly affected vitamins in chicken. In Barratt's (1973) review on effects of processing, he gave the following scale of vitamin losses in canned meat products: riboflavin - 0% to 10%; niacin - 0% to 10%; biotin - 20%; pantothenic acid - 20% to 30%; thiamine - 20% to

40%. Gilpin et al. (1952), Millares and Fellers (1949), and Harris and Van Loesecke (1971) all reported substantial reductions in thiamine values (up to 76%). Losses of vitamin B₆ occurred in canned chicken, with a mean loss of 42.6% (Schroeder, 1971). Lund (1973) reported approximate losses of 15% for both vitamin B₆ and pantothenic acid during canning. Other vitamin losses due to canning poultry included riboflavin (39%) and niacin (26%) Harris and Von Loesecke (1971).

Canning also affects the free fatty acid content of chicken. Gilpin et al. (1952) noted a significant increase from 0.34 mg/g in the raw chicken to 2.94 mg/g after canning. However, that increase was not high enough to indicate progressive rancidity.

Canned chicken has significantly less nutritional value than the raw product. Yet, because raw chicken meat is a good source of protein, vitamins and minerals, the canned product still retains much of its original nutritional value (see Table 12).

Methods of Freezing. Consumption and consumer acceptance of frozen chickens has been on the upswing because of three main factors: 1) improved methods of packaging, 2) improved methods of freezing and, 3) improved methods of marketing. In processing frozen poultry many different commercial methods are currently being used. Three major freezing methods are blast freezing in air, refrigerated plate freezing, and liquid gas freezing. Methods of freezing can be broken down into two types according to Mountney (1976): sharp freezing (-23.3°C or lower without mechanically agitated air) and quick freezing (resulting in the product passing through the zone of maximum crystal formation in 30 minutes or less and providing a completely frozen product in 90 minutes or less).

When comparing methods of freezing and their effect on biochemical changes in poultry, Khan and Van Den Berg (1967), found immersion CO₂ freezing at -80°C to be superior to freezing at -18°C in a conventional freezer. They noted that slower frozen poultry lost more amino acids, peptides and nucleic acid derivatives in the drip than the faster frozen birds. Crigler and Dawson (1968) also found quicker freezing resulted in less protein and total solids losses than longer freezing times. Huber (1969) compared liquid nitrogen freezing to plate freezing at -10°C and found that chicken muscle protein had greater solubility when frozen at -10°C.

Cook (1974) stated that freezing chicken meat caused muscle proteins to lose some of their water binding capacity and resulted in a drop in pH of as much as 0.3 pH units. Broilers, blast frozen at -35°C, had greater thaw and cooking losses than fresh birds (Hale and Stadelman, 1973). However, Khan and Van Den Berg (1967) found that chickens frozen at -80°C had less cooking loss than fresh birds.

Goddard and Heath (1979) evaluated the effects of three methods of freezing (liquid nitrogen at -65°C, freon at -34°C, and blast freezing at -23°C) on the TBA values of broiler muscle. Their results indicated no significant difference in TBA values between the three methods. Though there is little information available on the nutritional effect of freezing chicken muscle, indications are that effects are slight. Faster freezing rates reduce losses during thawing, reduce losses of drip during cooking, and provide higher overall quality than slower freezing methods.

Consumers show a preference for fresh broilers, but sometimes buy them in quantity for later home freezing. They will simply freeze the

bird in the original wrapper in home freezers. This can reduce the nutritional value of the thawed bird because of the slow freezing rate in most home freezers and increases the possibility of freezer burn occurring as many of the original wrappers become torn or punctured during handling.

Cut-up vs. whole. Many processors are marketing cut up broilers and broiler parts both fresh and frozen. Hale and Stadelman (1973) showed that cut-up carcasses, especially frozen ones, had more drainage than whole birds. However, they found no significant differences in moisture or fat content after cooking. Wyche and Goodwin (1974) compared hot-cut, pre-rigor broilers to those chilled before being cut-up. They found less cooking loss in the hot cut broilers. The work cited seems to indicate that warm cutting carcasses during processing slightly increases drip and cooking loss. However, pre-rigor hot cutting and fresh marketing may help reduce these losses.

Part III

Nutritional Changes After Processing

The greatest nutritional losses in chicken normally occurs after processing, during storage and preparation. Nutritional changes vary because of the many different storage times, thawing processes, and cooking conditions that can be used. Unintentional abuses by industry and the consumer sometimes increase nutritional loss.

Storage. Broiler processors try to provide a carcass with long shelf life. When marketing fresh carcasses a major problem is control of microbial numbers to insure a reasonable refrigerated shelf life. Refrigerated storage for normal storage periods will not greatly affect nutritional value of broilers. However, some changes occur as

shown by Lilyblade and Peterson (1962) who found inositol, glucose, fructose and ribose substantially increased during storage at 1°C. Khan (1968) and Miller et al. (1965) showed that most free amino acids and peptides in broiler carcasses increased during refrigerated storage from 1 to 7 days. Taurine and proline were exceptions. Their concentrations decreased during 1 week of storage. Shantz et al. (1969) compared dry ice and ice pack chill storage of broilers at both 4.4°C and 7.2°C and found that protein degradation occurred at both temperatures but was more extensive at 7.2°C. That indicated chill storage should be as near 0°C as possible to minimize nutritional loss. Privett et al. (1955) conducted storage tests at 1°C and reported that losses of essential fatty acids in meat were insignificant during refrigerated storage. Some vitamin reductions have been noted during chill storage. Rice et al. (1948) stored chickens at 4°C for 14 days and found that niacin in chicken decreased 11% in breast muscle and 21% in leg muscle. During the same test they found no changes in riboflavin, thiamine or pantothenic acid in pork loins but niacin was reduced after 14 days of storage, the same as in chicken.

Chicken can undergo several undesirable changes during frozen storage. Desiccation or freezer burn can occur causing an irreversible denaturation of protein and oxidation of fat in the dehydrated areas. Commercial processors have nearly eliminated this problem with the use of modern vapor and moisture proof packaging. However, many consumers using home freezing do not package foods properly and freezer burn is a common occurrence. During long term storage, fat stability can be a problem. Modern practices of inventory control have reduced the problem of holding frozen chickens for extended periods; however, consumers may hold frozen

birds in their home freezer too long resulting in a rancid product. Dawson (1969) suggested a minimum storage time of 6 month at -17.8°C for broilers. He also showed that as storage temperatures are lowered the shelf life of chicken is extended for example -34.4°C gave several months longer storage than -23.3°C .

Davidkova and Khan (1967) studied changes in lipids of frozen, stored chicken. During storage at -10°C they found that as phospholipids decreased the free fatty acid and triglyceride content increased, suggesting lipolysis during frozen storage. El-Warraki et al. (1975) studied lipid changes in frozen chickens and found that lipids actually decreased an average of 7.7% during frozen storage over 24 weeks at -20°C . In comparisons of storage temperatures, -4°C vs -20°C , they found free fatty acid content more than doubled in the -4°C chicken after 24 weeks of storage. That demonstrated the importance of colder temperatures in retarding rancidity. Privett et al. (1955) investigated losses of essential fatty acids of meats during frozen storage and found that even though the meat became unacceptable due to proteolytic activity and rancidity of surface fat, overall losses of essential fatty acids were insignificant.

Frozen storage has been found to cause several changes in the protein of chicken muscle. Khan et al. (1963) (Table 14) reported that protein solubility decreased with storage time and with higher temperature due to loss of solubility and denaturation of the actinomysin fraction. They also found amino acids and non-protein nitrogen increased as a result of proteolysis. Cold storage at -80°C , used as the control in that study, did not significantly change the protein solubility in breast muscle but an 8% decrease in leg muscle protein solubility did occur. Significant decreases

in protein solubility were noted at warmer storage temperatures of -18°C , -10°C and -4°C . Swanson and Sloan (1953) also found that total soluble nitrogen and amino nitrogen significantly decreased during storage at -5°C from 0 to 281 days. They attributed the decrease to free amino acids being converted metabolically to other nitrogen products. In another study, Prudent (1959) stored chickens at -23.3°C for 2 to 14 months. Percent nitrogen decreased with an increased storage time.

Specific changes during frozen storage in amino acids of chicken muscle were reported by Savian and Serbina (1971). Their tests showed muscle stored at -18°C for 6 months had significant losses of cystine, lysine and aspartic acid. They also reported prolonged storage decreased glutamic acid, glycine, alanine, and histidine. Davidek and Khan's (1968) work on chicken meat stored at -5°C , -10°C , -20°C and -80°C for up to 60 weeks revealed a progressive loss of inosinic acid. Inosinic acid decreased by $>75\%$ in 5 to 10 weeks storage at -5°C but at -80°C decreased by $<10\%$ in 60 weeks. Other research by Wladyka and Dawson (1968a, 1968b) found that increasing frozen storage times from 30 to 90 days at -18°C decreased the amount of essential amino acids present in chicken (Table 13).

Frozen storage for extended periods can affect significantly the vitamin content of chicken. Engler and Bowers (1975c) reported meats can be stored up to 6 months without loss of thiamine and riboflavin but longer storage can result in their loss. They stated that niacin, vitamin B_6 , and pantothenic acid are usually fairly stable during frozen storage. Harris and Karmas (1975) reported that broilers stored at -18°C for 8 to 12 months lost moderate quantities of thiamine, riboflavin, and niacin. Morgan's et al. (1949) work on broilers maintained in frozen storage for

extended periods found losses of niacin were negligible up to 8 mo but losses of 25-50% were found after 12 mo storage. Extended storage may also cause fat oxidation, resulting in loss of the fat soluble vitamins A and E. Burger and Walters (1973) and Cook (1974) stated that storage temperatures of -34.4°C or lower will help reduce those losses. To keep loss of vitamins in frozen poultry at a minimum, storage times should be short (6 mo or less) and low freezer temperatures should be maintained.

Today, a significant amount of chicken is marketed in the precooked frozen form. Processors use a variety of methods in precooking, ranging from open kettle to pressurized steam or pressurized deep fat frying. After precooking, the product is frozen and may remain in frozen storage for several months before it is reheated and consumed. Dawson (1969) stated that during storage, precoked chickens first lost its "freshly cooked" flavor, then developed a "warmed over" flavor, and eventually developed rancidity. Their precooked chicken stored at -17.8°C did not develop detectable off flavors until 2 months, staleness until 4 months, and rancidity until the eighth month. Warmer storage temperatures drastically reduced those storage times. All indications are that precooking and freezing affects shelf life and nutritional value when compared to raw frozen chicken.

Mickelberry and Stadelman (1962) found that cooking chicken meat before freezing resulted in a significantly less tender product. Berry and Cunningham (1970a) studied the effect of freezing on the amino acid content of fried chicken and determined that all amino acids, except tyrosine and phenylalanine, were present in greater quantities in the fresh frozen birds than in the fried frozen birds. Khan and Van Den Berg (1965)

investigated cooked, frozen chicken and found the sulphydryl-group content decreased gradually during storage, with the rate of reduction dependent on the storage temperature. After two years of storage little or no change had occurred in the protein quality of the cooked, frozen chickens.

West et al. (1959) found that thiamine was reduced by the freezing and cooking, but noted no differences in loss between the cooked, frozen, reheated and the raw frozen, cooked samples after 4 months of frozen storage.

Nutritional and quality changes occur in fats of precooked chicken. Lee and Dawson (1973) tested chicken fried in corn oil and found that percentage of polyunsaturated fats in the muscle of fried chicken decreased from 70 to 65% after 3 months and to 61% after 6 months storage. They found cooking with reused oil vs fresh oil also greatly influenced the storage life with rancidity and discoloration development noted after 6 mo frozen storage. Wyche et al. (1972) found that fat percentage in precooked chicken increased after 3 months frozen storage due to moisture loss.

The method of precooking influences storage life and rancidity development in precooked chicken. Deep fat frying will not provide a frozen storage life as long as most other precook methods due to the large amount of fat present and the high temperatures used in preparation.

The storage of canned chicken can affect some nutritional components. Gilpin et al. (1952) studied the effect of storage on canned chicken and found significant reductions in thiamine (Table 15). Burger and Walters (1973) reported thiamine retention in canned meat product decreased after storage but riboflavin, nicotinic acid, and pantothenic acid remained fairly

stable. They also stated a 9-year storage period had no effect on the protein quality in canned corned beef but two extremely aged samples of canned meat over 100 years old had protein quality values considerably lower than that of the fresh meat. Thiamine is the nutrient most affected by canned storage and that prolonged storage should be avoided if possible.

Thaw, drainage losses. The term "drainage" is synonymous with the blood-like fluid that is exuded or lost from fresh meat during holding and from frozen meat as it thaws. Drainage in chicken, as with most meats, contains a variety of nutrients which are lost if the drainage is discarded. In frozen chicken, not only chilling method but rate of freezing, length of frozen storage, state of rigor, and thawing method influence the amount of drainage. Chilling methods and state of rigor have been discussed in part II.

Rate of freezing has been shown to affect nutrient concentration and quantity of drainage in broilers. Empey and Howard (1954) reported that slower freezing rates increased amount of drainage. Khan and Van Den Berg (1967) found that slower freezing not only increased drainage losses on thawing but increased the amount of nutrients lost in the drainage (see Table 16). Crigler and Dawson (1968), also, reported that short freezing times resulted in less total drainage which contained less nitrogen and total solids than drainage from broilers with longer freezing times.

The length of storage can affect not only the nutritional value of the chicken, as discussed earlier, but it may influence the concentration and amount of drainage. Pearson and Miller (1950) found that as frozen storage time increased the amount of drainage increased on thawing. Wladyka and Dawson (1968a,b) determined that increasing frozen storage time from 30 to

90 days not only increased drainage volume but protein in the drainage also increased. Protein lost in the drained fluid varied from 1 - 4% of that in the original meat sample and losses were greater from light meat than from dark meat. Khan and Nakamura (1971) compared drainage losses in frozen chicken stored for one week, to those stored for 39 weeks. They found a 169% increase in drainage between 1 and 39 weeks of frozen storage.

Singh and Essary (1971a,b) showed that method of thaw significantly influenced the drainage from broilers. They compared four methods of thawing: room temperature at 26-28°C for 6 hours, cold water at 21-22°C for 3.5 hours, refrigerator at 3-5°C for 36 hours, or warm water at 44-46°C for 1.5 hours. They found longer thawing times gave larger drainage losses. Faster thaw times reduced the amount of drainage and loss of solids, protein and vitamins. Significantly higher losses of riboflavin occurred in the drainage fluid of the refrigerator and room temperature thawed birds compared with the two other methods. Additional nutritional loss in the drainage was attributed to thawing methods. Niacin was significantly decreased in thigh muscle by the warm water thaw method.

Reports on the nutrients lost in the drainage fluid of frozen, thawed poultry are few. Larson (1956) and Singh and Essary (1971a) evaluated drainage from thawed, frozen chicken and identified thiamine, riboflavin, and niacin. Khan and Lentz (1965) measured volume and composition of drainage during thawing, and found substantial concentrations of ribose and protein. Wladyka and Dawson (1968a,b), found that protein lost in the drainage fluid of thawed broilers included all essential amino acids (as shown in Table 17). Savian and Serbina (1971) reported significant amounts of lysine, cystine, and aspartic acid in the drainage fluid of thawed,

frozen chicken. Cunningham et al. (1978), in an extensive study on composition of drainage from thawed poultry carcasses, found that significant amounts of protein and minerals were lost in the drainage from thawed broilers. Tables 17, 18 and 19 shows data from various sources on concentrations of nutrients lost in drainage from thawed chicken meat. Judging from the nutrients found in drainage it is obvious that reducing drainage would enhance the nutritional value of thawed chickens.

Changes in Nutritional Value due to Cooking. Cooking causes both desirable and undesirable changes in chicken meat. The desirable effects associated with heat processing includes increased palatability (texture, flavor, and aroma), sterilization or pasteurization, enzyme destruction, and some enhancement of protein digestibility. The undesirable effects include a significant reduction in some nutritional components of chicken flesh. However, effects can vary significantly among cooking methods. Specific cooking methods and their effects will be discussed later in this section.

Cooking could destroy certain amino acids. Lund (1973) found that lysine and threonine are the most "heat-labile". Fry and Stadelman (1960) found reductions of proline, hydroxyproline, and glycine during cooking, however, methionine and cystine increased. They attributed the reductions of the three amino acids to the action of heat on collagen. Pudelskewicz et al. (1963) determined lysine and methionine retention levels in chicken to be over 100% after cooking compared to the raw meat concentrations. Khan and Van Den Berg (1965) reported that cooking chicken muscle caused an overall increase in total nitrogen, accompanied by a decrease in extractible N. They attributed the decrease to loss of solubility of myofibrillar and

sarcoplasmic proteins. Even though some changes in proteins occur during normal cooking, the losses are small as pointed out by Harris and Von Loesecke (1960). They noted that significant damage or destruction of amino acids in meat occurred only after use of extreme heating times and temperatures. Hurrell et al. (1976) demonstrated this by significantly reducing the lysine content and digestibility of protein in chicken muscle after extended periods of heat (27 hours at 121°C). In a review in 1970, Lang stated, "Cooking at 100°C does not alter in any way the biological value of poultry or other meat tested as judged by amino acid analysis". Cooking increases protein percentage due to moisture loss as shown by Scott (1956) who gave a value for total edible protein of raw broiler flesh of 18.2%, compared with 24.5% after roasting. The moisture in those birds was reduced from 74.8% to 68.3% after roasting. Stadelman (1978) compared raw and cooked broiler parts for percent moisture, fat, protein, and ash. A general change of those constituents caused by cooking can be seen in Table 20.

Of all the nutrients present in chicken meat, water soluble vitamin and minerals are most susceptible to loss or destruction during cooking. Spencer (1973) in discussing the stability of vitamins in cooking noted that the fat soluble vitamins were heat stable; vitamin C, thiamine, and pantothenic acid were reported as unstable to heat; and riboflavin, nicotinic acid, vitamin B₁₂, and folic acid as somewhat more stable to heat. Lang (1970) in a review on the influence of cooking on food listed vitamin A, biotin, choline, folic acid, inositol, niacin, and riboflavin as fairly heat stable. Thiamine, pantothenic acid, and ascorbic acid were listed as heat labile. Lund (1973) noted that of the vitamins, ascorbic acid, thiamine, vitamin D,

and pantothenic acid are most heat labile.

Harris and Von Loesecke (1960) in evaluating the effect of cooking on vitamins stated: thiamine was significantly reduced up to 40% in chicken; riboflavin was fairly well retained in cooked poultry (80 - 90%); niacin was heat stable but some losses occurred due to leaching (80 - 86% retention in chicken meat), pantothenic acid was reduced both by heat and by leaching into the cooking drip (50-85% retention); folic acid was affected by cooking, with losses up to 90%; vitamin B₆ was unstable to heat with losses of up to 90% during cooking; choline was stable during cooking; and up to 33% biotin was lost during cooking. Of all the vitamins mentioned the most heat labile were folic acid, vitamin B₆, pantothenic acid, and thiamine. The retention levels of thiamine, riboflavin, and niacin in cooked chicken are shown in Table 21.

Hawley (1971) presented data that showed vitamin A unstable during cooking at high temperatures, 200°F, with losses of 70% after 15 minutes cooking time. Smirnov (1970) found slight reductions (10-15%) of vitamin A in chickens after cooking. Lund (1973) noted that fat soluble vitamins are less heat labile but are susceptible to degradation at high temperatures in the presence of oxygen. Substantial concentrations of water soluble vitamins have been found in the cooking drip of meat. McIntire et al. (1943) found that appreciable amounts of thiamine, nicotinic acid, and riboflavin were lost in the drippings. Engler and Bowers (1975d) showed significant amounts of vitamin B₆ were lost in the cooking drip. Harris and Van Loesecke (1960) attributed significant losses of pantothenic acid during cooking to leaching. Cooking drip is a worthwhile source of vitamins and should be saved and consumed if possible.

Cooking can also affect mineral content of chicken meat. Hewston *et al.* (1948) found substantial reductions in ash during moist heat cooking, pinpointing specific reductions in phosphorus and iron (Table 22).

Fox *et al.* (1960) found a 17.7% reduction in magnesium content of hens during stewing. They attributed the loss to leaching out into the cooking drip.

Harris and Von Loesecke (1960) stated that iron is often water soluble and thus may be lost in the cooking drip. Posati (1978) found that all minerals evaluated, with the exception of zinc, suffered reductions in concentration during cooking of chicken (Table 23). Both moist and dry heat cooking methods were evaluated. Moist heat cooking (stewing) reduced some minerals but not all. Baking reduced some minerals more than stewing did. Significant losses of minerals occur in both moist and dry heat cookery.

The amount of lipid in chicken normally increases in concentration due to the loss of moisture during cooking. However, method of cooking can directly influence amount and type of fat in the cooked product. Chang and Watts (1952), in a study on fatty acids content of chicken before and after cooking, found saturated fat increased and the essential fatty acids varied between roasting and stewing methods (Table 24). Lee and Dawson's tests in 1973 measured lipid changes in chicken fried in fresh corn oil. They identified losses in arachidonic, oleic, stearic, and palmitoleic acid, but found linoleic acid increased. Smirnov (1970) also found slight reductions in the amount of essential fatty acids in chicken meat during cooking.

The nutritional value for raw chicken was given in Part I.

Tables 25, 26, 27, and 28 show nutritional values for chicken prepared

by various methods of cookery. Table 25 covers protein, fat, ash, carbohydrate, and water content; Table 26 shows vitamin concentrations; Table 27 shows concentrations of minerals, and Table 28 shows fatty acid composition.

Cooking from the Thawed vs. Frozen State

Cooking chicken from the frozen state has both advantages and disadvantages. Obvious advantages include eliminating the time and bother of thawing, reducing nutritional losses, and eliminating the possibility of spoilage due to improper thawing. Some inconveniences associated with cooking from the frozen state are increased cooking times and greater energy consumption.

Fulton and Davis (1974) reported on cooking chicken from the frozen and thawed state. They found that eating quality and yield were not affected by the state of the chicken at the start of cooking. Longer cooking times were required to cook frozen chicken for three cooking methods used (roasting, frying, and broiling).

A significant amount of nutrients may be lost in the drip of thawed chicken. Cooking from the frozen state may reduce this loss as no thaw drip would occur. Engler and Bower (1975d) found turkey cooked from the frozen or partially frozen state retained more vitamin B₆ than turkey cooked from the thawed state. Lehrer et al. (1951) found meat cooked from the frozen state retained significantly more thiamine and riboflavin than meat cooked after thawing.

Cooking from the frozen state seems advantageous for safety reasons too. Recent articles (ANON, 1977) advise the consumer of frozen meat not to thaw the product before cooking to prevent microbial growth. It also provided cooking times and temperatures for various cooking methods to be

used when cooking from the frozen state.

Comparison of Cooking Methods

Different cooking methods have different effects on the nutritional values of food. Several of the best known and commonly used cooking methods were compared to determine their affect on the nutritional value of chicken. The methods were:

1. Boiling or stewing: a moist type of heat cookery, seldom used in cooking broilers, but used in cooking older, less tender birds. Hwang et al. (1975) found that stewing increased fat, protein, and energy content of chicken, but reduced moisture and ash compared to the raw bird. Stewing tends to have lower cooking losses than many other cooking methods. Cooking losses of 16% and 25% were given by Ragnewd (1972) and Matthews and Garrison (1975), respectively. A problem associated with stewing was that cooking in water caused losses of the water soluble vitamins and some minerals due to leaching. Hewston et al. (1948) listed ash losses of over 50% after stewing, with specific losses of 45.4% for phosphorus and 30.8% for iron. Seiler et al. (1977) found stewing produced losses of 40-50% in Na, K, Mg, and Co while Fox et al. (1960) found specific leaching losses of 17% in magnesium during stewing. Stewing caused significant reduction in various mineral concentrations (Posati, 1978). Similar reduction in vitamins may occur as shown by Uherova et al. (1975) who found pantothenic acid in chicken was reduced 33% in the breast and 30.5% in thigh muscles after stewing. Hewston et al. (1948) attributed a 49.8% reduction in niacin and 15.5% reduction of riboflavin to the stewing of chicken. In a recent evaluation, Posati (1978) determined retention levels, in stewed chicken, for thiamine, riboflavin and niacin to be 54.5, 92.7 and 60.8 respectively,

indicating substantial reductions.

Most nutrients lost during stewing go into the cooking drip and cooking liquid. If the cooking liquid is not utilized, those will be lost.

2. Roasting or baking: a popular dry type of heat cookery, can be especially detrimental from a nutritional standpoint if over cooking occurs. This problem is due to high temperatures, and extended periods of cooking times often used. Matthews and Garrison (1975) gave an average cooking loss of 29% for ready to cook broilers roasted to 123.3°C internally, while cooking losses of 22% were given for birds roasted a specified time. Harris and Karmas (1975) cited instances where reduced roasting temperatures gave significantly lower losses of the vitamins, riboflavin, niacin, and pantothenic acid. Smirnov (1970) attributed decreases of 10-15% essential fatty acids and vitamin A in roasted chicken, to the high temperatures used. Other reductions of nutrients were noted by Wing and Alexander (1972) who found the vitamin B₆ content of chicken was reduced an average of 17.3% by roasting. Robertson et al. (1966) compared thiamine contents of fresh raw, and roasted chicken. They found roasting at 177°C reduced the thiamine content in breast muscle an average of 28.9% and in dark meat an average of 34.3%. Prudent (1959) also found significant reductions of thiamine averaging 41.5% during roasting of chicken. McCance and Widdowson (1960) listed retention percentages in roasted poultry for thiamine as 50%, riboflavin 80%, and niacin 80%. Other retention mean values for baked chicken were recently reported by Posati (1978) who listed thiamine as 73.1%, riboflavin at 90.1%, and niacin at 81.7%. Uherova et al. (1975) reported that roasting reduced the pantothenic acid in raw chicken breast an average of

36.4% and in raw chicken thigh an average of 48.6%.

Loss in minerals during roasting at 220°C were given by Seiler et al. (1977) as 30-40% for Na, K, and Mg but smaller losses (3-12%) for Cu and Zn. Posati (1978) found significant loss of various minerals occurred during roasting chicken meat. A great deal of evidence indicates that significant losses of nutrients can occur during the roasting of chicken. Those losses can be reduced, however, by using lower cooking temperatures or by reducing the cooking time.

3. Microwave or electronic cooking: more and more consumers are using this type of cookery. The speed, convenience, and energy savings it offers has revolutionized home food preparation in the U.S.A.

Harris and Karmas (1975) review of electronic cooking effects gave little, if any, difference in nutritional values of food cooked by microwave versus conventional methods. Lorenz (1976) published a review of the literature on changes in nutrient and chemical composition of food and reported no essential nutritional differences caused by microwave radiation.

Wing and Alexander (1972) compared cooking losses in chicken cooked by microwave or conventional oven roasting. They found microwave cooking resulted in high moisture losses, but less drip loss than roasting. Cunningham and Lee (1975) compared cooking losses of broilers cooked by different cooking methods: oven roasting, microwave, pan-frying, and deep fat-frying. They found losses were 21.6%, 23.6%, 37.2% and 40.5% respectively, indicating microwave cooking gave significantly lower cooking losses than frying, but more than roasting.

Lorenz (1976) found microwave cooking gave less denaturation of protein than conventional roasting; however, the author believed oven hot spots

could affect protein composition. Due to less drip loss (faster cooking times) microwave cooked meat has usually been reported to contain slightly more protein than conventionally cooked meat (Table 29).

When considering unwanted changes in protein, lipids, and other nutrients, Rosen (1972) believed microwave energy too low in frequency to cause any chemical changes due to direct interaction with molecules and chemical bonds. The effect of microwave cooking on the retention of water soluble vitamins has been the subject of several research reports. They range from no difference between microwave and conventional method to microwave cooking giving better retention.

Lorenz (1975) evaluated the literature on microwave versus conventional cooking losses of thiamine and revealed that even though there are conflicting data, if the same internal temperatures are reached, nutritive loss in microwave and conventional methods are about the same.

Wing and Alexander (1972) compared vitamin B₆ retention of broilers cooked by microwave or by oven roasting. They found that microwave treatment gave significantly higher retention levels, 91.6% as opposed to 82.5% by oven roasting and the drip from roasting contained almost three times as much vitamin B₆ as the microwave drip. They attributed the higher losses to longer cooking times required by the conventional method. Further work is needed to determine the affects of microwave cooking on the nutrients of foods.

Although microwave cooking seems to give greater overall moisture losses in cooking, most vitamins and other nutrient retention levels are generally the same or similar to conventional cooking. Most reports indicate that thermal energy cause these changes in nutrients

rather than microwave energy. Microwave cooking may be more desirable when considering such nutrients as protein and vitamin B₆ and the reduction in time of preparation and energy consumption.

4. Slow or crock-pot cooking method: a method used for its convenience and economy by today's consumers. Many manufacturers of slow cookers claim their product gives a more nutritious, more tender and juicier product than conventional cooking methods. There is very little information in the literature on how this cooking method effects eating quality and nutrient retention in foods. Slow cooking seems to improve tenderness especially in tougher products such as roasters and fowl, but one study (Engler and Bowers, 1975a), indicated some detrimental effects for this cooking method. Those researchers compared turkey breast cooked with the slow cooker or oven roasted. They found slow cooking not only gave significantly higher cooking drip loss, but destroyed significantly more thiamine (Table 30). The slow method provided significantly lower total and volatile cooking losses than roasting and gave a more tender product. Slow cookery destroyed some nutrients due to long cooking times, but a more tender product was achieved.

5. Pressure cooking: a fast cooking method, normally used on tougher, older type chickens. This type of cooking can be accomplished in a regular home type pressure cooker or by steam pressure cookers used by large institutions. Two research groups found that pressure cooking had little affect on amino acids in poultry. Pudelskewicz et al. (1963) found pressure cooking chickens at 10 psi had little appreciable affect on the lysine or methionine content. Schlosser et al. (1957) determined no appreciable difference in lysine concentrations of turkey prepared by

pressure cooking or by braising. In two separate reports, changes in fat concentration were attributed to pressure cooking by Yingst et al. (1971) and Webb and Goodwin (1970) who found pressure cooking reduced fat in raw chicken meat.

Pudelkewicz et al. (1963) found that pressure cooking of chicken meat significantly affected thiamine and riboflavin retention levels. They found a very low retention of 38% for thiamine and 86% for riboflavin. Their thiamine value was significantly lower than values in the literature for other methods of cooking (Table 31), but similar to the thiamine retention obtained in canned chickens by Millares and Fellers (1949), who found light meat had 33% retention of thiamine and dark meat retained only 23%.

No reports were found on the effects of pressure cooking on other nutrients; however, the method would likely affect the water soluble vitamins and minerals in chicken similar to boiling. However, reduced cooking time could negate this loss. Pressure cooking is a fast method to cook and tenderize chicken; however, large amounts of thiamine can be destroyed due to the high temperature. This destruction may make it less nutritionally desirable than many other cooking methods.

6. Frying methods: standard pan frying, deep fat-frying and pressurized frying (broasting) are the methods most commonly used to fry chicken. The first two methods are used primarily in the home and the last two more commonly used in the food service industry.

The frying process tends to significantly increase fat content of chicken. Hwang et al. (1975) compared fat levels of raw, boiled, fried, roasted and smoked, and roasted chicken. Their findings revealed

that fat content was significantly higher in fried chicken than in raw chicken or in chicken cooked by other methods.

Frying tends to produce significant greater cooking losses than roasting or microwave cooking. Essary (1960) and Cunningham and Lee (1975) both determined deep fat frying gave significantly higher cooking losses than roasting and microwave cooking of broilers (Table 32).

On the positive side, Seiler et al. (1977) found that frying caused less than 10% loss of Na, K, and M compared with stewing or roasting which caused 40-50% and 30-40% losses, respectively. However, Ragnewd (1972) found significant reductions of thiamine 45% caused by frying chicken. McCance (1960) reported frying losses of niacin and riboflavin in chicken to be 30 and 20 percent respectively.

Mastert and Stadelman (1964) compared several methods of frying, such as deep fat-frying, deep fat-frying with steam pressure, pan frying, and oven frying. They found pressurized deep fat-frying gave minimum cooking losses, maximum moisture retention, and less fat absorption than the other frying methods. Pressurized frying (broasting), was discussed by Harris and Karmas (1975). They stated broasting is not only more rapid than regular deep fat-frying but resulted in less absorption of fat into the product. Undoubtedly, broasting will give a more nutritionally desirable product by reducing fat and may also provide a more nutritious product by reducing cooking times and cooking losses.

7. Broiling or grilling: a dry type of heat cookery, is a fairly rapid method of cooking. Broilers are normally used with this method of cooking since it is most desirable to use a tender bird. Grilling produces moderate cooking losses in chicken. Ragnewd (1972) found grilling

(broiling) on a rack and grilling on a spit gave 26 and 24% losses, respectively. In the same study he determined that thiamine was reduced 22% by grilling on a rack, 24% by grilling on a spit, and 35% by broiling (commercial barbeque style). Morgan et al. (1949) determined broiling reduced thiamine, riboflavin, and niacin in chicken an average of 24, 17, and 20% respectively. Those losses, especially when considering the heat sensitivity of thiamine, were low compared to many other cooking methods. The short cooking times normally used in broiling may help reduce nutritional and cooking losses.

An overall comparison of several cooking methods can be seen in Table 31. For thiamine retention; broiling, roasting, and microwave cooking gave high retention. Pressure cooking yielded lower retention values. Niacin, which is considered fairly heat stable, was retained much better by broiling, roasting, or microwave cooking than by boiling or frying. In analyzing riboflavin retention only small differences were noted between different cooking methods, indicating riboflavin is relatively stable regardless of method of cooking. The average percent retention for riboflavin among the twelve values found in the literature was 86.5%.

According to published data (Table 31), three methods of cooking (broiling, roasting, and microwave) produced lower nutritional losses in chicken than other methods.

SUMMARY AND CONCLUSIONS

The nutritional value of chicken meat can be significantly altered by many different factors as the chicken progresses through the many phases of processing, packaging, marketing, and home preparation.

Processing steps such as scalding, immersion chilling, freezing, and further processing can significantly reduce nutritional value. Nutritional losses can be increased by improper storage and handling conditions, length of time in storage, and methods of packaging. Further nutritional loss can be attributed to methods of cooking, storing, and further processing, such as canning. Combinations of factors can result in considerable loss of nutrients.

More research is needed to determine how each processing step, as well as further processing, alter the nutritional value of chicken meat. Research is lacking in several areas. Up-to-date nutritional data for chicken are needed, with special emphasis on methods of cooking commonly used by the homemaker.

Data are lacking on the effect of further processing, such as canning and dehydration, in relation to retention of nutrients. These data would call attention to the need for processors, wholesalers, and consumers to use the best possible means to conserve the natural goodness of chicken and thus prevent excessive loss of nutrients.

In most countries, economically and nutritionally, chicken is an important menu item. A natural food product should be presented to the consumer so that it provides maximum nutrition. This review should benefit all handlers of poultry, from the processor to the consumer, and increase awareness of how the nutrients in chicken meat can be retained. Thus, everyone involved in chicken meat preparation can help preserve the nutritional value of the product.

Table 1. Nutrient content of raw broiler meat from various published sources.

Description of Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Food Energy (%)
Fryers flesh & skin (100g) ¹	75.4	18.8	5.1	.7	126
Broiler edible portion(100g) ²	74.5	21.0	3.4		
Male Broilers ³ (average)					
White meat	66.2	20.8	10.2	2.9	
Dark meat	64.5	17.8	14.1	3.6	
Breast with skin ⁴		21.0	6.7	.8	
Chicken raw(100g) ⁵	74.9			1.1	
59 day male broiler ⁶	63.2	19.3	14.3		
59 day female broiler	60.4	19.0	17.4		
Broiler males ⁷	71.8	19.3	6.4	2.8	115
females	69.9	18.6	9.3	2.6	
Pectoral muscle(100g) ⁸	73.7	23.2	2.1		
13 wk broiler: Males ⁹	74.8	18.2	6.2	.8	
Females	73.4	17.7	8.0	.8	
Chicken: light meat ¹⁰	70.6	23.3	5.6		129
dark meat	69.3	18.4	11.4		143
Broiler meat ¹¹					
Breast	74.8	21.5	2.5	1.1	
Dark	74.2	21.2	2.4	1.3	
Broiler pieces(100g) ¹²		17.0	12.0		
Broiler meat: light ¹³	74.8	22.8	4.6		
dark	73.2	17.6	1.0		

¹Watt and Merrill (1963).²Robertson et al. (1966).³Goodwin and Simpson (1973).⁴Polansky and Toepfer (1969).⁵Ragneud (1972).⁶Twining et al. (1978).⁷Edwards and Denman (1975).⁸McCance and Widdowson (1960).⁹Scott (1956).¹⁰Millares and Fellers (1948).¹¹Lee (1971).¹²Cook (1974).¹³Wladyka and Dawson (1968b).

Table 2. Concentrations of amino acids present in raw chicken meat.

Type of meat	% protein	Leucine	Valine	Phenylal- anine	Meth- ionine	Trypto- phan	Thre- onine	His- ti- dine	Argi- nine	Ly- sine	Iso- leu- cine	Cys- tine	Tyro- sine	Al- anine	Aspar- tic acid	Glu- tam- ic acid	Gly- cine	Ser- ine	Pro- line
Broilers ¹ (per g total N)	20.6	1.49	1.01	.81	.54	.25	.88	.59	1.30	1.81	1.09	.28	.72		2.02	3.31	1.38		
Chicken meat ²																			
Light	23.30	6.95	4.72	3.78	2.14	1.20	3.86	3.69	5.92	7.50	5.32								
Dark	18.40	7.17	4.56	4.02	2.77	.92	3.81	2.88	6.10	8.75	5.70								
(% of crude protein)																			
Broilers ³																			
Light meat	.21	.21	.11	.24	.42	11.5	.28	16.2	.12	.19	.78	.13	.64	.60	.87	.50			
Dark meat	.23	.21	.11	.17	.72	2.42	.45	6.05	.10	.20	2.13	.25	1.53	1.42	4.87	.60			
(average in micromole)																			
Chicken meat ⁴ (% of protein)	6.63	6.72	3.95	1.76	2.49	4.02	1.96	6.71	7.46	4.12	1.75	2.49				13.25	10.09		
Broilers ⁵																			
Light meat	6.90	4.48	3.68	2.53	1.08	3.91	2.35	6.03	7.18	5.17	1.03	3.07	2.76	8.74	15.18	5.52	3.17	3.79	
Dark meat	7.50	4.82	3.91	2.65	1.11	3.94	2.48	6.76	7.71	5.66	1.11	3.09	3.07	9.37	16.48	5.89	3.21	4.18	
(% of protein)																			
Broiler meat ⁶																			
Light meat	8.83	5.89	2.41	1.34	4.06	3.13	5.68	8.99	5.49										
Dark meat	8.58	5.04	2.47	1.18	4.13	2.24	6.08	8.88	5.30										
(% of protein)																			

¹Orr and Watt (1957).²Millares and Fellers (1948).³Miller et al. (1965).⁴Williams et al. (1954).⁵Kik (1962).⁶Wladyka and Dawson (1968a).

Table 3. Vitamin content of raw chicken meat.

Food description	Vitamin A	Thiamine (B ₁)	Riboflavin (B ₂)	Pyridoxine (B ₆)	Vitamin B ₁₂	Niacin (Nicotinic acid)	Pantothentic acid	Ascorbic acid	Vitamin D	Biotin	Folic acid	Inositol
Fryer¹												
Flesh, skin & giblets	730 I.U.	.07mg	.38mg									
Flesh & skin	170 I.U.	.05mg	.23mg									
Chicken meat ²												
Dark				.32mg	.0004mg		1.00mg					
Light ³				.68mg	.00045mg		.80mg					
Chicken ³												
Breast												
Leg & thigh				5.57µg								
Chicken ⁴				2.89µg								
Chicken meats ⁵				6.83µg			8.00µg					
Light												
Dark		83										
Chicken meat ⁶		108										
Chicken meat ⁷						1-5mg						
Chicken meat ⁸		.082mg										
Light												
Dark		.14mg	.12mg									
Fryers ⁹		.16mg	.31mg									
Breast		.34mg	.31mg			9.6mg						
Leg		.05mg	.06mg			4.3mg						
Broilers ¹⁰												
Breast		1.30mcg/g	2.12mcg/g			344mcg/g						
Thigh		2.11mcg/g	2.88mcg/g			174mcg/g						
(mcg/g)												
Chicken livers ¹¹	32,500 I.U.	.20mg	2.46mg			11.8mg				20mg		
Chicken meat ¹²												
Breast	Trace	.1mg	.07mg	1.0mg		10mg	.7mg			Trace	10mg	3mg
Leg			.25mg			5mg	1.0mg					
Chicken ¹³												
Dark				25mcg			0.692mg				10.0mcg	2.8mcg
White meat				130mcg			0.804mg				11.3mcg	3.0mcg
Fresh Chicken ¹⁴												47mg
Tissue												48mg
Leg		1.9	2.8					7.0		40		
Breast		.77	.7									

- ¹ Watt and Merrill (1963) - (100g/edible portion) ⁶ Dondero Cortes (1952) - (%).
- ² Orr (1963) - (100g/edible portion) ⁷ Gilpin et al. (1952) - (100g/edible portion).
- ³ Polansky and Toepfer (1969) - (µg/gram). ⁸ Pudelskewicz et al. (1963) - (mg/100g).
- ⁴ Schroeder (1971) - (g/gram). ⁹ Morgan et al. (1949) - (mg/100g).
- ⁵ Roberston et al. (1966) - (µg/100g) ¹⁰ Singh and Essary (1971b).
- ¹¹ Mountney (1976).
- ¹² McCance and Widdowson (1960).
- ¹³ Cooper et al. (1963) - (100g portion).
- ¹⁴ Harshaw (1942) (mcg/g).

Table 4. Minerals in raw chicken meat.

Food Description	Calcium	Phosphorus	Iron	Sodium	Potassium	Magnesium	Sulfur	Chlorine
Chicken ¹ Flesh only	12mg	203mg	1.3mg	58mg	285mg	23mg		
Chicken ¹ Flesh, skin & giblets	12mg	201mg	1.9mg					
Broiler Chickens ² Raw	10.9mg		1.3mg					
84 day old Broilers ³ muscle				12.7MEq/1	99.5MEq/1			
Chickens ⁴ Raw						23.2mg		
Chicken pieces ⁵ frozen			1.5mg	80mg	260mg			
Raw dark & light chicken meat ⁶		216mg	3.5mg					
Chicken muscle raw ⁷	5.8mg	407mg	.7mg	46mg	248mg	29mg	268mg	61mg
Chicken ⁸ Light				65mg	265mg			
Dark				95mg	250mg			
Chicken ⁹	.0119%	0.266%	.0047%	.091%	.401%	.0288mg	.303%	.074%

¹Watt and Merrill (1963) (mg/100g edible portion)⁶Hewston et al. 1948 (mg/100g).²Ragnewd (1972) (mg/100g).⁷McCance and Widdowson (1960) (mg/100g).³Kravis & Morley (1960) (expressed as meq per kg).⁸Cooper et al. (1963) (100g portion).⁴Fox et al. (mg/100g).⁹Harshaw (1942).⁵Cook (1974).

Table 5. Total lipid phospholipid and neutral lipid content (%) of poultry tissue.*

Tissue	Total lipids ^a	Phospholipids ^b	Neutral lipids ^b
White meat	1.0	48	52
Dark meat	2.5	21	
Skin	25	2.0	
Depot fat	60 - 80	.9	

^aAs percentage of raw tissue.

^bAs percentage of total lipids.

*From Katz et al. (1966).

Table 6. Approximate cholesterol content of a 100g edible portion.*

Type meat	Cholesterol content mg
Beef, raw without bone	70
Lamb, raw without bone	70
Fish fillet	70
Chicken, flesh only, raw	60
Pork, without bone	70

* From Watt and Merrill (1963).

Table 7. Amount of inostol and free sugars present in broiler muscle.*

Sugar	Dark meat mg/100 g	Light meat mg/100 g
Inositol	124	50
Glucose	188	141
Fructose	10	13
Ribose	1	3
Mannose	1	1

*From Lilyblade and Peterson (1962).

Table 8. Vitamin content of raw breast muscles of broilers.*

Age weeks	Thiamine mcg/g	Niacin mcg/g	Riboflavin mcg/g
4	1.75	308	4.65
6	2.56	374	2.71
8	1.30	344	2.12
10	1.75	353	2.18

*From Singh and Essary (1971b).

Table 9. Milligrams of nutrients leached per gram of broiler soaked.*

Time in hours	Solids	Ash	Nitrogen	Sodium	Chlorine	Calcium	Phosphorus	Potassium
1	1.3454	.6015	.1205	.0365	.1205	.0087	.0379	.1569
8	2.8119	1.3279	.3219	.1059	.3219	.0124	.0956	.3694
24	4.8012	2.3265	.5942	.2307	.5942	.0234	.1978	.7483

*From Hurley et al. (1958).

Table 10. Digestibility values of cooked and freeze dried chicken.*

Process	Biological value	True digestibility	Net protein utilization
Chicken cooked	72.4	100.4	72.9
Chicken cooked, freeze dried	73.5	100.9	74.4

* From deGroot (1963).

Table 11. Effect of canning, curing and smoking on chicken meat.*

Sample	Thiamine μg/g	Riboflavin μg/g	Nicotinic acid μ/g	Protein %
Fresh				
Light meat	.97	.90	97.0	--
Dark meat	1.76	1.80	48.0	--
Canned (15psi)				
Light meat	.32	.90	94.0	31.10
Dark meat	.41	2.00	46.0	28.30
Cured, smoked & canned (15psi)				
Light meat	.29	1.06	81.0	27.30
Dark meat	.29	2.10	40.0	27.30

* From Millares and Fellers (1949).

Protein	Fat	Calcium	Phosphorus	Iron	Potassium	Vitamin A I.U.	Thiamine	Riboflavin	Niacin	Ascorbic acid	Food Energy Calories
g	g	mg	mg	mg	mg		mg	mg	mg	mg	
98.4	53.1	95	1,120	6.8	626	1,040	.18	.54	2.0	18	898

* From Adams (1975).

Table 13. Percent reduction in concentration of specific amino acids in light and dark chicken meat from 30 to 90 days of frozen storage.*

Amino acid	Dark meat (%)	Light meat (%)
Arginine	12.5	24.1
Histidine	25.9	17.6
Isoleucine	15.1	13.3
Leucine	17.7	16.0
Lysine	10.2	12.0
Methionine	21.9	21.2
Threonine	36.8	23.2
Tryptophan	9.3	4.5
Valine	6.6	16.6

* From Wladyka and Dawson (1968a).

Table 14. Changes in protein solubility of chicken breast muscles at various temperatures and lengths of storage times.

Storage time weeks	Storage temp °C	Extractable nitrogen % of total nitrogen	g Nitrogen/100 g muscle			Non Protein
			Myofibular	Actomyosin	Sarcoplasmic	
50	-80	83.0	1.34	1.28	1.20	.56
80		85.6	1.51	1.35	1.01	.52
95		85.2	1.45	1.37	1.11	.52
50	-18	83.0	1.33	1.29	1.24	.58
80		76.8	1.12	.90	.91	.53
95		80.0	1.30	.92	1.01	.55
50	-10	71.4	.85	.83	1.10	.60
80		67.9	.71	.68	.96	.56
95		52.9	.65	.43	.78	.58
50	-4	56.2	.59	.56	.96	.68

*From Khan et al. (1963).

Table 15. Effect of storage times on thiamine content.*

Cockere[chicken, 3-months old	Content per 100 g edible portion	Content per 100 g moisture-fat-free meat
Raw sample	.082	.287
Canned: freshly processed	.020	.066
Canned: stored 4 months	.018	.057
Canned: stored 8 months	.008	.023
Canned: stored 12 months	.008	.032
Sample precooked in water	.065	.238
Canned: freshly processed	.016	.048
Canned: stored 4 months	.016	.053
Canned: stored 8 months	.007	.023
Canned: stored 12 months	.008	.024

*From Gilpin et al. (1952).

Table 16. Volume and composition of drainage from thawed fresh frozen broilers with values on the basis of drainage obtained per 100 g of carcass.*

Freezing rate	Drip ml	Nitrogen	
		Total	Protein
Fast (-80°C)	0.5	2.7	1.9
Slow (-18°C)	1.4	12.4	8.7

* From Khan and Van den Berg (1967).

Table 17. Protein and essential amino acid concentrations in drainage from frozen chicken.

Sample	Protein	Amino acids								
		Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenyl- alanine	Threonine	Tryptophan	Valine
Broilers ¹	4.4%	6.0%*	.6%	7.3%	4.5%	.3%	4.7%	5.8%	1.6%	.9%
Heavy hens ²										
Light meat	5.2%	4.2g ⁺	4.2g	6.9g	7.7g	1.8g		4.0g		6.1g
Dark meat	9.2%	2.9g ⁺	3.06g	6.32g	7.5g	1.6g		3.0g		5.2g

* Amino acid % of protein in drainage.

⁺ g amino acid per 100 g protein in drip.¹ Cunningham et al. (1978).² Wladyka and Dawson (1968a,b).

Table 18. Vitamin concentration in the drainage of thawed frozen chicken.

Sample	Thiamine	Riboflavin	Niacin
Chicken ¹	.64	.67	26.7
10 week old broilers ²	.05	.06	6.48

¹Singh and Essary (1971a) (Values $\mu\text{g/ml}$ of drainage).

²Larson (1956) (Mean values $\text{mg}/100 \text{ gm}$ of drainage).

Table 19. Mineral concentration in the drainage of thawed frozen chickens.*

Sample	Ash(%)	Mineral in drainage (ppm of ash)							
		K-Ca	Fe	Cu	Zn	As	Br	Rb	Sr
Broiler	.44	84	773	42	387	1	162	709	42
Rock Cornish	.53	73	670	117	400	4	71	305	9

* From Cunningham et al. (1978).

Table 20. Percent change in moisture, fat, protein and ash concentrations of chicken parts after cooking by the oven frying method.*

Anatomical part	% change			
	Moisture	Fat	Protein	Ash
Breast	-20.4	+471.4	+53.1	+32.2
Thigh	-22.9	+126.3	+62.4	+51.2
Leg	-23.1	+159.3	+73.4	+39.8
Wing	-20.5	+140.7	+57.7	+41.4

* Adapted from Stadelman (1978).

Table 21. The percent retention of vitamins in cooked chicken.

Product	Cooking method	Vitamin % retention		
		Thiamine	Riboflavin	Niacin
Chicken ¹				
Meat & Skin	Baked	71.07	89.48	81.92
	Stewed	54.51	92.74	60.77
Chicken ²	Simmered (240 min)		117.24	51.45
	Boiled (194 min)		84.48	50.18
Broiler 8 wks old ³				
Breast	Stewed 40-60 min	79.23	93.40	84.01
Thigh	Stewed 40-60 min	59.72	87.50	71.26
Fowl ⁴				
Light meat	Pressure cooked 10psi	44	81	
Dark meat	Pressure cooked 10psi	55	79	
Broiler meat ⁵	Boiled	58		
	Pan fried	65		
	Broiled on back	78		
	Grilled on spit	76		
	Broiled (barbeque)	65		
Chicken ⁶	Roasted	50	80	80
	Fried		80	70
Chicken ⁷				
Breast	Boiled (160°C)	67	114	91
Leg	Boiled (160°C)	80	92	80
Broilers ⁸				
Fresh	Roasted (177°C)	66.85		
Frozen	Roasted (177°C)	69.44		

¹Posati (1978) (Mean).

²Adapted from Hewston *et al.* (1948).

³Adapted from Singh and Essary (1971b).

⁴Pudelkewicz *et al.* (1963).

⁵Ragnewd (1972).

⁶McCance and Widdowson (1960) (Percentage factors).

⁷Morgan *et al.* (1949).

⁸Adapted from Robertson *et al.* (1966).

Table 22. The concentrations and percent retention in the mineral content of raw (dark and light combined) chicken meat per 100g.*

Product	Ash		Nutrient Phosphorus		Iron	
	mg	% retention	mg	% retention	mg	% retention
Raw light and dark meat	1,850		362		3.5	
Simmered, disjointed, covered, 240 min. in H ₂ O	1,035	46.9	233	53.9	2.9	67.9
Boiled, disjointed, covered, 194 min. with H ₂ O to cover	986	48.8	216	54.6	2.7	69.2

*From Hewston et al. (1948).

Method of Preparation	Ash	Calcium	Iron	Magnesium	Potassium	Phosphorus	Sodium	Zinc	Copper	Manganese
Baked	70.25	91.83	86.75	76.34	77.87	78.64	76.12	100.00	90.72	72.35
Stewed	73.58	80.19	88.02	66.79	58.00	69.15	68.93	98.68	91.08	73.09

* From Posati (1978).

Table 24. Changes in fatty acid content of chickens after cooking expressed as a percent of total fat.*

Method of preparation	Saturated fat	Oleic	Linoleic	Linolenic	Arachidonic
Chicken stewed	+0.7	-1.5	+0.54	-0.01	+0.01
Chicken roasted	+1.3	-1.3	-0.24	-0.01	-0.04

* From Chang and Watt (1952).

Table 25. Nutrient content of cooked chicken meat from various published sources.

Description	Cooking Method	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	CHO (%)	Food Energy (calories)
Fryers, Flesh & Skin ¹	Fried	53.5	30.6	1.2	11.9	2.8	250
Broilers, flesh only ¹	Broiled	71.0	23.8	1.1	3.8	-	136
Chicken, all classes ²							
Light meat w/o skin	Roasted	63.8	31.6	-	3.4	-	165
Dark meat w/o skin	Roasted	64.4	27.9	-	6.3	-	172
16 wk old roaster hens ³							
Breast	Roasted	66	31.5	1.0	1.3	-	138
Leg	Roasted	67	25.4	.9	7.3	-	168
13 wk broilers(males) ³	Roasted	68.3	24.5	1.04	6.2	-	154
Fowl ⁴	Pressure cooked						
	10 psi	58.97	35.3	-	5.21	-	-
Chickens(boneless) ⁵	Boiled	-	26.2	-	10.3	-	203
	Roasted	-	29.6	-	7.3	-	189
Fresh whole broilers ⁶	Roasted (177°C)	68.5	25.5	-	4.9	-	-
Chicken, cooked ⁷							
Flesh & skin, whole	Broiled	61	27	-	11	-	218
Breast	Fried	52	30	-	15	-	270
Spent hens ⁸	Simmered 100°C	65.41	28.88	.62	-	-	-
	2.5 h						
Cockere1(3 mo old) ⁹	Stewed	67.45	-	.90	5.06	-	-
Roast chickens ¹⁰							
Portion	Roasted	71	25.3	1.0	14.0	-	220

¹Watt and Merrill (1963).²Adams (1975).³Scott (1956).⁴Pudelkewicz et al. (1963).⁵McCance and Widdowson (1960).⁶Robertson et al. (1966).⁷Cooper et al. (1963).⁸Zenoble et al. (1977).⁹Gilpin et al. (1952).¹⁰Harjes and Smith (1970).

Table 26. Vitamin content of cooked chicken meat.

Food description	Method of cooking	Vitamin A	Thiamin (B ₁)	Riboflavin (B ₂)	Niacin (Nicotinic acid)	Biotin	Folic acid
Chicken ¹	Roasting	Trace	.05	Breast .06 Leg .20	Breast 8 Leg 4	....	....
Chicken, whole ²	Broiled	310 I.U.	.05	.18	8.4	....	....
Breast	Fried	75 I.U.	.04	.08	12.0	....	....
Broilers, flesh only ³	Broiled	90 I.U.	.05	.19	8.8	....	....
Fryers, flesh & skin ³	Fried	170 I.U.	.06	.36	9.7	....	....
Roasters, flesh & skin ³	Roasted	420 I.U.	.08	.14	8.2	....	....
Hens, flesh & skin ³	Stewed	670 I.U.	.04	.14	8.8	....	....
Broilers (8 wk old) ⁴	Stewed	....	1.30	2.12	344	....	....
Breast	Stewed	....	2.11	2.88	174	....	....
Thigh	Broiling at 160°C	.03	.03	.06	8.5	....	....
Chicken, breast ⁵	Broiling at 160°C	....	.04	.11	3.4	....	....
Thigh	Broiling at 160°C	....	....	....	....	....	....
Fowl ⁶	Pressure cooked 10 psi	....	.08	.14	....	....	....
Light meat	Pressure cooked 10 psi	....	.13	.40	....	....	....
Dark meat	Pressure cooked 10 psi	....	....	....	....	....	....
Chicken boned ⁷	Roasted	....	.30	....	10.5	....	....
Breast	Roasted	....	.60	....	5.6	....	....
Leg	Roasted	....	25	....	....	....	....
Broilers (Fresh) ⁸	Roasted	....	25	....	....	....	....
Breast	177°C	....	29	....	....	....	....
Leg	Roasted	....	....	....	....	....	....
Fowl ⁹	Steamed	....	.55	1.10	68.0	....	....
Light meat	Steamed	....	.56	1.70	45.0	....	....
Dark meat	Steamed	....	....	....	....	....	....
Chicken ¹⁰	Simmered	....	....	.068	2.84	....	....
Dark & light meat	Boiled	....	....	.049	2.77	....	....

¹McCance and Widdowson (1960) (mg/100g).²Cooper et al. (1963). (mcg/g).³Matt & Merrill (1963) (mg/100g).⁴Singh and Essary (1971b) (mcg/g).⁵Morgan et al. (1949) (mg/100mg).⁶Pudelkewicz et al. (1963) (mg/100g).⁷Scott (1956) (mg/100g).⁸Robertson et al. (1966) (µg/100g).⁹Millares & Fellers (1949) (µg/g).¹⁰Hewston et al. (1948) (mg/100g).

Table 27. Minerals in cooked chicken meat.

Food description	Method of cooking	Calcium	Phosphorus	Iron	Sodium	Potassium	Magnesium	Sulfur	Chlorine
Chicken ¹	Boiled	10.7	270	2.1	98	381	26.4	293	62
Broilers ²	Roasted	14.5	271	2.6	80	355	23.0	324	100
Flesh only	Broiled	9	201	1.7	66	274	.....	.....	.....
Fryers ²	Fried	13	257	1.6	78	381	.....	.....	.....
Flesh only ²	Fried	13	257	1.6	78	381	.....	.....	.....
Hens & cocks ²	Stewed	12	149	1.5	55	272	19	.....	.....
Flesh only ³	Roasted								
Chicken ³	Broiled								
	or Fried	9-15	.....	.....	.....	.....	23	.....	.....
Heavy hens ⁴	Stewed	.....	.....	.....	.....	.....	19.1	.....	.....
Chicken ⁵									
Dark & light meat	Simmered	.....	233	2.9	.....	.....	.....	.....	.....
	240 min								
	Boiled	.....	216	2.7	.....	.....	23-30	.....	.....
	294 min								
Chicken whole ⁶									
Flesh & Skin	Stewed	11	200	1.6	.....	.....	23-30	.....	.....
Breast	Fried	13	200	1.4	.....	.....	.....	.....	.....
Leg	Fried	15	200	2.0	.....	.....	.....	.....	.....
Broiler ⁷	Broiled	16.3	.....	1.4	.....	.....	.....	.....	.....
Roast chicken									
Portion	Roasted	16.4	186	1.3	74	270	.....	.....	....

¹McCance and Widdowson (1960) (mg/100g).²Watt and Merrill (1963) (mg/100g).³Hankin et al. (1970) (mg/100g).⁴Fox et al. (1960) (mg/100g).⁵Hewston et al. (1948) (mg/100g).⁶Cooper et al. (1963) (mg/100g).⁷Ragnewd (1972) (mg/100g).⁸Harjes and Smith (1970) (mg/136g portion).

Table 28. The fatty acid composition in the edible portion of chicken and drip after cooking.*

Sample	Method cooking	Fatty acid-% in edible portion				
		Saturated	Oleic	Linoleic	Linolenic	Arachidonic
Fryer	Fried	3.3	4.2	6.83	.63	.23
Stewing chicken	Stewed	3.6	6.3	3.75	.11	.11
(Drip)		6.5	12.6	6.94	.23	.14
Roaster	Roasted	3.4	5.1	2.07	.12	.07
(Drip)		24.5	31.4	12.02	.54	.25

* From Chang and Watts (1952).

Table 29. Cooking losses and nitrogen content of rib-eye steaks cooked by microwaves and by a conventional method.*

Cooking method	Cooking losses			Nitrogen content	
	Evaporation (%)	Drip (%)	Total (%)	Meat (g/100 g muscle)	Drip (g/100 g drip)
Microwave	19.3 ⁺	16.0 ⁺⁺	35.3 ⁺	4.738 ⁺⁺	1.197
Conventional	14.1	5.7	19.8	4.128	1.511 ⁺⁺

⁺p<0.05.

⁺⁺p<0.01.

*From Lorenz (1976).

Table 30. Means of cooking losses and thiamin levels of "slow cooked" and conventionally cooked thawed turkey breast muscle.*

Factor	Thawed		Significance of F value Heat treatment (H)
	Roasted	"Slow-cooked"	
Total cooking loss, %	30.21	28.30	+
Drip loss, %	5.33	26.50	++
Volatile loss, %	25.01	3.20	++
Thiamin, $\mu\text{g/g}$ of muscle, wet-weight basis	0.56	0.47	++
Thiamin, $\mu\text{g/g}$ of muscle, moisture-and-fat-free basis	1.61	1.39	++

* $p < 0.05$.

++ $p < 0.01$.

* From Engler and Bowers (1975a).

Table 31. The percentage of retention of vitamins in chicken and other meats.

Method of cooking	Vitamin retention percentage									
	Thiamine									
Boiling	58 (1)	53 (4)								
Frying	65 (1)									
Broiling	78 (1)	70 (2)	67 (8)							
Roasting	70 (2)	59 (3)	73 (4)	50 (6)	71 (7)	79 (11)	88 (12)			
Microwave	79.4 (11)									
Braising	50 (2)									
Pressure cooked	38 (13)									
	Niacin									
Boiling	60 (4)	50 (9)								
Frying	70 (6)									
Broiling	85 (2)	86 (8)								
Roasting	85 (2)	80 (6)	88-90 (13)							
Microwave	93-95 (13)									
Braising	65 (2)									
	Riboflavin									
Boiling	95 (4)	85 (9)								
Frying	80 (6)									
Broiling	85 (2)									
Roasting	85 (2)	90 (4)	80 (6)	92 (11)	82-84 (13)					
Microwave	86 (11)	90-92 (13)								
Pressure cooked	86 (13)									
	Pantothenic acid									
Stewed	67 (5)									
Roasted	64 (5)									
	Vitamin B ₆									
Microwave	92 (10)									
Roasted	83 (10)									

- | | |
|---|---|
| 1. Ragnewd (1972) chicken. | *8. Morgan et al. (1949) chicken breast (Avg. of 3 lots). |
| 2. McIntire et al. (1943) pork. | *9. Hewston et al. (1948) chicken. |
| *3. Prudent (1959) chicken. | *10. Wing and Alexander (1972) chicken. |
| 4. Posati (1978) chicken. | 11. Bowers and Fry (1972) turkey breast. |
| *5. Uherova et al. (1975) chicken. | *12. West et al. (1959) chicken. |
| 6. McCance and Widdowson (1960) poultry. | 13. Lorenz (1976) beef. |
| *7. Robertson et al. (1966) fresh broiler breast. | 14. Pudelnkewicz et al. (1963) chicken. |

*Adapted from data presented.*8.

Table 32. Percent loss of thawed broiler halves
after cooking.*

Cooking method	(%) Loss
Microwave	32.7
Deep-fat fry	52.7
Oven-roast	25.5
Pan-fry	43.4

*From Cunningham and Lee (1975).

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FACTORS AFFECTING THE COMPOSITION OF CHICKEN MEAT

by

JOE HOWARD DEMBY

B. S., ARKANSAS POLYTECHNIC COLLEGE, 1969

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A B S T R A C T

A review of the literature related to factors that affect the nutritional value of chicken is presented. Included are composite tables of the nutritional values of raw and cooked chicken. Nutritional changes caused by commercial processing steps, storage, and cooking are discussed. Various cooking methods affects are described and compared. Many of these factors in combination or alone can result in considerable loss of nutrients in chickens.

Processors and consumers who are aware of the various factors which reduce the nutritional value of chicken can take steps to control these factors and thus prevent excessive loss of nutrients.