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Microbiology of Poultry Meat

Y. H. Yi
Dept. of Food Sci. Kangnung National University
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I. Microbiology of Fresh Poultry Meat

Several hundred different species of microorganisms have been reported in poultry meat. Many of them are present as a result of contamination from feathers, feet, and intestinal contents of the bird. Equipment and personnel on the processing lines contribute to spreading microorganisms. Walker and Ayres (1956) reported that eviscerated poultry carcasses had 11,000 to 93,000 organisms per sq. cm. Elliott and Michener(1961) reported that off-odors appeared from poultry carcasses when the log number of microorganisms reached 6.5 to 8.0 per sq. cm. Slime formation occurred when the number of microorganisms reached a log number of 7.5 to 9.0/cm^2. However, Schmidhofer(1969) indicated that bacterial counts gave no conclusive information as to the possible shelf life of poultry meat.

Few types of bacteria are responsible for spoilage, but those that cause spoilage do so mainly because they can break down fats and proteins and cause other biochemical changes that produce undesirable odors and flavors in poultry meat. The genera: *Pseudomonas, Micrococcus, Achromobacter, Flavobacterium, Alcaligenes, Proteus, Bacillus, Sarcina, Streptococcus, Eberthella, Salmonella, Escherichia, Aerobacter, Streptomyces, Penicillium, Oospora, Cytococcus,* and *Rhodotorula* were identified on eviscerated cut-up poultry by Ayres et al.(1950). They reported that immediately after processing, chromogenic bacteria represented 50–60% of the total microflora on the carcass, *Pseudomonas,* colorless cocci and closely related forms represented 20-25%, while the remaining 20-25% of the microorganisms consisted of miscellaneous bacteria. When cut-up poultry parts were stored until spoiled, chromogenes and other miscellaneous bacteria accounted for less than 1% of the total microorganisms while *Pseudomonas* and *Alcaligenes* were found to be the principal microflora on slimy spoiled parts. In later studies, Ayres (1960) and Kraft (1971) reported that *Pseudomonas* was the most significant of the gram negative non-spore forming rods associated with the spoilage of poultry meat. The microflora responsible for the spoilage of cut-up fresh poultry meat have also been isolated and identified by Arafa and Chen (1975). Of the isolates from packaged cut-up broiler parts, 95.8% were found to be member of the genus *Pseudomonas* while 4.2% belonged to the genus *Enterobacter.* The microbial population on poultry carcasses often includes potential pathogens, such as *Salmonella* sp., *Staphylococcus*

sp., and *Clostridium* sp. These pathogenic microorganisms are present in very small numbers and they tend to remain low in number because they produce less vigorously than the many nonpathogenic microorganisms which out-number them from the beginning (May, 1969).

II. Microbiology of Processed Poultry Products

Ostovar et al (1971) evaluated the microbiological quality of mechanically deboned poultry meat stored for 12 days at 3°C. In their study, the gradual increase in total microbial counts of all samples indicated the presence of psychrophilic organisms in the products. This supports the finidings of previous workers (Ayres et al. 1950; Walker and Ayres, 1956). The bacterial population of mechanically deboned meat increases after each step of processing. Maxcy et al. (1973) studied the density and nature of the microbial population in ground poultry meat prepared from both hand and mechanically deboned fresh and frozen fowl meat. They concluded that the poultry products prepared using either hand deboned or mechanically deboned meats were commercially acceptable based on a microbial sanitation standard like that proposed by Zottola and Busta (1971).

The stability of raw poultry meat patties at refrigerated temperature has been studied by many researchers. Cunningham and Bowers (1977) studied the stability of chicken patties made from ground white Leghorn hens and indicated that total microbial counts of the patties ranged from $9X10^3$ to $7X10^6$/g after 10 days storage at 3°C. Microbiological profiles of chicken patty products containing broiler giblets have been evaluated by Cox et al. (1983). Ground thigh meat incorporated with 10% ground broiler giblets and the finished patties spoiled in 2 to 4 days at 2°C. Craven and Mercuri (1977) studied the total aerobic and coliform counts in chicken-soy patties during refrigerated storage. They reported that *Escherichia* was the predominant genus at Day 0 of storage, but *Enterobacter* was predominant after 10 days of storage. The total plate counts reached $1.0X10^6$ to $5.0X10^7$/g between Days 4 and 6.

Information concerning the microbiological quality of precooked chicken products is limited. Certainly the microbial population would be expected to change with cooking and further processing. Zottola and Busta (1971) reported the microbiological quality of further processed turkey products. Numbers of aerobic bacteria observed on the cooked products were lower than those on the raw products. In the 38 cooked products examined, neither *Salmonella* sp. nor *Escherichia coli* were found, whereas 16 out of 38 contained coliform types, 6 out of 38 contained *Clostridium perfringens*, and only 1 out of 38 was positive for *Staphylococcus aureus*. Mercuri et al. (1970) reported that the bacterial counts of ready-to-eat turkey rolls increased following storage at 5°C.

Micrococci and Staphylococci have been isolated from both hot water and microwave energy precooked chicken parts and from commercial ready-to-eat sliced chicken products (Chen et al., 1973). Wang et al. (1976) examined commercial frozen fried chicken products and reported that the log number of mesophilic bacteria counts for the frozen fried chicken samples ranged from 2.90 to 4.78/g with a mean value of 3.40/g; psychrophilic bacteria counts varied from 2.74 to 4.66/g with a mean reading of 3.26/g; and S-110 medium counts ranged from 2.84 to 4.54/g with a mean of 3.40/g. A slightly higher counts for mesophiles over psychrophiles was observed for all samples examined. Higher mesophilic than psychrophilic counts suggested that some of the mesophilic microflora associated with the product might be heat resistant strains that survived the cooking process. No mold or yeast was observed on the acidified potato dextrose agar plates. All samples tested were negative in *Salmonella*. All of 144 isolates were gram-positive cocci and found to be members of *Staphylococcus* species.

III. Hazardous Microbes of Poultry Meat

The microbe that cause food poisoning consists of two kinds: Those that can form toxins by growing in or on a food and produce illness in the consumer and the other types, which, if ingested, multiply in

Table 1. Characteristics of important bacterial food intoxications and foodborne infections[1]

Disease	Causal agent	Time of onset	Symptoms
Botulism.....	*Clostridium botulinum* A.B. E.F. toxin.	Usually 1 to 2 days : range 12h to more than 1 wk.	Difficulty in swallowing double vision and difficulty in speech. Occaslonally nausea, vomiting, and diarrhea in early stages. Constipation and subnormal temperature. Respiration becomes difficult, often followed by death from paralysis of respiratory muscles.
Staphylococcal food poisoning	Staphylococcal enterotoxin.	1 to 6h : average 3h.	Nausea. vomiting, abdominal cramps, diarrhea, and acute prostration. Temperature subnormal during acute attack may be elevated later. Rapid recovery—usually within 1 day.
Salmonellosis.....	*Salmonella* spp. (specific infection).	Average about 18h : range 7 to 72h.	Abdominal pain, diarrhea, chills, fever, frequent vomiting, and prostration. Duration of illness - 1 day to 1 wk.
Shigellosis (bacillary	*Shigella sonnei*, *S. flexneri*, *S. dysenteriae*, *S. boydii*.	Usually 24 to 48h : range 7 to 48h.	Abdominal cramps, fever, chills, diarrhea, watery stools (frequently containing blood, mucus, or pus), spasm, headache, dehydration, and prostration. Duration - a few days.
Enteropathogenic *Escherichia coli* food poisoning.	*Eschorichia coli* serotypes associated with infant and adult infection	Usually 10 to 12h : range 5 to 58h.	Headache, malaise, fever, chills, diarrhea, vomiting, and abdominal pain. Duration - a few days.
Clostridium perfringens food poisoning.	*Clostridium perfringens*.	Usually 10 to 12h : range 8 to 22h.	Abdominal cramps, diarrhea, nausea, and malaise : vomiting very rare. Rapid recovery.
Bacillus cereus food poisoning	*Bacillus cereus*.....	Usually about 12h : range 8 to 16h.	Similar to *Clostridium perfringens* food poisoning.
Vibrio parahaemolyticus food poisoning.	*Vibrio parahaemolyticus*.	Usually 12 to 14h : range 2 to 48h.	Abdominal pain, severs watery diarrhea, usually nausea and vomiting, milk fever, chills, and headache. Duration - 2 to 5 days.

[1] From "prevention of microbial and Parasitic Hazards Associated with Processed Foods - a Guide for the Food Processor," Committee on Food Protection, National Academy of Sciences, Washington, D.C., USA, 1975

the intestinal tract and produce toxins that cause illness. Virtually without exception the food-poisoning microbes do not produce the usual signs of spoilage or an "off" condition in the food. However, certain clostridia may cause off-odors in canned foods. Spoilage microbes, on the other hand, cause the development of off-odors and off-flavors, slimy surface, color changes, and related defects (Brant et al., 1978). The harmful bacteria and the symptoms they produce in humans are shown in table 1.

Clostridium botulinum

Botulism is the most serious and highly fatal type of food poisoning affecting man. Fortunately

it is also among the most rare and has no known significance for fresh and frozen raw poultry. Poultry meat canned or vacuum packaged in oxygen-impermeable flexible container, however, is a potential source of botulism toxin unless proper precautions are taken. Because this bacterium is anaerobic, i. e., it grows only in the absence of oxygen and is widely distributed in nature. Since it forms spores that can survive adverse conditions for long periods of time, the spores can be assumed to be present frequently on processed poultry. The conditions under which these spores germinate to produce growing cells and toxin are unique (warmth over 4.4°C and absence of oxygen). The botulism toxin is destroyed by thorough cooking. This is another reason why fresh or frozen poultry has never been implicated in poisoning humans.

Staphylococcus aureus

The most prevalent and familiar kind of food poisoning is caused by this bacterium. As with botulism, illness is caused not by the organism itself but by toxins elaborated by some strains during growth in foods before they are eaten. Apparently healthy persons frequently carry *S. aureus* in the nose and throat and on the skin. Present knowledge and technology are unable to eliminate all *Staphylococci* from raw poultry meat, but gross contamination can be prevented. Refrigeration is highly important in controlling this bacterium since it will not grow below 4.4°C. Toxins may be formed when poultry meat is undercooked or is held in a warm place (4.4° – 60.0°C) for several hours after cooking and recontamination occurs.

Salmonella

The frequent occurrence of salmonellae in raw poultry meat has created considerable concern because it can cause an extremely serious disease in humans, especially in the very young, the old, and the infirm, occasionally resulting in death. The common problems are undercooked poultry or poultry contaminated after cooking. Refrigeration at 4.4°C or below prevents growth of salmonellae. This is a major reason for requiring quick removal of body heat after processing.

Clostridium perfringens

This is another anaerobic spore-forming bacterium that occurs almost everywhere in the environment, including the intestinal tract of man and animals. It is frequently present in processed poultry. Sometimes the spores are sufficiently resistant to heat to withstand cooking temperatures. If the cooked poultry is then held between 10.0° and 48.9°C for several hours, *C. perfringens* may grow rapidly. About 1 million organisms per gram of food are believed necessary to cause illness. In comparison with the other food borne illness, those caused by this organism are considered to be the mildest.

IV. Retarding the Microbial Growth on Poultry

Microbes on poultry are ultimately found on the product and come from three main sources. The birds themselves carry more microbes into the processing plant than any other single source. The number of microbes can vary widely, however, depending on the relative cleanliness of the birds. It is well known that the higher the contamination of a product entering a process, the higher will be the contamination after processing. Any efforts to reduce the initial numbers of microbes on live poultry will help reduce contamination in later stages of processing. The second most important source of microbes brought into the processing plant is the workers themselves. The third major source is water, air, and the many different kinds of supplies, especially dusty packing materials which mainly contribute spoilage bacteria.

A major concern is the transferring of microbes from one bird to another during processing, especially during scalding and evisceration. The scald thank has always been considered as a reservoir for microbes and general filth from the birds passing through it. The evisceration process is extremely critical to contamination of the carcasses with fecal material and crop contents. Since these are major sources of food-poisoning bacteria, extreme precautions are required. The two most important steps in reducing microbial numbers on poultry carcasses following evisceration are final spray wash and immersion chilling (Brants et al., 1982). The importance of the many processing steps to the final microbial quality of the

Table 2. Sources of microbial contamination according to relative importance in broiler processing[1]

Operation	Workers hands	Equipment and tool surfaces	Bird to bird	Environment[2]
Grow out	○	○	×	××
Catching	○	○	×	×
Live haul	○	○	×××	×××
Hanging	○	○	○	○
Stunning	○	○	○	×
Killing	○	○	○	○
Scalding	○	○	××	××××
Picking	○	××××	×	○
Washing	○	×	○	××××
Singeing	○	○	○	○
Pinning	×××	××	○	○
Hock cutting	○	×	○	○
Surging	○	××	×××	○
Rehanging	×××	○	○	○
Evisceration (manual)	××××	××××	○	○
Evisceration (mechanical)	×	××××	○	○
Inspection	××××	○	○	○
Trimming	××××	××××	○	○
Vacuum lunger	×××	×××	○	○
Washing	○	×	○	××××
Chilling	○	○	×	××××
Surging	○	×××	×××	○
Rehanging	××××	○	○	○
Sizing	○	×××	×××	○
Boxing	××××	×	×	○
Further Processing	××××	○	○	×

[1] ×××× = critical, ××× = significant, ×× = important, × = potentially important, ○ = unimportant or not involved.

[2] Refers to water, ice, air, litter, and all aspects of the environment not in the 3 other categories.

From Brant, A.W., J. W. Goble, J. A. Hamann, C. J. Wabeck, and R. E. Walters, 1982. Guidelines for establishing an operating broiler processing plants. US Dept. of Agriculture, Agriculture Handbook No 581.

carcasses is summarized in table 2.

A number of methods to delay spoilage of poultry have been tested. Of these methods low temperature remains the most dependable and widely used method.

Temperature

A number of studies to determine the effect of temperature on growth of bacteria on poultry carcasses have been made. These studies have been reviewed by Dawson and Stadelman (1960). When carcasses were refrigerated, the spoilage was delayed. Most of the poultry that is not marketed fresh is commercially frozen. Freezing is usually done by air blast or by brine immersion followed by air blast. Freezing poultry by air blast destroyed 96 to 99%

of the total surface microflora (Kraft et al., 1963). Major spoilage is caused by microbial growth in the non-frozen products and oxidative rancidity is the major cause of deterioration in the frozen poultry meat (Froning, 1976).

Hydrogen ion concentration

Preservation of poultry carcasses by the use of edible acids or sorbate has been demonstrated by several workers. Kaloyereas et al. (1961) reported that the shelf life of eviscerated, refrigerated cut-up poultry was extended by synergistic effect of a two-step process consisting of dipping in a solution of sodium dihydrogen phosphate and spraying with a sorbic acid solution. Murphy and Murphy (1962) showed that immersion chilling with lactic, citric, or hydrochloric acid lowered the bacterial count of chill water as well as of the surface of the carcasses. Mountney et al. (1964) demonstrated similar result with hydrochloric acid and Mountney and O'Malley (1965) with acetic, adipic, succinic, citric, fumaric, malonic, sorbic, hydrochloric, phosphoric, and lactic acids. Dipping cut-up broiler parts in an ascorbic acid solution retarded microbial growth without adverse effect on the organoleptic characteristics of the cooked meat (Arafa and Chen, 1978). Potassium sorbate extended the shelf life of fresh poultry meat (Cunningham, 1979) and controlled the growth of spoilage organisms assiciated with fresh poultry parts (Cunningham, 1980).

Antibiotics

Of the materials tested for use in preserving chilled poultry carcasses, antibiotics have received the most attention. Fresh poultry is the only food product to which the United States Food and Drug Administtation permitted antibiotics to be added. Poultry flesh was immersed in solutions containing 30μg/ml of chlortetracycline or oxytetracycline to absorb a concentration of 7μg/g of flesh at the surface to extend the shelf life of poultry carcasses. Health officials view the use of antibiotics with suspicion and foresee the following problems:

1. it appears that antibiotic resistant strains of bacteria and have been developed;
2. antibiotics are only effective against some bacteria and have no effect on yeasts and molds;
3. residual antibiotic may sensitize some consumers;
4. antibiotic treatment may be substitute for good sanitation practices; and
5. the cost of poultry processing will increase (Aryes et al., 1980).

Ozone

Ozone is polymerized oxygen with a molecular weight of 48. It is a powerful oxidizing agent, attacking almost all organic compounds and destroying the most elementary forms of life, such as fungi and bacteria (Stumm, 1958). Walter and Sherman (1976) reported that there was a significant increase in ozone concentration upon small additions of acetic acid to water.

Dickerman et al. (1954) reported that ozone was effective in reducing spore forming organisms and when organic contents are high, larger concentration and longer contact time of ozone were needed. The germicidal action of ozone was slightly affected by temperature or pH changes (O'Donovan, 1965), but Gabovich (1966) indicated that, although its bactericidal action did not diminish, the efficiency of ozone utilization decreased with an increase in pH. Yang and Chen (1979b) examined several factors, such as contact time, temperature, pH value and presence of inorganic and organic materials that influence the germicidal properties of ozne on poultry meat microorganisms. Ozone treated broiler parts extended shelf life for 2.4 days (Yang and Chen, 1979a).

Kaess and Weidemann (1968) exposed fresh beef to ozone mixed with air and examined the beef for microbial counts. Some meat samples were inoculated with meat spoilage non-pigmented and pigmented *Pseudomonas* spp., *Candida scotti* and *Thamnidium* and *Penicillium* spp. The population densities of most microbes showed a significant decrease with less decrease in non-pigmented *Pseudomonas* spp. under ozone. Fournaud and Lauret (1972) found that atmospheres containing controlled additions of ozone had little effect on the surface microflora of beef due to reaction between the ozone, fat, and proteins. Ozone treated broiler parts contained about 52.7% gram-positive cocci, while the air treated control samples had 39.6% gram-positive cocci. Air treated

control samples had 22.4% gram-negative rods while the ozone treated samples had only 12.7% gram-negative rods. Thus, ozone treatment preferentially destroyed gram-negative rod-type organisms (Yang and Chen, 1979a).

Others

The modified atmosphere packaging and irradiation have been used o extend the shelf life of many perishable products including meat and poultry with some sucess.

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