Use of Chicken Meat and Processing Technologies

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ABSTRACT : The consumption of poultry meat (chicken and turkey) grew the most during the past few decades due to several contributing factors such as low price, product research and development, favorable meat characteristics, responsive to consumer needs, vertical integration and industry consolidation, new processing equipments and technology, and aggressive marketing. The major processing technologies developed and used in chicken processing include forming/restructuring, tumbling, curing, smoking, massaging, injection, marination, emulsifying, breading, battering, shredding, dicing, and individual quick freezing. These processing technologies were applied to various parts of chicken including whole carcass. Product developments using breast, thigh, and mechanically separated chicken meat greatly increased the utilization of poultry meat. Chicken breast became the symbol of healthy food, which made chicken meat as the most frequent menu items in restaurants. However, the use of and product development for dark meat, which includes thigh, drum, and chicken wings were rather limited due to comparatively high fat content in dark meat. Majority of chicken are currently sold as further processed ready-to-cook or ready-to-eat forms. Major quality issues in chicken meat include pink color problems in uncured cooked breast, lipid oxidation and off-flavor, tenderness PSE breast, and food safety. Research and development to ensure the safety and quality of raw and cooked chicken meat using new processing technologies will be the major issues in the future as they are now. Especially, the application of irradiation in raw and cooked chicken meat products will be increased dramatically within next 5 years. The market share of ready-to-eat cooked meat products will be increased. More portion controlled finished products, dark meat products, and organic and ethnic products with various packaging approaches will also be introduced.

(Key words: poultry meat, processing technology, healthy food, ready-to-eat)

TRENDS IN MEAT CONSUMPTION AND BROILER PROCESSING

1. Current Status of Broiler Industry

FAO data indicated that the world production of chicken meat increased about 8-fold during past 40 years while the increases in beef and pork are 2-fold and 4-fold, respectively. In the U.S., the consumption of poultry meat (chicken and turkey) also showed linear increase during the past few decades and chicken became the number one meat consumed by Americans since early 1990's. Between 1970 and 2000, the per capita consumption of poultry became more than double while beef decreased by more than 20 Lb and pork remained unchanged(Table 1). Among the 100 Lb of poultry consumed in 2000, 82 Lb is chicken and is the largest of any meat type. Among the 82 Lb chicken meat consumed, 44.3 Lb was white meat and 37.7 Lb was dark meat(Table 2).

In 1970s, 60% of chickens were sold as whole bird, 30% as cut-up parts, and only 10% were used for further processing. However, the way of using poultry meat changed dramatically over the 30-year period: in 2000, only 10% of chicken were sold as whole bird, 50% as cut-up, and 40% as furthered processed meat. The distribution channels of chickens also has experienced similar change during that period: grocery stores were the main distribution channel for poultry in 1970s but food service became the major in 2000. The importance of export market continuously grew over the 30-year period, and about 14~15% of chicken produced in the U.S. was exported in 2000(Table 3).

2. Factors Contributed to the Success of Poultry Industry

Several factors have contributed to the increased appeal of poultry products. First, characteristics of poultry meat: the fat in poultry is almost exclusively associated with the skin and is easy to remove in response to dietary guidelines for reducing

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Table 1. World meat production (1,000 M/T)

Meat	1962	1972	1982	1992	2002
Beef and veal	29,203	38,542	45,899	53,014	57,711
Pork	26,050	40,620	53,195	72,921	93,624
Chicken	7,880	14,654	25,194	38,915	61,892
Turkey	813	1,410	2,183	4,035	5,192
Poultry	9,194	16,824	28,451	45,257	72,238
Meat total	74,466	107,537	140,347	187,449	242,630

FAO (2003).

Table 2. Changes in per capita meat consumption in the U.S. (Lb)

Year	Beef	Pork	Poultry
1970	84.6	56.0	45.0
1975	88.2	43.0	45.6
1980	76.6	57.3	57.1
1985	78.9	51.7	64.2
1990	67.4	49.8	79.3
1992	66.5	53.1	86.2
1994	67.0	53.1	89.5
1997	66.9	48.7	90.9
2000	63.4	53.5	99.9

White meat: 44.3 Lb, dark: 37.7 Lb, turkey: 18 Lb (USDA, 2002).

Table 3. Changes in market forms and distribution in broilers between 1970 and 2000

	Market forms		
	Whole bird (%)	Cut-up (%)	Further processed (5)
1970	60	30	10
2000	10	50	40
	Distribution		
	Grocery stroes (%)	Food service (%)	Export (%)
1970	72	24	4
2000	38	48	14

USDA (2002).

dietary fat. This is contrasted with mammalian meats such as beef and pork, which have more fat included in the lean part of the commonly consumed portions. Second, the industry has been very responsive in developing new products to meet the changing consumer needs. A good example of this is the enormous success of nuggets and similarly formed products, breaded and battered products, fried products, and breast and thigh products. Introducing new products using wing and thigh, and mechanical separation of meats from back and neck portions of broiler carcass and using such meat in further processing significantly increased the value of poultry meat. Poultry scientists should be credited for their excellent work in both basic and applied research, which covered genetics, nutrition, management, and processing, to solve industry problems and to improve production and quality of final products. Development of efficient, automated, and innovative slaughtering and processing equipments also played an important role. Third, poultry is extremely versatile meat, a factor that has possibly contributed to the product development efforts. Poultry meat is more homogeneous in composition, texture and color, and a milder in flavor than red meats, making poultry easy to formulate products with various flavors. Fourth, the U.S. broiler industry is a vertically integrated production, processing and distribution system where the physical production of birds is handled almost entirely by contract growers. The broiler industry is often considered as a role model for the industrialization of agriculture. The vertical integration has enabled the economic production of broilers with uniform size, appearance, and composition. The uniformity has allowed processing plants to develop into highly automated slaughtering and processing facilities with efficiency(Fig. 1). Poultry industry is the most highly consolidated among agriculture and the consolidation is continue to grow. In 2001, about 90% of broilers in the U.S. are produced by top 20 companies(Table 4). Fifth, poultry industry has been aggressive

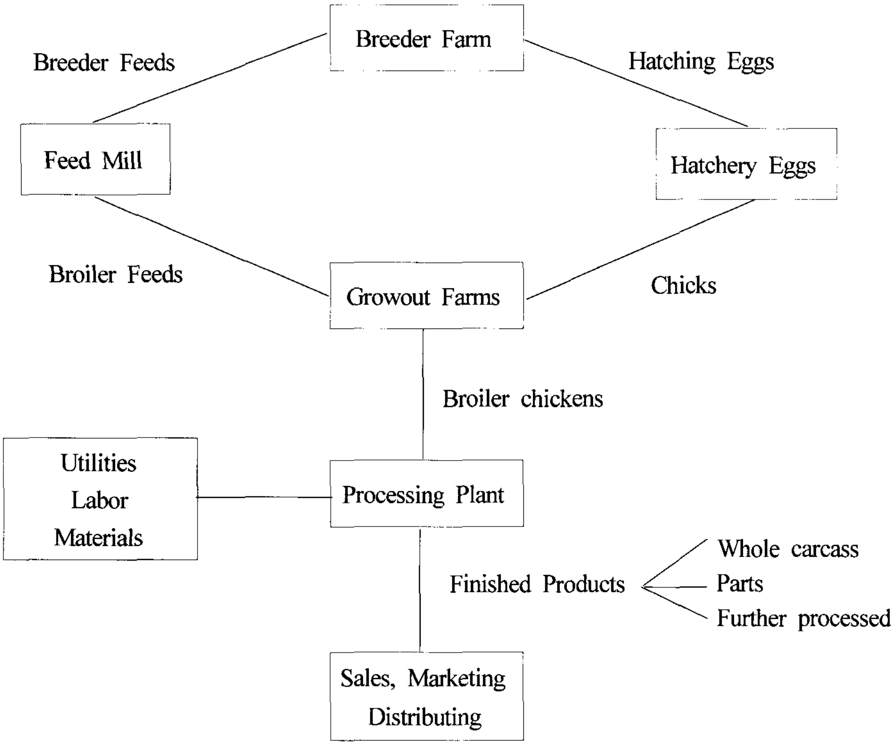

Fig. 1. Material flow between the components of a vertically integrated poultry farm (Adopted from Sams, 2001)

Table 4. Industry consolidation - Percentage (%) of total broilers produced by largest poultry companies (RTC meat basis)

Year	Firms 1~3	Firms 4~5	Firms 7~10	Firms 11~20	Others
1983	26.09	11.16	18.22	21.31	23.22
1990	35.47	10.76	16.26	16.93	20.58
1993	34.50	11.10	18.22	21.31	23.22
1995	38.50	12.20	15.20	17.60	16.50
1998	41.26	11.87	14.29	18.29	14.29
2001	40.60	14.60	17.10	16.90	10.80

Broiler Industry (1999, 2002).

in marketing and consumer education. While red meat industry was enjoying their inherited dominance and consumer preferences, poultry industry and researchers not only put enormous efforts in research and product development but also campaigning to win the heart of consumers since 1960s. Thirty years after the efforts, poultry products became the most popular items in restaurants and fast food chains and poultry breast meat became the symbol of low fat, healthy meat. Poultry industry became the model for beef and pork industry in designing vertical integration for production, product development, distribution, and marketing.

POULTRY PROCESSING AND PRODUCT TECHNOLOGY

1. Preslaughter Handling and Slaughtering

Poultry production and processing involve a series of interrelated steps designed to convert live birds to ready-to-cook (RTC) whole carcasses, cut-up parts, or various forms of deboned meat products. The quality and acceptability of poultry meat as food depends largely upon physical, chemical, and structural changes of muscle as it is converted to meat. The diet and management of poultry during production influence muscle growth, composition and development, and pre-slaughter handling of chicken determine the conversion of muscle to meat, which determines the quality of chicken. Also other factors such as genetics, physiology and disease as well as feed and water withdrawl, catching, transportation, holding, unloading, shackling, stunning and killing can have significant impact on the quality of chicken meat.

Withdrawl of feed and water reduces incidence of carcass fecal contamination during slaughtering. The ideal length of feed withdrawl before slaughtering chicken should be the shortest amount of time required to empty the bird's digestive tracts. However, this time varies because of environmental conditions and management practices. The recommended feed withdrawl time for broilers before processing is between 8 and 12 hours. Longer feed withdrawl (13~15 hr) will increase live shrink, intestinal sloughing, and increase intestinal tearing during evisceration, which will increase the likelihood of carcass contamination.

Some of the major pre-slaughter problems that may occur include bird injuries (bruising, broken or dislocated bones, and scratches) during catching and bird mortality during transportation. To reduce worker and bird stress, and bird injuries during catching, mechanical harvesting are under consideration. Although automatic broiler harvesters has been used in Europe for years, they are not used in the U.S. due to high capital investment. However, pressure from the producers in the European Union, a tight labor market, and animal welfare movement put pressure on using the automatic catchers in the U.S.

Although poultry is not required by law to be stunned before slaughter in the U.S., virtually all commercial poultry is stunned for humane, efficiency, and quality reasons. Stunning renders the bird unconscious prior to killing, which reduce struggle during killing, improve the efficiency of killing machine, more complete bleeding, and better feather removal during picking. Electrical stunning and gas stunning are the two most common stunning methods for chicken. Electrical stunning is the most commonly used in the U.S., and both electrical and gas stunning is used in Europe. The conditions of electrical stunning used in the U.S. and Europe are different. In the U.S., broilers are stunned at 10~20 mA for 10~12 sec, which is enough to make birds unconscious during neck cutting and bleeding. In most European countries, law requires birds to be stunned at 90 +mA for 4~6 sec to prevent them from regaining consciousness mainly for humane reason. Harsher stunning conditions, however, can cause quality defect such as broken bones and hemorrhages from ruptured arteries and capillaries. Gas stunning is developed to replace electrical stunning in areas that require higher electrical conditions. Combinations of gases such as carbon dioxide, argon, and nitrogen are used(Table 5).

Electrical stimulation of dead carcass at 450 volts, with a 2-second on-and-off pulse for 15 seconds immediately after bleed out speeds up postmortem chemical reactions and can reduce aging time by 60%. The forceful contractions by high voltage provide mechanical tenderizing effect, and reduced aging time can save space, labor, time and energy for the processors.

Chilling the carcass immediately after evisceration is important for tenderness of chicken meat (Table 6). Chilling of chicken carcasses in the U.S. is accomplished using ice water. Air chilling is widely used in Canada and Europe. Air chilling involves circulating cold moist air around a processed carcass to reduce its temperature without causing excessive surface drying. Air chilling is less efficient way of lowering carcass

Table 5. Incidence of hemorrage (%) by different stunning methods

Stun method	Breadt fillets	Breast tenders
Gas/CO_2	7.1	3.4
Electric	45.75	41.60
No stun	11.85	7.25

Gas/CO_2: 40% CO_2 in air and 105 sec exposure, Electric: 45 mA, 60 hz for 7 sec. (Bauer, 1997).

Table 6. Effect of chilling treatments on pH, sarcomere length and shear force of broiler breast muscle

	Water chilling treatments[a]		
	A	B	C
PH15min	6.55	6.59	6.54
PH24 h	5.81	5.79	5.80
Sarcomere length (m)	1.87	1.87	1.79
Shear force (kg/cm^2)	2.42[a]	3.20[b]	3.93[c]

[a]A; 10℃ for 24 h, B: 10℃ for 10 h followed by 0℃ for 13 h, C: 10℃ for 23 h. n=15. (Dunn *et al*., 1995).

temperature than water chilling, but air-chilled chicken meats are more flavorful and have denser muscle tissues than water-chilled meats. Water-chilled poultry tends to pick up quite a bit of moisture and shrink more when the product is cooked. Also, air-chilled carcass has lower microbial counts and lower chance of cross contamination than water-chilled carcasses during chilling.

2. Product Development and Processing Technologies

The major contributing factor for the success of poultry industry during past decades is products development using various parts of poultry meat. Researchers in academia, government research laboratory, and R & D department of private sectors put concerted efforts in developing products and processing technologies. The major processing technologies developed and used in chicken processing include forming/restructuring, tumbling, curing, smoking, massaging, injection, marination, emulsifying, breading, battering, shredding, dicing, and individual quick freezing. One or combinations of these processing technologies were applied to various parts of chicken. From whole chicken, injected, basted, smoked, and rotisserie were developed. Various injection and marination mix that can be used for whole chicken and parts were also developed. From breast, oven roasted breast, chicken breast roll, breast strips, breast tender, marinated chicken breast, diced and shredded, formed breast were developed. Developing breast meat products, and using the low fat, high protein, and tender characteristics of chicken breast as the selling point made chicken as the symbol of healthy food, which made chicken meat as the most frequent menu items in restaurants. In contrast to breast meat, the use of and product development for dark meat, which includes thigh, drum, and chicken wings were rather limited due to comparatively high fat content in dark meat. The price of dark meat used to be only about 1/5 of the breast meat and a large proportion of dark meat has been exported. In recent years, however, breaded fried drum and wing products with various flavor and taste opened a new chapter for the use of under utilized dark meats. Using mechanical deboner, meats from back and neck were separated and used for emulsified products. Using either breast or dark meat portion, various formed products such as chicken nuggets, patties, and finger foods were also developed. New product development was not limited to cooked products. Various forms of raw meat products were also developed to meet various consumer needs. All these processing technologies developed during past few decades diversified the utilization of chicken meat, which made the consumption of chicken meat the highest among meat types. Some of the products are sold as ready-to-cook raw meat forms and others are in ready-to-eat forms.

3. Major Quality Issues in Chicken Meat

Pink color problems: Pink discoloration is one of the major quality defects in uncured broiler breast meat because consumers associate the presence of pink in uncured cooked poultry with undercooking or contaminated. The pink pigment was characterized as the heme complex with ligands such as pyridine, nicotinamide, and proteins. Oxidation-reduction potential of cooked poultry breast, pH, and the contents of total heme pigment and cytochrome c were the most important factors to the pink color development in cooked poultry breast meat. However, many other factors such as undenatured myoglobin, contamination with nitrite or nitrate, severe stress at, or absorption of combustion gases such as nitric oxide or carbon monoxide could also be involved in the generation of pink defect. Although usual concentration of nitrate and nitrite in turkey breast meat was not high enough to cause a pink color defect, the possibility of pinking may be high by nitrate or nitrite under certain combined conditions such as high nitrate levels in feed or water supplies, a high microbial load, and long storage conditions. During cooking in a gas oven, as little as 0.4 ppm of nitrogen dioxide gas caused pinking of turkey roll, but the solubility of nitrogen monoxide gas at meat surfaces was not great than nitrogen dioxide. Irradiation also increases the pink color in poultry breast meat. The pinking in poultry could be reduced by addition of some ingredients such as nonfat dry milk or citric acid.

Lipid oxidation and off-flavor: Pre-cooked uncured poultry meat products such as oven roasted turkey breast, breaded chicken nuggets and chicken strips are very susceptible to a quality defect called warmed-over flavor. Fatty acid composition, especially that of phospholipids of the muscle cell membranes, is important in determining the oxidative stability of meat, since the oxidative changes in meat are initiated mainly from the membrane components of muscle. Ionic iron is an important catalyst for lipid oxidation in both living tissue and meat. In living tissues under physiological conditions there isno real free ionic iron available for lipid peroxidation. Most of the iron involved in lipid peroxidation is loosely-bound, and can be released only under certain conditions. Cooked meat is more susceptible to lipid oxidation than uncooked meat. The high susceptibility of cooked meat to lipid oxidation involves at least three factors. First, iron containing proteins denatured by heat may lose their binding capability and release ionic iron. Second, the enzymes involved in aerobic metabolism (which consume oxygen) and the defensive enzyme systems in tissues become inactive by heating. Third, the integrity of cell membranes is destroyed and oxygen is allowed to contact poly-unsaturated fatty acids more easily. The heat denaturation also exposes the reactable domain of heme-pigment, considered as a primary ingredient for lipid oxidation, to oxygen and accelerates lipid oxidation. This problem is aggravated when additives such as salt are added in raw meat. Additionally, any degree of lipid oxidation in raw meat accelerates the development of oxidized off-flavors in cooked meat, due to the free-radical chain reaction nature of lipid oxidation. Warmed-over and rancid flavor and aroma scores correlated highly and consistently with TBARS values, and hexanal, an oxidative products of linoleic acid, is also used as an indicator of lipid oxidation.

Lipid oxidation in cooked meat can be prevented using antioxidants and packaging. "Hot packaging" is an approach to reduce oxygen contact with meat by packaging meat immediately after cooking, while it is still hot. Since oxidative deterioration in meat is closely related to the incorporation of oxygen during and after processing procedures, reducing the opportunity for the meat products to come into contact with oxygen after cooking and subsequent storage can prevent oxidative change in cooked meat during storage(Table 7).

Table 7. Effect of packaging methods on the TBARS values of cooked poultry breast meat patties during storage

	Storage (days)			
Packaging method	0	1	3	7
Hot-vacuum packaging	0.70	0.89	0.89	1.02
Cold-vacuum packaging	0.75	1.24	1.52	2.01
Aerobic packaging	0.79	1.72	3.66	7.81

Ahn *et al.* (1993).

1) Tenderness

Toughness in chicken meat is not as serious a problem as in other meats such as beef. However, improper postslaughter handling can cause the chicken meat tough. Unlike in red meat, cold shortening is not a problem with poultry. However, heat shortening can cause chicken meat tough. Therefore, poultry should bechilled in ice water immediately after evisceration. Usually 8 to 24 hours of aging time is recommended to ensure chicken meat tender. Application of on-line electrical stimulation can reduce the aging time by about 60%.

2) PSE

PSE conditions occur in pork most frequently, but this defect is being seen with increasing frequency in broilers and turkeys. PSE conditions occur due to accelerated postmortem glycolysis, which accelerate the decline in muscle pH while the carcass temperature is high. The low pH and high temperature combination causes the denaturation of muscle proteins, which makes the muscle pale in color, soft in structure, and low in water holding capacity. PSE animal has low tolerance to stress. Various factors such as genetic, and stress from environment and preslaughter handling can cause PSE conditions. It is believed that stress susceptible animals are unable to regulate the flow of calcium, a key regulator of muscle contraction and relaxation. Certain mutation in a protein that controls the calcium flow from storage compartment to the fluid surrounding the myofibrillar proteins (Ryanodine receptor) can make the channel leak. The calcium imbalance in muscle cells drastically accelerates energy metabolism and muscle activity, which increases the body temperature. PSE meat has unattractive color, has poor binding ability when used in formed products, and has very high cook loss(Table 8).

3) Food Safety

Bacterial food-borne illnesses account for an estimated 76 million cases, 325,000 hospitalizations, 5,000 deaths, and $6.7 billion in human medical and productivity losses annually each

Table 8. Characteristics of PSE and normal broiler breast meat

Characteristics	PSE	Normal
pH at 2 hr postmortem	5.75	6.01
Lightness at 2 hr postmortem	63.9	55.1
Water holding capacity as expressible moisture	31.95	27.14
Drip loss during 24 h storage at 4℃(%)	4.87	3.80
Cook loss(%)	31.95	26.99

Sams (1999).

year in the U.S. About 26% of foodborne outbreaks are linked to contaminated poultry and *Campylobacter*, *Salmonella* and *L. monocytogenes* are the major pathogens in poultry. Interventions at various steps and methods have been developed to reduce these pathogens in poultry.

The epidemiology and transmission of *Campylobacter* and *Salmonella* in turkeys and broilers indicated that they spread easily during grow-out period via litter, feeders, drinkers, and air. Thus, intervention efforts for these microorganisms have been focused on identifying farm management practices, which may lower the prevalence of foodborne pathogens in birds. These include strict biosecurtiy efforts, including rodent and insect control, maintenance of drinkers, and assignment of boots and clothing to individual bird-houses. Clearly, reducing the on-farm prevalence of potential human food-borne pathogens will contribute to the overall decline in illness linked to poultry consumption. Dietary supplements such as vitamin E, selenium and conjugated linoleic acid are also being tested to determine their effect on stimulating the immune responses of live turkeys and enhancing gut clearance of these pathogens. If effective, these dietary supplements will reduce the contamination of carcasses at slaughter and result in a decrease in human bacterial foodborne illness. At slaughtering plant, various microcidal agents such as sodium triphosphate, acidified chlorite, electrolyte water etc. are used in chill water or washing step to kill pathogens.

L. monocytogenes enters the abattoir in low numbers with live birds and survives in the processing plant environment to subsequently contaminate processed foods. Unlike other pathogens, *L. monocytogenes* can grow under refrigerated conditions and resistant to salt. Although *L. monocytogenes* can easily be killed by cooking, they can grow during refrigerated storage if the cooked product is recontaminated with *L. monocytogenes* during repackaging and handling. Therefore, *L. monocytogenes* can be a serious threat to cooked meat products. To ensure safety of cooked poultry, addition of antimicribial ingredients, hot water dipping, irradiation, and combination of those are under consideration.

Irradiation is among the best-known methods for control of potentially pathogenic microorganisms in raw meat(Table 9), but its application is limited because of quality and health concerns about irradiated meat. Irradiation produces a characteristic aroma as well as alters meat flavor and color that significantly impact upon consumer acceptance. The generation of off-odor and pink color defect is a critical issue for the use of irradiation in meat because consumers associate the presence of off-odor and off-flavor with undesirable chemical reactions, and a pink color in raw and cooked poultry breast meat with contaminating or undercooking. As a result of these consumer perceptions, poultry industry has difficulties in using irradiation to achieve its food safety benefits. Recent research indicated that volatiles responsible for off-odor were S-containing compounds such as methanethiol, dimethyl sulfide, dimethyl disulfide, and dimethyl tri-sulfide generated by the radiolytic degradation of sulfur amino acids(Table 10). The pigment responsible for pinking in irradiated light meats was carbon monoxide-myoglobin (CO-Mb) and the changes of oxidation-reduction potential (ORP) in meat by irradiation played an important role in the formation of CO-Mb. Lipid oxidation in irradiated poultry can be a problem only under aerobic conditions and the volatiles produced by lipid oxidation had no correlation with irradiation off-odor in meat(Table 11). Studies

Table 9. Susceptibility of foodborne pathogens in fresh meat to irradiation

Pathogen	D value (kGy)
Listeria monocytogenes	0.40～0.60
Salmonella	0.40～0.50
E. coli O157H7	0.25～0.35
Campylobacter	0.14～0.32

Radomyski *et al.* (1994).

Table 10. Production of volatile compounds from sulfur-containing amino acid oligomers by irradiation

Volatiles	0 kGy	5 kGy
	-------- Total ion counts × 10^4 -------	
Glutathione (-Glu-Cys-Gly)		
Carbon disulfide	0^b	589^a
Dimethyl disulfide	0^b	214^a
Met-Gly-Met-Met		
Mercaptomethane	0^b	$17,325^a$
Dimethyl sulfide	0^b	$201,541^a$
(Methylthio) ethane	0^b	$2,053^a$
1-Heptanethiol	0^b	94^a
3-(Methylthio)-1-propene	0^b	122^a
Ethanthioic acid, S-methyl ester	0^b	170^a
2-Methyl-2-(methylthio) propane	92^b	149^a
Dimethyl disulfide	$1,430^b$	$351,320^a$
Methyl ethyl disulfide	0^b	$1,935^a$

[a,b] Means with no common superscript differ significantly ($p<0.05$), n=4. (Ahn, 2002).

are under way to develop methods that can minimize or prevent irradiation-dependent quality changes in poultry and other meat products. However, most of irradiation research has been done in raw meat, and future irradiation research should emphasize more on cooked meat.

Detection of foreign particles and bone chips in poultry products is also another major food safety issue. X-ray technology is currently employed to detect metals, contaminants and bone particles in poultry products. Packaging: The major functions of packaging are extending shelf life and limiting contamination, but processors are beginning to add another message "value-added" to the packaging. Over the past several years, various new packaging methods have been introduced to poultry products. Although the basic concepts of packaging, which include overwrapping, vacuum packaging, gas flush, and modified packaging are not changed, various modifications in containers, packaging materials, and sizes and shapes have been tested. Incorporation of antimicrobial agents or antioxidants into packaging materials are also being used. Use of proper packaging material and method is critical for not only for eye

Table 11. Effect of raw-meat packaging, irradiation, and cooked-meat packaging on lipid oxidation of cooked pork patties[1]

	A-C-A*	A-C-V	A-IR-A	A-IR-V	V-IR-A	V-IR-V
		---------TBARS (mg MDA/kg meat)---------				
0 day storage after cooking[2]						
0 day after IR[3]	0.26^b	0.19^b	0.34^b	0.26^b	0.32^b	0.20^b
3 days after IR	0.61^a	0.61^a	0.67^a	0.67^a	0.59^a	0.59^a
3 days storage after cooking						
0 day after IR	2.46^{bx}	0.32^{bz}	2.83^{bx}	0.34^{bz}	1.68^{by}	1.36^{bz}
3 days after IR	5.34^{ax}	0.71^{az}	4.85^{ax}	0.66^{az}	4.11^{ay}	0.79^{az}
7 days storage after cooking						
0 day after IR	3.48^{bx}	0.44^{bz}	3.44^{bx}	0.39^{bz}	2.44^{by}	0.45^{bz}
3 days after IR	5.46^{ax}	0.81^{ay}	5.88^{ax}	0.79^{ay}	5.47^{ax}	0.75^{ay}

[1] Raw-meat patties were irradiated at 0 or 4.5 kGy dose (ave.).

[2] Samples were analyzed within 1 hr after cooking.

[3] Storage of raw meat before cooking. 0 d after IR samples were stored 2 hr after irradiation.

[x-z] Different letters within a row are significantly different ($P<0.05$).

[a,b] Values with different superscript letters within a column of the same storage time after cooking are different ($P<0.05$). n=12.

* Abbreviation of treatments: A, aerobic packaging; V, vacuum-packaging; C, control, nonirradiated; IR, irradiated at 4.5 kGy. (Ahn et al., 2000).

appeal but also for maintaining high eating quality of meat products.

PERSPECTIVES OF POULTRY MEAT PROCESSING

Research and development to ensure the safety and quality of raw and cooked chicken meat using new processing technologies such as additives, irradiation and high pressure treatments will be the major issues as they are now. Especially, application of irradiation in raw and cooked chicken meat products will be increased dramatically within next 5 years. One important emphasis of ensuring food safety using intervention technologies is maintaining good eating quality of chicken products because no matter how effective the intervention technology is, the method cannot be used if consumers do not accept the product. The market share of ready-to-eat cooked meat products and individually quick frozen products will be increased. More portion controlled finished products using various packaging approaches will be introduced. Also, dark meat, organic and ethnic products market will be expanded rapidly.

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