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Moisture Management and Texture Enhancement in Chicken Patties Containing Methylcellulose

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MOISTURE MANAGEMENT AND TEXTURE ENHANCEMENT IN CHICKEN PATTIES CONTAINING METHYLCELLULOSE

By

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ABSTRACT

MOISTURE MANAGEMENT AND TEXTURE ENHANCEMENT IN CHICKEN PATTIES CONTAINING METHYLCELLULOSE

By

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The objectives of this study were to determine specific physical and chemical characteristics of chicken patties containing two types and two concentrations of methylcellulose (MC), compared to a control containing no gum. Specific goals included understanding the effects of MC on moisture management and textural attributes, along with the feasibility of its incorporation in a processed poultry product. A two-level two variable factorial with augmented control experimental design was used to evaluate juiciness and texture via mechanical and organoleptic methods. Results indicate both supergelling and conventional MC contributed to a 25-30% reduction in shear force, which may be interpreted as an improvement in tenderness. While cooked yields were similar for all treatments; a 15% increase in thickness of cooked patties was noted with MC, potentially indicating “plumpness”, when compared to control patties. Based on these results, a concentration of 0.5% MC or less is recommended to obtain these positive contributions.

I dedicate this work to my father, William G. Worden, who walked into Heaven a year before my graduation. His drive and perseverance lives on in me. May he smile from above as he witnesses the completion of this project.

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LIST OF ABBREVIATIONS

BL/SL .... Boneless, Skinless (referring to poultry meat)
CFR .... Code of Federal Regulations
cPs .... Centipoise (Brookfield viscosity)
FDA .... Food and Drug Administration
FSIS .... Food Safety and Inspection Service
FSPC .... Functional Soy Protein Concentrate
g .... Gram
GRAS .... Generally Recognized As Safe
HPMC .... Hydroxypropyl Methylcellulose
ISP .... Isolated Soy Protein
kg .... Kilogram
MC .... Methylcellulose
NFDM .... Nonfat Dry Milk
psi .... Pounds per square inch (pressure)
ppm .... Parts per million
SAS .... Statistical Analysis System
SG .... Supergelling
SGMC .... Supergelling Methylcellulose
SPC .... Soy Protein Concentrate
STPP .... Sodium Tripolyphosphate
RT .... Room Temperature
USDA .... United States Department of Agriculture

INTRODUCTION

Poultry consumption has continued to rise in recent years compared to red meats. Americans consumed 9.5 kg (21lb) less red meats, and 14.1 kg (31lb) more poultry in 1997, compared to 1970 (USDA, 1999). Per capita consumption (in pounds) of poultry meat in the U.S., based on retail sales, is shown in Table 1.

TABLE 1: Per Capita Consumption (in lb) of Poultry Meat in the United States. Based on Retail Disappearance. From the USDA (Barbut, 2002).

Year	Chicken	Turkey	Poultry (Total)	Beef	Pork
1960	26.5	6.5	34.0	69.4	60.3
1970	40.6	8.1	48.7	84.6	56.0
1980	48.8	10.3	59.1	76.6	57.3
1990	63.0	17.6	80.6	67.8	49.8
1998	73.9	18.1	91.1	68.1	52.6

Poultry consumption has steadily increased while beef and pork consumption have slowly declined. The change actually began after 1950 when new poultry farming and processing techniques began to lower production costs, making poultry more price competitive with red meat. The price of whole chicken fryers dropped from about half to one-sixth the price of beef from 1960 to 1977.

Today, the average chicken plant produces about four times as much product as it did 20 years ago. Americans' appetite for chicken has grown, along with the variety of products offered, from chicken nuggets to marinated, fully cooked whole chickens (Ollinger, 2000). To further expedite the sales of poultry products, the poultry industry has promoted chicken's lower fat content relative to beef and pork. They also have developed new, ready-to-cook products such as boneless chicken breasts, marinated chicken pieces, and poultry frankfurters.

However, poultry products can supply elevated levels of fat in the diet via incorporation of chicken skin into processed poultry products, as long as the natural proportions of white to dark meat and skin are maintained. According to Friesen (2001), breast meat is lower in fat (3-5%, boneless/skinless (BL/SL) breast with rib meat) and subsequently drier, while dark meat is higher in fat (8-10% for BL/SL thigh fillet), resulting in a juicier product. Skin and/or skin emulsions (containing additional water and soy protein concentrate to stabilize the emulsion) are added to processed poultry products, particularly patties and burgers, to reduce cost and improve palatability of the finished product (Bacon, 2001).

Consumers continue to look for convenience and variety in their food choices, while maintaining a healthy diet to either maintain or lose weight. They are increasingly interested in products such as ground chicken burgers, as a perceived healthier alternative to higher fat beef patties. Chicken and poultry consumption in general continues to rise, significantly replacing red meats in the majority of diets. Between 1997 and 1999, 13% of food servings growth in national burger chains was due to chicken nuggets. Chicken sandwiches comprised 12% growth (NPD Foodservice Information Group, 2001). Reports by the NPD Foodservice Information Group also indicate that increased demand for convenient "finger food" is a primary motivator, but added that improved quality and diversity of offerings is another (McDowell, 2001). Processors continue to look for ways to boost product yields while maintaining quality, and the addition of functional ingredients is one way to provide better texture and succulence in boneless chicken products.

The meat and poultry industries have continued to investigate ways to reduce fat in processed products, while maintaining the high quality of eating characteristics and health benefits of protein-based foods in consumer diets (Osburn and Mandigo, 1998; Lin and Mei, 2000; Yang *et al.,* 2001). One of the challenges facing the poultry industry is to produce a value-added chicken product that is capable of retaining moisture during the cooking process. The desired result is a juicy, tender product without any negative textural qualities (i.e. rubbery or mushy texture).

During the late 1980's and into the 1990's, considerable research was conducted to develop fat replacers for processed meat and pork products. Examples include the McDonald's McLean Deluxe, developed at Auburn University (Huffman and Egbert, 1990); ConAgra's Healthy Choice® Extra Lean Ground Beef (Mandigo, 1991); and Lean-Maker®, developed by a team from Webb Technical Group, Quaker Oats, and Heller Seasoning & Spices (Anonymous, 1991). The meat industry was developing low-fat products to meet consumer demands for healthier foods. However, food must taste good and have desirable texture. Consumers are not willing to sacrifice taste and texture, in order to reduce calories and fat intake (Vu, 2001).

Consumers and foodservice operators appreciate the convenience of pre-flavored, pre-cut, and/or precooked poultry products (Parlin, 2001). A key challenge for meat and poultry processors today is to develop value-added products that taste good and provide eating qualities and textures that satisfy the discriminating tastes of educated consumers. Examples of the direction that the meat and poultry industries are focusing on include enhanced pork and marinated poultry products. Most value-added products are made from high quality meat trimmings, are lean and flavorful, and depend on functional ingredients to assist in binding the products together (Juttelstad, 1998). Incorporating non-meat ingredients into these types of products, to enhance the eating experience by improving juiciness and tenderizing the finished product, can bring value to the food processor and ultimately the consumer.

The objectives of this study were to determine the physical, chemical, sensory, and textural characteristics of chicken patties containing different concentrations and types of methylcellulose. Specific goals were to understand the effects of methylcellulose on moisture management and textural attributes, along with the feasibility of its incorporation in a processed poultry product.

LITERATURE REVIEW

MOISTURE MANAGEMENT IN MEAT AND POULTRY PRODUCTS

Moisture management is multi-faceted, encompassing several issues. They can include 1) water holding capacity (WHC) of the proteins, 2) matrix binding or cohesion, 3) cooked yields, i.e. release of water during cooking and/or gel tightening, 4) syneresis, resulting in package purge, 5) juiciness noted during sensory evaluations, releasing moisture via mechanical means, and 6) chemical analysis of water vs. apparent moistness via sensory. These issues need to be considered when evaluating the management of moisture in meat and poultry products.

WATER-HOLDING CAPACITY

Water-holding capacity is the ability of meat or poultry to retain its water during application of external forces such as cutting, heating, grinding, or pressing (Hedrick, *et al.*, 1989). Many of the physical properties of processed meat and poultry, including color and firmness, are a result of the water-holding capacity of the muscle fibers. Cooked juiciness and tenderness are partially dependent on this phenomena (Anonymous, 2001c). Water in muscle exists in three forms: bound, immobilized and free. This water is wrapped around muscle proteins in layers, with weakening bonds as the layers get further from the protein molecules. Bound water (4-5% of the total) is held tightly by the muscle proteins via charged hydrophilic groups on the muscle proteins that attract water, forming a highly ordered structure. Immobilized water (16-17% of the total) is the next layer, and is less tightly bound to the protein molecules. Processing factors, including pH changes and heating may affect the retention of this type of water. Capillary forces hold the free water (79% of the total) with limited ordering of the molecular structure and highly independent orientation from the charged groups on the protein molecules. Free water is easily lost via "weep" or "drip" in fresh cuts of meat, or purged in vacuum packed processed products (Hedrick, *et al.,* 1989). Muscles that have a high proportion of bound water are firm, with a tight structure, while muscles with poor water-holding capacity are soft and have a loose structure (Osburn, 1998). By comparing the percentages of the three types of water in muscles, one can better understand the water retention challenges that we faced.

PROTEIN-WATER INTERACTIONS

The functional properties of muscle proteins are influenced by other ingredients in a formulation and by the processing conditions used (Shand *et al.*, 1993; Smith, 2001). Protein functional properties important in meat and poultry products are generally classified into three categories: 1) protein-water interactions, 2) protein-fat interactions, and 3) protein-protein interactions. The water holding capacity of a poultry product highly depends on the protein-water interactions within that matrix. Lyon *et al.* (1978) reported chicken patties containing 100% hand deboned fowl meat (HDFM) contained the highest protein content and lowest moisture-to-protein ratio, but obtained the highest cooked yield. This agrees with the functionality of protein, the primary contributor to water-holding capacity of meat unless other non-meat water binding ingredients are employed.

The three most important functional properties of protein-water interactions in raw poultry products are a) protein extraction and solubility, b) water retention, and c) viscosity. Water retention was already discussed via the WHC section, but refers to the ability of the protein matrix to retain water or absorb additional water when exposed to an external stress, such as cooking or slicing. Viscosity highly influences the stability of the raw product before cooking, increasing as the muscle fibers swell and absorb water during processing. Protein extractability is described as the amount of protein released from the myofibrillar protein structure during processing of the poultry product. This solubility particularly depends on the hydrophilic and hydrophobic amino acids on the surface of the protein, plus the thermodynamics of the protein-water interaction. Type of salt and concentration level, pH, and temperature of the formulation affect the extractability of the muscle proteins as well (Smith, 2001).

Comminuted (either ground or chopped) meat products are complex systems, consisting of solubilized muscle proteins, muscle fibers, fragmented myofibrils, fat cells and droplets, water, salts, phosphates, and other added ingredients. Typically, a small amount of protein is expected to bind together a large amount of water in these types of products (Smith, 2001). Comminution physically disrupts the muscle tissue by damaging the sarcolema (muscle cell membrane) plus the supporting network of the connective tissue. Salt levels of 1.5 to 2% are used to allow for proper extraction of the soluble myofibrillar proteins, assisting with the water holding and fat stabilization in the system. Once these products are cooked, the extracted and solubilized proteins form a cross-linked gel matrix that binds the water and fat, and provides the final texture of the cooked comminuted poultry product.

INGREDIENTS/CONDITIONS ENHANCING MEAT PROTEIN FUNCTIONALITY

Salt and Phosphates

It is well known that salt and phosphates are used in processed meat and poultry products to assist in extraction of salt soluble proteins, which usually provides sufficient binding of the muscle fibers in the finished product. Salt and phosphates also increase the water holding capacity (WHC) of the meat (Lamkey, 1998). Young *et al.* (1987) reported that both sodium tripolyphosphate (STPP) and sodium chloride (NaCl) tend to increase moisture retention of chicken breast meat patties. Salt and phosphates work synergistically, with lower levels of both needed when used in conjunction with each other (Juttelstad, 1998). They provide binding of both meat particles and water in the finished product. Salt at a concentration of about 6.0% solubilizes the protein myosin (Frank, 2000). Typically, 1.5 to 2.0% salt is added to most finished poultry product formulations, with the bulk of the salt added initially to the meat block to effectively extract the salt soluble proteins and enhance water retention (Smith, 2001). This initial high concentration of salt in the meat block extracts the myosin, providing its function as a natural binder in the final processed meat product. Salt is self-limiting, since too much can be overpowering to the finished flavor profile.

Phosphates increase water-holding capacity, solubilize proteins, retard oxidative rancidity, stabilize flavor and color, and reduce package purge in vacuum-packaged products (Orcutt, 2001). Phosphates assist with two types of binding: 1) increase stickiness of proteins via enhancing solubility, and 2) water binding via increasing the pH of the meat mixture. STPP appears to be most effective in improving WHC in chicken breast meat patties containing less than 3% NaCl (Young *et al.*, 1987). These patties contained 10% added moisture, with 0.0, 1.5, and 3.0% salt and 0.0, 0.3, and 0.5% STPP added. These combinations increased textural attributes (especially springiness and cohesiveness) as the levels of both STPP and salt increased.

Young and Lyon (1997) studied the effects of postchill aging and the addition of STPP on moisture binding and shear values of chicken breast meat. Marinade absorption and cooked yields increased with STPP treatments, while aging of the meat was not significantly different. They found tenderness to improve with aging and the addition of STPP, recommending marination to occur in the plant at least two hours postchill to reduce toughness, rather than at the point-of-sale.

According to 9CFR 424.21(6)(c) (USDA, 2001), phosphates are allowed in poultry products, "except where otherwise prohibited by the poultry products inspection regulations". Up to 0.5% phosphate can be used in processed poultry products, but typically can induce a "soapy" off-flavor if used near the maximum level allowed (Keeton, 2001). When adding to meat products, formulators must account for 0.1% of naturally occurring phosphate in the muscle tissue, so 0.4% is the additive maximum (Anonymous, 2001a). Phosphates may contribute to a rubbery texture in very lean products, especially if levels are at or near the 0.5% cut-off (Sams, 2001). By reducing the level of STPP, the rubbery texture is reduced (Pearson and Gillett, 1996). Health concerns regarding the ingestion of excess salt and phosphates may provide another opportunity for these ingredients to be reduced, and replaced by other non-meat ingredients to help bind water (Jimenez-Colmenero *et al.*, 2001).

Effect of pH

The effect of pH on water binding ability of poultry meat is directly related to the isoelectric point (pH ~5.4) of the proteins. At this point, the positive and negative charges are balanced and the proteins are highly attracted to each other, forming aggregates. Protein solubility and hydration state are often minimal at the isoelectric point. Alkaline phosphates (i.e. STPP) increase the pH of the meat, encouraging the proteins to unfold and bind moisture (Lamkey, 1998). As the pH is increased, the proteins become more negatively charged, thus repelling each other and allowing for the myofibrillar proteins to swell and retain water, resulting in increased water-holding capacity (Osburn, 1998).

Young *et al.* (1992) confirmed that the ability of polyphosphates to improve moisture-binding characteristics of meats is largely due to the effect of the phosphate on ionic strength, not pH. However, they also determined the pH and ionic strength are not necessarily independent. The effectiveness of the phosphate to bind moisture can be reduced when the pH is low and ionic strength is high.

TEXTURE ENHANCEMENT IN MEAT AND POULTRY PRODUCTS

QUALITY OF RAW MEAT INGREDIENTS

Preslaughter

To manufacture wholesome, high quality, value-added chicken products, it is critical to start with high quality raw ingredients. The finished product characteristics desired dictate the type of raw materials used (Friesen, 2001). Several preslaughter factors can affect the final meat quality, including genetics, physiology, nutrition, management, and disease (Northcutt, 2001). Proper nutrition, including high quality feed, is important for growing healthy meat broilers. Living conditions also dictate the health of a bird, increasing the potential for disease if unsafe. Feed withdrawal before harvesting is utilized to reduce contamination from waste during evisceration. However, if feed is taken away from the chicken for too long before harvesting, glycogen levels can reduce significantly in the muscle, as typically occurs during stress or activity. Muscle tissue normally contains 1% glycogen, which converts to lactic acid when muscle goes into rigor mortis. The amount of glycogen in the muscle affects the pH of the meat tissue, which can affect WHC, color, tenderness, and shelf life (Anonymous, 2001b). Today, poultry processors are required to follow several strict guidelines during live production, to satisfy USDA's "farm-to-table" food safety and meat quality initiatives (Sams, 2001).

Slaughter through Chilling

Once the chickens have been collected for harvesting, several slaughter steps are followed, which can also affect the overall quality of the poultry meat. These include unloading, stunning, killing, feathering, evisceration, and chilling. During unloading, birds are typically "dumped" onto a conveyor belt, becoming a source for bruising and broken bones, which can lead to blood spots in the meat. Minimizing the distance the birds have to fall when unloaded can significantly reduce damages. Manual unloading can also cause carcass damage if handled too rough, but educating workers on proper handling procedures helps minimize injuries (Sams, 2001).

Stunning is part of the "humane" slaughter procedure, causing the bird to fall unconscious before the actual kill is accomplished. Electrical and gas stunning are used in the meat industry, with electrical being the most common (Barbut, 2002). Damage of the carcass is greatly reduced by the stunning process, eliminating struggling during the automated neck cutting and involuntary convulsions during the bleeding. Low electrical currents are recommended, to reduce hemorrhaging in the muscle tissue, which can cause undesirable dark red spots.

Scalding and feathering are the next steps of the primary processing of poultry. Feathering is greatly affected by the scalding technique used, because the hot water bath denatures the protein structures holding the feathers in place

(Sams, 2002). Scalding water temperatures between 50-53°C (122 to 128°F) for 120 seconds are optimal conditions for efficient feather removal when skin is retained for a "fresh poultry look" after processing (Barbut, 2002), better known as "soft scalding". Higher scalding temperatures such as 62-64°C (145-148°F) for 45 seconds are considered "hard scalding". This process removes the outer waxy cuticle on the skin surface, providing a better surface for adhesion of batter and breading on down the processing line. If the water is too hot, cooking of the outer layer can occur, resulting in decreased adhesion of coatings (Friesen, 2001). Minimal time to de-feather is desired to reduce the amount of damage subjected to the carcass as the rubber fingers massage the bird.

Evisceration is the removal of both edible and inedible internal organs from the carcass. Several automated methods are utilized, with a common goal of eliminating the inside contents from the bird. This includes: 1) cutting the body cavity open, 2) scooping out the viscera (gastrointestinal tract, reproductive tract, heart, and lungs), and 3) removing the edible giblets (heart, liver, and gizzard) from the inedible viscera and washing them for downstream use (Sams, 2002). Whether this process is automated or done manually, care must be taken to not puncture the viscera or the contents may spill onto the carcass and contaminate the meat (Barbut, 2001).

Chilling is done after the bird has been washed inside and out, and must be done quickly to minimize microbial growth (Barbut, 2002). Days from kill and temperature abuse, especially in the summer, are also critical to maintain microbial quality. Muscle has limited ability to hold water, and if it is soaked in chilled (33°F) water for a long time, the amount of marinade it can absorb may be limited, resulting in a less tender product (Friesen, 2001). Salt is allowed to aid in the chilling of raw poultry, with a ratio of ~318 kg (700lb) of salt to 37,879 liters (10,000 gallons) of water as the chilling media, facilitating the absorption of the water into the poultry (9CFR 424.21, USDA, 2001).

Aging and Deboning

Based on the high demand for poultry, particularly boneless, skinless breast meat, it is difficult for processors to allow for the minimum amount of time (4hr under refrigeration) to properly "age" the meat before cutting up the bird. Aging, or the development of rigor mortis, is important to obtain a tender product. This is mainly a concern for whole muscle, premium products such as chicken fillets. Deboning adds physical disruption to the muscle fibers, increasing the potential for additional loss of juices, which greatly reduces its ability to remain tender upon cooking (Froning and McKee, 2001). In addition, removing the skin can reveal blemishes, which can deter discriminating consumers. Fortunately, this does not affect restructured products as much, since they undergo further mechanical stresses that increase the chances of moisture and texture changes (Sams, 2001).

Composition

The composition of poultry meat can vary from species to species, and from bird to bird. Genetics, nutrition and environment play a big role in determining these factors. Moisture, fat, protein, pigmentation, and the ability to bind water and fat all depend on the make-up of the muscle tissue (Osburn, 2001). The concentration of fatty triglycerides and degree of saturation, the type of protein, and whether the moisture is bound or free are all factors affecting the quality of raw meat ingredients. When fat content goes up, typically the moisture content goes down. Protein content is not affected by this inverse relationship between fat and moisture. Table 2 provides the composition and nutritional value of white and dark chicken, with and without skin (Barbut, 2002).

TABLE 2: Composition and Nutritional Value of Chicken (white and dark meat), with and without skin (Barbut, 2002)

Species	***Meat***	***Skin***	***Water %***	***Protein %***	***Fat %***	***Ash %***	***Iron %***	***Calories (kcal)***
Chicken	White	+	68.6	20.3	11.1	0.86	0.8	186
		-	74.9	23.2	1.6	0.98	0.7	114
	Dark	+	65.4	16.7	18.3	0.76	1.0	237
		-	75.9	20.1	4.3	0.94	1.0	125

Poultry fat is less saturated than that of beef and pork and thus is considered somewhat healthier from a nutritional perspective. However, a higher degree of unsaturation makes the fat less stable, increasing the potential for lipid oxidation and development of off flavors (Potter and Hotchkiss, 1995).

The moisture content of boneless, raw chicken can range from 65 to 75% and lean poultry muscle tissue contains ~19 to 23% protein, depending upon the part of the carcass and the method of preparation (Barbut, 2002; Keeton, 2001). The fat content is very low in the muscle portion of the bird (typically 1.3% fat in cooked chicken breast). Most fat in poultry is contained in the skin and the layer just below the skin, rather than intramuscular fat or marbling which is common in beef and pork (Mountney, G. J., 1983). White meat includes chicken breasts, accounting for approximately 40% of the bird, and wings at 12%. Dark meat, primarily thighs, accounts for 34% of the carcass, and legs at 14%. The dark meat category has been the least utilized portion of the bird, mostly due to consumer perception. Dark poultry meat is more flavorful, tends to absorb more moisture than white meat, and is still perceived as a fatter piece of meat, compared to the breast (Rice, 1999).

Ground poultry is defined as "fresh, boneless, skinless comminuted poultry meat that has a fat content identified by one of the following: 1) regular, 30% fat; 2) medium, 23% fat, 3) lean, 17% fat, and 4) extra lean, 10% fat" (Barbut, 2002). Processed poultry products require "natural proportions" of skin when combining white (breast) meat, dark (thigh and leg) meat in formulations (USDA, 2001). Natural proportions for chicken equal 50-65% for breast (white) meat and 35-50% for thigh (dark) meat (Friesen, 2001). Table 3 lists the proper labeling terminology for certain poultry products, per 9CFR381.156 (USDA, 2001).

TABLE 3: Poultry meat content standards for certain poultry products (USDA, 2001)

Label terminology	Percent light meat	Percent dark meat
Natural proportions	50-65	50-35
Light or white meat	100	0
Dark meat	0	100
Light and dark meat	51-65	49-35
Dark and light meat	35-49	65-51
Mostly white meat	66 or more	34 or more
Mostly dark meat	34 or less	66 or more

9CFR381.160 (USDA, 2001) cites chicken burgers or patties to consist of 100 percent poultry of the kind indicated, with skin and fat "not in excess of natural proportions". Products containing fillers or binders will be called "chicken patties."

PROCESSING CONDITIONS

Processing (chopping, grinding, mixing, or tumbling) can greatly influence the final texture of a value-added, reformed meat or poultry product. The physical manipulation improves the pliability of the meat, allowing for easier shape formation. This mechanical action also frees some of the proteins in the muscle, allowing for natural bonding between adjacent pieces or chunks of meat, which affects the overall texture of the finished cooked product (Pearson and Gillett, 1996).

Grinding, chopping or flaking are used to reduce the size of larger pieces of meat. Ensuring that the grinder plates and knives are sharp reduces the possibility of rising product temperature, which can cause "fat smearing" (Osburn, 1998). Flaking involves shaving off pieces of meat from frozen meat blocks, which provide a muscle-like texture in restructured products. Chopping relies on blades, and the number and speed can determine the final consistency of the mixture. More blades and faster speeds result in a very homogenous emulsion, which can produce a softer bite in the end product, compared to a coarser grind or whole muscle, which is much firmer (Frank, 2000). Removing the air from the product is important to reduce the incidence of lipid oxidation and air pockets in the final cooked product (Barbut, 2002).

Mixing is another common step in meat and poultry processing, providing uniformity if different meats are used, adding non-meat ingredients to the meat batter, and assisting in salt extraction of the muscle proteins (Barbut, 2002). However, overmixing can also result in fat smearing and toughening due to excessive extraction of salt soluble proteins (Osburn, 1998) and too much muscle fiber separation (Barbut, 2002). Mixing also assists in softening the meat, making it easier to shape into the desired products (Pearson and Gillett, 1996).

Tumblers were the first types of equipment specifically designed for producing sectioned and formed meat and poultry products (Pearson and Gillett, 1996). Tumbling involves a rotating drum with different baffles, ribbons, or paddles along the interior wall, which assist in mixing. This agitation can involve "lifting and dropping" which can be abusive in some cases (Barbut, 2002). Maximum absorption of marinades is actually achieved by following a "mix and rest" treatment, where uptake occurs typically during the "rest" period (Osburn, 1998). Processing factors may also affect the retention of water, which will affect the final texture of the formed product. Increased water retention may soften the product while decreased water retention can toughen the product.

COOKING CONDITIONS

Murphy and Marks (2000) found that increasing the meat temperature from 23°C to 80°C reduced soluble proteins, dissociated myofibrillar proteins, increased collagen solubility, increased cook loss and affected the texture of ground chicken breast patties. A strong linear correlation ($R^2 > 0.85$) was cited for heating temperatures in relation to soluble proteins, collagen, toughness, and cook loss. These results suggest that both muscle and connective tissue changes during heating may influence the final texture and cooked yields in processed poultry products. Pearson and Gillett (1996) reported that shaped and formed meat and poultry products need to be cooked to a high enough temperature to denature the myofibrillar proteins; otherwise, they will not bind properly. Also, if the product is not cooled properly, the proteins do not coagulate, resulting in a less effective bind.

Cooking methods affect the chemical composition of poultry meat in different ways (Barbut, 2002). The types of cooking methods include 1) roasting, 2) stewing, 3) steam/convection and 4) frying. Roasting results in the highest protein content (29.02g per 100g sample compared to 20.27g of raw poultry), because of the dry heat cooking conditions. Unfortunately, this also leads to poor juiciness. Stewing and frying elevate protein levels as well, compared to the raw meat, due to the moisture and fat loss (or protein concentration). Increased protein content can improve firmness of the product texture. Of these four cooking methods, further discussion will follow regarding the use of steam/convection and pan-frying, since these cooking methods were used during this research.

Steam/convection

Air-steam impingement (or superheated steam/convection) ovens are widely used for commercial thermal processing of poultry products, with ~2 billion pounds cooked with this method annually (Murphy, 2001). Heat transfer is highly efficient, which increases cook times, resulting in higher productivity. Steam-injected oven cooking may actually improve cooked yields compared to clamshell cookers, griddles or pan-frying. The high moisture environment in a steam-injected oven introduces additional moisture to the cooked product during the heat treatment, which may cause an increase in juiciness in the finished product. Searing of the product is eliminated, reducing the possibility of a drier, leather-like finished texture. Compression of the patties, typically seen with a clamshell cooker used in retail stores, is eliminated, greatly reducing the possibility of juice loss from excess squeezing during cooking. Murphy *et al.* (2001) found, during cooking, that product yield was affected by product temperature and cooking conditions. Process lethality (microbes) increased rapidly as the product temperature neared 67°C (~153°F), while cooked yield decreased slightly, depending on air velocity. Methods of cooking, including times and temperatures are critical to obtain desired end products. STEIN and Allen Systems manufacture steam-injected impingement ovens, conveyors, and other cooking equipment which enhance the value of poultry products (FMC Technologies, Inc., 2001).

Convection cooking is well known as the "old fashioned" production method and the typical consumer method. This type of cooking involves transferring heat mainly by convection, from a fan blowing hot air onto the product surface. Conduction continues carrying the heat from the surface to the center of the product, completing the cook. In the meantime, moisture moves from the center of the product to the surface and evaporates (Chen *et al.*, 1999). As fully-cooked poultry products become increasingly popular, determining proper thermal processes to maintain safety and quality of retail and foodservice products is critical. In a study to determine a model for convection cooking of chicken patties, Chen *et al.* (1999) found that an increase in air temperature (or heating rate) yielded a less uniform temperature distribution within the patties. This could result in improper cooking of a product, which can lead to safety and quality issues.

Pan- frying

Pan-frying is commonly used in retail or by consumers in the home. This method involves cooking small, thin cuts of meat, such as patties, by applying direct heat of conduction to the substrate. Preheated frying pans or electric griddles are used, cooking the patties with no added water or fat. This cooking method is recommended when determining cooked yields and texture properties in ground cooked beef patties (AMSA, 1995). Patties are frequently flipped during the cooking process to prevent sticking and excess surface crust formation, which could also increase loss of juices and increase toughness due to the frequent handling. This particular cooking method is probably not the most effective at maintaining moisture within the product, due to the frequent handling during the cooking process. Establishing proper cooking methods, whether steam-injected, convection, or pan-frying, is essential to obtain consistent and dependable results for cooked yields, bacterial lethality, and desirable texture.

STORAGE CONDITIONS

According to Friesen (2001), whether the raw meat ingredients are stored fresh or frozen before processing will affect the final qualities of the processed poultry product. Using fresh meat offers more handling options, including grinding, bowl chopping, slicing, and dicing immediately upon acquiring the raw ingredients. Fresh raw meat ingredients typically produce products with firmer textures. Use of fresh product limits the storage time in which to use the materials, generally about 5-12 days (Barbut, 2002). Freezing allows extension of that timeframe, providing more flexibility in processing. As frozen meat is tempered or thawed before processing, purge of water in the muscle occurs. As storage time increases, so does purge loss, for either fresh and/or frozen/tempered raw meat ingredients. Careful planning is required to optimize the qualities of all ingredients.

Adequate chilling and freezing of raw materials is critical to control contamination and growth, and minimize textural changes from protein denaturation. Optimum fresh storage temperature for poultry is 1.7°C (35°F), and maximum storage temperature for frozen poultry is –17.8°C (0°F). Recommended "quick freeze" for poultry is –29° to –40°C (-20° to –40°F) (Barbut, 2002). Poultry should not be held at –11.1° to –10°C (12° to 14°F) for extended periods or quality will suffer. A critical phase transition can occur between intercellular crystalline ice and a combination of ice and water, causing severe ice crystal formation, which can act like glass, cutting and shredding the meat fibers (Keeton, 2001).

Freezing rate has a strong effect on the texture (Pearson and Gillett, 1996). Slow freezing results in large ice crystal formation, and water is slowly squeezed out of the meat, causing dehydration, and resulting in ice crystals on the surface. This can cause increased purge and a softer texture, due to the damaged muscle fibers (Osburn, 1998). Fast freezing results in small crystals, reducing the protein damage so it can reabsorb moisture and reduce drip loss.

NON-MEAT INGREDIENTS FOR MOISTURE MANAGEMENT AND TEXTURE ENHANCEMENT

Non-meat ingredients have been evaluated over the years to determine their effects on moisture management and textural attributes in meat and poultry products (Shand *et al.*, 1993). They are typically categorized as protein-based and carbohydrate-based. Protein-based moisture and texture enhancers include soy proteins, milk proteins, hydrolyzed proteins, and gelatin. Carbohydrate-based moisture and texture enhancers include starches and hydrocolloids (gums). These non-meat binders and extenders are used to reduce formulation cost, improve cooked yields (via improved WHC), enhance slicing characteristics, and bind fat (Lamkey, 1998). They also reduce product costs by replacing more expensive cuts of meat, may increase protein content, improve emulsion stability, and can lighten the color of the end product (Orcutt, 2001).

Basic formulations for processed meat and poultry products have evolved to address a variety of needs including food safety concerns, raw material availability, consumer trends, or changing economic conditions. While U.S.

manufacturers formulate lowfat and fat-free products for health-conscious consumers, some manufacturers in Europe may highly extend a product, while others restrict the use of additional ingredients, to maintain a "standard of identity". Nevertheless, non-meat ingredients are needed to assist in all of these opportunities, to either enhance or supplement the desired characteristics (Lamkey, 1998). Reducing fat in processed meat and poultry products can be accomplished by two basic approaches: 1) use leaner meats or 2) dilute the ingredients by adding and managing water and other low or non-caloric ingredients (Claus *et al.*, 1989). Increasing the amount of leaner meats in a processed product also improves the nutritional quality of the product by increasing protein and essential vitamins and mineral content, while reducing the total fat content. However, formulation costs also increase; in addition, textural attributes may suffer, especially in the case of all-breast meat in a processed poultry product, which can lead to dry, rubbery finished products. Diluting the overall formulation with water and other non-meat ingredients can be beneficial, as long as the added water is not lost during storage, cooking, or holding before consumption. In addition, when the protein content is reduced, the texture of the product may become softer, which may or may not be detrimental to consumer preference and overall sales of the product (Claus *et al.,* 1990). It is very rare for one non-meat ingredient to provide all the functional characteristics desired in a meat or poultry product. Combinations of both protein-based and carbohydrate-based ingredients are often used to achieve meat-like textures in poultry products (Sams, 2001). However, achieving full functionality from any ingredient requires an understanding of its chemistry and how conditions affect its performance.

According to 9CFR 424.21, "no meat or poultry product shall bear or contain any food ingredient that would render it adulterated or misbranded, or which is not approved in this part, part 318 or part 319 of this chapter, or by the Administrator in specific cases" (USDA, 2001). Furthermore, no food ingredient is allowed in a meat or poultry product, unless it is listed under 21CFR chapters 172 thru 184. Ingredients specified in part 319 of 9CFR 424.21 are approved for use in the preparation of meat and poultry products, provided they are used for the purposes indicated and within the limits specified. Individual criteria as binders and extenders in poultry products will be explained for each of the following non-meat ingredients.

PROTEIN-BASED MOISTURE AND TEXTURE ENHANCERS

Protein-based ingredients are typically lower in cost compared to meat and poultry, and are commonly added to formulations to increase the protein content. These additives appear to apply their binding functionality through gel formation instead of direct interaction with the muscle proteins of the meat pieces, as is seen with salt, phosphates, and pH (Pearson and Gillett, 1996). Adding proteins to processed meat and poultry products can deliver a compound benefit. Whey and soy proteins provide several essential amino acids, plus additional nutrients such as iron, calcium, sodium, and zinc to improve the nutritional balance of the finished product. Whey proteins aid emulsification and provide adhesion of the meat after chopping and blending. Soy proteins contribute to the adhesion of the mixture (Juttelstad, 1998).

Soy proteins

Soy proteins are the most widely used non-meat protein in meat and poultry formulations around the world, with soy concentrates specifically formulated with higher soluble protein content, thus improving the functionality of the proteins in the meat and/or poultry product. Soy concentrates have been formulated to provide functionality to meat/poultry products, while also providing added health benefits. Soy-extended products (i.e. breaded chicken patties, meat patties, etc.) have historically been less palatable, when compared to all-meat or chicken patties until recently. Now, with the introduction of functional soya concentrates (FSPC) combined with textured soy protein (TSP), nutrition, flavor, texture and consumer acceptance has improved considerably, thus reducing the negative impact from the past (Central Soya Company, Inc., 2001).

Soy proteins assist with water binding, gelation, fat absorption, and emulsification (Frank, 2000). The use of textured soy protein concentrates (TSPC) are also considered due to their moisture and fat binding characteristics, along with the unique textural properties in the finished food. TSPC are commonly used in meat patties, meatloaves, and pizza toppings, enhancing both juiciness and texture. (Anonymous, 2001a).

Soy Protein Concentrates

Soy protein concentrates (SPC) contain 60-70% protein, come either as flour or in granular form, and are typically used in emulsion-type sausages. SPC can actually dry out a formula because of a high surface area to volume ratio, so it acts as a sponge, absorbing excess water (3 parts water to 1 part SPC) in a formula. Functional soy protein concentrates (FSPC) are used in conjunction with textured soya concentrates in ground meat and poultry products, dramatically increasing cooked yields. They are also incorporated in ground and formed poultry products (replacing as much as 20-25% of the meat per Frank, 2000) to control moisture and improve the utilization of economical raw materials, thus allowing for reduction of poultry meat.

FSPC are also used in skin emulsions to assist in reducing the amount of fat present in the product, plus stabilizing the combination of skin and water. When precooked ground products are reheated, the FSPC maintains its functionality, retaining moisture and enhancing the texture of the reconstituted products. Concentrates also absorb fat easily and hold it through multiple cooks, and this functionality is not affected by the presence of salt (Central Soya Company, Inc., 2001).

Concentrates are very flexible in terms of hydration and are used in a wide range of applications. They can hold between three and seven times their own weight in water, depending on the application. In ground meats, TSPC provide a firm, fibrous texture compatible with meat and are easily controlled by simply adjusting hydration levels.

<u>Isolated Soy Proteins</u>

Isolated soy proteins (ISP) contain 90% protein and are used to bind and extend various poultry products, such as poultry rolls, "sufficient for purpose" in accordance with 21CFR 172.5 (USDA, 2001). A 2% usage level is typical, with higher levels requiring it mentioned in the product name or label it as "imitation" (Barbut, 2002). Due to more extensive processing and lower production yields, ISP are somewhat more expensive than other soy protein ingredients (Central Soya, 1993). Isolates are very hydrophilic and perform well in systems where higher levels of moisture must be retained, but tend to dry out products upon re-thermalization, particularly in soy-based vegetarian patties (Conklin, J. R., The Dow Chemical Company, personal communication, 2001). Lin and Mei (2000) reported ISP had the greatest percent moisture loss from raw to any cooking temperature (65.6° to 82.2°C), resulting in lower final yield. However, based on "bound water" analysis, they found the control to have the lowest value at any heating temperature compared to the other systems containing hydrocolloids and isolated soy proteins. This indicates that incorporation of gums and ISP can improve WHC during cooking processes.

ISP's are excellent fat absorbers but can also fail to retain fat through a second cook, which is an important feature in precooked products (Central Soya Company, Inc., 2001). Isolates provide meat products with excellent texture but tend to turn rubbery during repeated cooking or a freeze/thaw cycle. Typically, ISP's are rehydrated at a moisture:protein ingredient ratio of 4:1 to allow hydration and provide proper functionality (Keeton, 1996).

Milk Proteins

Dairy proteins are not to exceed 3.5% in products labeled as meat, by weight of finished product (Frank, 2000). Whey protein concentrates and sodium caseinates are nutritious milk proteins, which are used as emulsifiers and water binders. Milk proteins provide smooth textures and bland flavors, plus water and fat binding (Keeton, 2001).

Whey protein concentrates

USDA allows the use of whey (dry or dried) in various poultry products, to bind or thicken, at levels sufficient for purpose (typically 0.5% to 2.0%) in accordance with 21CFR 184.1322 (FDA and USDA, 2001). Whey protein concentrates form gels upon heating and cooling in the meat's protein matrix, adding to structural stability, and they also provide emulsion stability (Frank, 2000). Whey protein concentrates, typically 12% protein (Osburn, 1998), are used to replace meat in sausages in some parts of the world, while still maintaining firmness (Pearson and Gillett, 1996). Using whey as an ingredient provides an environmental benefit since this by-product of the cheese industry is often discarded.

The effect of using preheated or unheated whey protein isolate (WPI) to replace part of the poultry meat proteins in batters formulated with different salt levels was studied by Hongsprabhas and Barbut (1999). WHC significantly increased when preheated WPI was added to salt free and low salt meat batters. They also demonstrated reduced cook loss and increased gel strength of the raw and cooked products, especially at 0% and 1.0% salt levels.

Sodium Caseinates

Caseinates are allowed in various poultry products to bind and extend the products; 3% in cooked products and 2% in raw, in accordance with 21 CFR 172.5 and 182.1748 (FDA and USDA, 2001). Sodium caseinates contain 90% protein, are completely soluble in water, absorb at the fat/water interface in meat emulsions, contribute significantly to binding and firmness, but have no gelation capabilities (Anonymous, 2001a). Therefore, they do not bind meat pieces well, but still provide firmness in meat products, such as hams in Mexico to retain moisture (van den Hoven, 1987). Su *et al.*, (2000) reported the use of sodium caseinate as a stabilizer for pre-emulsified fat in a reduced-fat frankfurter which may assist in maintaining the desired texture that can be lost when salt is reduced and water is added.

Hydrolyzed Proteins

Hydrolyzed plant and animal proteins enhance flavors, bind water, and include hydrolyzed soy proteins, gelatin, vegetable protein, and milk protein (Keeton, 2001). Hydrolysis shortens the protein chain and frees up acids that act as flavor potentiators. Since they are proteins, they do have some moisture and fat binding capabilities, with typical usage levels of 1-2%. When used as a natural flavoring, the specific source of the hydrolyzed protein must be specified, such as "hydrolyzed soy protein" or hydrolyzed whey protein" (FSIS, 2001b).

Transglutaminase

Transglutaminase (TG), a genetically modified enzyme system that covalently crosslinks proteins (opposed to ionic crosslinks like Ca^{+2}), is new to the meat and poultry industry, and provides enhanced textural properties to formed meat and poultry products. (Orcutt, 2001). Enzymes enhance meat *protein* functionality by binding small chunks together to form uniform shapes. Transglutaminase binding is accomplished by various techniques including 1) application as a powder directly on the surface of the muscle piece, 2) incorporation into a marinade or brine at 0.65 to 1.5%, or 3) addition directly to emulsified sausage at a level of 0.1 to 0.3% (Keeton, 2001).

AJINOMOTO USA markets Transglutaminase as Activa® TG. (Ajinomoto U.S.A., Inc., 2001). Activa® TG-RM is specifically designed to restructure muscle foods such as red meat, poultry and seafood, with the main components of this system including sodium caseinate, maltodextrin, and transglutaminase. Activa® TG-RM is approved for use in all non-standardized meat and poultry products at 65ppm, and must be declared on the product label as "enzyme", "TG enzyme", or "TGP enzyme" when used.

On October 31, 2001, the Food Safety and Inspection Service (FSIS, 2001a) announced the amendment of the meat and poultry inspection regulations to allow transglutaminase enzyme (TG enzyme), in limited amounts, as a binder in certain standardized meat and poultry products. This regulations includes the request to label products, indicating that it has either been formed from pieces of whole muscle meat or has been reformed from a single cut. This rule will be effective December 31, 2001, unless FSIS receives adverse comments. This exemplifies the course of action taken to approve the use of non-meat ingredients in meat and poultry products (FSIS, 2001a).

Gelatin

Gelatin is derived from animal hides, is a soluble protein derived from insoluble collagen, and is water dispersible, dissolving in hot water and swelling in cold water (Juttelstad, 1998). It forms gels that set at 20°C (68°F) and melt at 30°C (86°F), thus providing little to firmness when consumed. Gelatin is approved to bind and extend various poultry products, only at concentrations sufficient for purpose in accordance with 21 CFR 172.5 (FDA and USDA, 2001). Usage levels are from 0.5% to 15%, depending on the application, but usually range between 0.5 and 3% (Keeton, 2001). However, only limited amounts are incorporated into low-fat meats since gelatin has poor particle binding ability (Keeton, 1996).

Canned chicken and turkey are typically canned with broth for flavoring, using gelatin or other water binders to assist with tying up the excess water. Sometimes, gelatin displays a rubbery texture in meat products, which can be a negative attribute. However, like other hydrocolloids, gelatin can bind a large amount of water and reduces the firmness of the product texture (Pearson and Gillett, 1996).

CARBOHYDRATE-BASED MOISTURE AND TEXTURE ENHANCERS

Starches

The most commonly used starches in meat and poultry products are potato, corn, wheat, oats, tapioca, waxy maize, and rice (Keeton, 1996). They are widely used due to costs and availability (Keeton, 2001). The type of starch used depends on the economics and availability in a particular region.

Starches bind water (up to 2-4 times their weight), provide a firm texture, and supply various levels of freeze/thaw stability. Waxy maize is particularly well suited for applications where processors desire increased cooked yields and reduced package purge (Juttelstad, 1998). Corn and potato starches are well known for their binding and firmer texture attributes, especially in low-fat and fat-free products. Native starches require high temperatures to gel and obtain smooth textures and water binding abilities. This fact requires starches to be modified, thus lowering their "gelling" temperatures to a range of 60 to 75°C (140-167°F), which is more user-friendly for meat systems (Keeton, 2001). Modified starches distribute more readily throughout the meat block, compared to native starches, reducing the possibility of starchy pockets throughout the finished product. Hachmeister and Herald (1997) studied a number of corn starches in reduced-fat turkey batters, and found they significantly influenced most textural attributes. This included increased hardness, chewiness, and gumminess.

Functionality of a starch is obtained upon gelatinization (Pearson and Gillett, 1996). The amount of amylose and amylopectin in the starch will determine its gelling and water binding characteristics. Starches high in amylose will set to a very firm gel, allowing for slicing. Starches are sometimes used for texture control, although they may produce a soft texture to the meat systems. Optimum texture and water binding functions are not achieved unless the gelation temperature of the starch being used is attained during processing. While protein denatures as it is cooked, starches will still hold onto the water (Frank, 2000).

Whether or not the starch needs to function in raw or cooked meat also dictates the type of starch used. Instant starches with a slow hydration rate are used in brines (either injected or tumbled), binding excess water as it slowly hydrates. Pregelatinized starches are typically used in meat systems (such as coarse and emulsified sausages) to build up viscosity. Use levels range from 1% to 3.5% (and sometimes up to 18%), depending on the application, desired functionality, and regulatory restrictions in products with standards of identity (Sams, 2001).

Hydrocolloids/Gums

Hydrocolloids (gums) are long chain, typically high molecular weight polymers that disperse in water to thicken or gel and function as emulsifiers, binders, or other rheological modifying agents in food systems including meat and poultry products (Glicksman, 1979). They are predominantly carbohydrates in structure, and provide creamy slippery properties that are useful in mimicking fat (Pearson and Gillett, 1996).

The terms "water holding capacity" (WHC) and "water binding capacity" (WBC) are used interchangeably in the literature, and refer to how a hydrocolloid holds on to water under certain circumstances. Typically, WHC quantifies a gum's ability to pick up water and hold on to it, while WBC usually refers to a gum's ability to retain added water when subjected to physical stresses (Labuza and Busk, 1979; Rey and Labuza, 1981). Enhanced poultry products, where additional water is added to the product along with various flavors, may require additional non-meat ingredients, like hydrocolloids, that can help bind the extra water during the processing, cooking, storage, and re-thermalization stages.

What is not well understood is the compatibility of meat protein-polysaccharide gum gelling systems, and whether there are any synergies or antagonistic interactions between meat proteins and hydrocolloids, thus limiting the use of gums in specific meat product applications (Shand et al, 1993). Non-protein products, such as starches and gums, are sometimes used for texture control, although both sometimes produce a somewhat unnatural mouthfeel. Gums may impart an undesirable slippery texture and starches a soft texture to meat systems.

When hydrocolloids are used in brines, the alkaline phosphate should be dissolved first, followed by salt and other dry ingredients blended with the gums. This aids in proper dispersion and dissolution of all the ingredients. However, this high concentration of salt and phosphate in the brine can be a harsh environment for hydrocolloids to hydrate, resulting in partial hydration. This can be a positive attribute, reducing the potential viscosity of the brine to facilitate transfer of the marinade, especially if it is destined for injection into muscle. Once the marinade is distributed evenly throughout the meat, the concentration of salt and phosphate reduces, thus allowing the hydrocolloids to fully hydrate and function more readily (Bellekom, 2001).

For many gums, any advantage of inclusion based on cooked yield can generally be offset by significant reductions in bind and textural properties of both raw and cooked state. However, they all have individual contributions and should be considered part of a system to best obtain desired results in a processed meat or poultry product (Shand *et al.*, 1993).

Alginates

Alginates are extracted from brown seaweed, and are used as gelling agents, purge controllers, and texture modifiers (Keeton, 2001). They, along with salt, phosphates, and enzymes, enhance the protein functionality of a processed poultry product, assisting with the binding of the muscle pieces to form shaped products. Alginates can form gels with addition of calcium ions to form ionic crosslinks and therefore inhibit syneresis (Pearson and Gillett, 1996). When used as a binder, 0.4% sodium alginate is combined with poultry pieces and 0.4% calcium lactate and slowly mixed. The mixture is then stuffed into a casing or mold, and allowed to cold-set or gel at refrigerated temperatures for 7 to 10 hours. Sodium alginates are soluble in both hot and cold water, and are minimally affected by pH (Juttelstad, 1998).

Berry (1997) evaluated the effects of sodium alginate and tapioca starch on cooked yields and texture in lowfat beef patties, based on various cooking methods. The study indicated that a combination of the two non-meat ingredients increased tenderness, juiciness, and cooked yields, when compared to beef patties containing 8% and 20% fat.

A mixture of sodium alginate, calcium carbonate, lactic acid, and calcium lactate are allowed to bind poultry pieces in ground and formed raw and cooked poultry products. Maximum usage levels of these ingredients include: 0.8% sodium alginate, 0.15% calcium carbonate, and a combination of lactic acid and calcium lactate at 0.6%, based on the product formulation. This combination of non-meat ingredients can not exceed 1.55% of the total formulation and must be added in dry form (9CFR 424.21(6)(c), USDA, 2001).

<u>Carrageenan</u>

Carrageenan is used to extend and stabilize various poultry products at "levels sufficient for purpose" according to 21CFR 172.5 (FDA and USDA, 2001). The carrageenan family is extracted from red seaweed, with kappa and iota carrageenan typically used in processed meats and poultry products. Kappa forms firm gels, which can result in syneresis, while iota forms weaker elastic gels which do not cause syneresis (Anonymous, 1997). Typically, mixtures of the two are used in processed meats at combined levels of 0.3-0.6%, based on the final product, to provide modifications in texture.

Carrageenan is also used to improve yields, control purge by binding water, improve sliceability of finished products, enhance juiciness, and protect products from freezer burn (Keeton, 2001). First, carrageenan is heated to achieve complete solubility, dissipating throughout the meat matrix during thermal processing (Prabhu and Sebranek, 1997). Gels form during chilling [between 50-60°C (122° and 140°F)] of the processed meat or poultry product (Pearson and Gillett, 1996). Lin and Mei (2000) reported that addition of iota-carrageenan improved WHC of the salt-soluble meat protein gel in a reduced-fat meat model system, which may be the result of physical entrapment of proteins and water by carrageenan. This was also the case for sodium alginate, potentially because of a more heat-stable alginate gel. This study demonstrated a possible protective effect of gums and soy protein on meat proteins.

Carrageenan is also stable in low-pH products (i.e. high acid), but can become mucilaginous in some formulations (Juttelstad, 1998). Addition of iota- or kappa-carrageenan in low-fat meat batters resulted in increased water-holding capacity and firmness (Foegeding and Ramsey, 1986). Prabhu and Sebranek (1997) evaluated for synergies between carrageenan and starch in high-moisture cooked hams. Increasing levels of starch increased the perception of juiciness by taste panelists, but also increased purge. Adding carrageenan increased the cooked yields and decreased purge, but sensory perceptions indicated reduced juiciness. Carrageenan binds water effectively, but may hold on to it so tightly that it is not easily released during chewing.

Xanthan

A fermentation process using carbohydrate medium and Xanthomonas campestris produces xanthan gum. It does not gel, but rather increases viscosity of meat and poultry systems. Xanthan is soluble in either hot or cold water, and makes aqueous solutions viscous. Due to its shear-thinning properties, fluids thickened with xanthan actually thin during shearing (i.e. pumping through injection needles), returning to its thickened state upon standing. Xanthan is patented for brine use to provide tenderness (Miller and Gray, 1988). Xanthan may be used in various poultry products to maintain uniform viscosity, suspension of particulates, emulsion stability, and freeze/thaw stability. Exceptions include uncooked products such as sausages and other products with a moisture limitation established in Subpart P of Part 381 (9CFR 424.21(6)(c)) (USDA, 2001).

Methylcellulose and hydroxypropyl methylcellulose

Methylcellulose (MC) and hydroxypropyl methylcelluloses (HPMC) are water-soluble gums derived from cellulose, a naturally abundant resource. They are used as a binder, emulsifier, stabilizer, suspension agent, protective colloid, and thickener in a variety of food products (Anonymous, 1999c). MC and HPMC also form films, contribute lubricity, are surface active, retain moisture, and provide freeze/thaw stability. In addition, MC and HPMC are among the only hydrocolloids that thermally gel and reverse with cooling. This unique feature provides a network during the cooking process where moisture is locked into the food product, thus providing a means to reduce cooking losses and improve eating texture.

Poultry does not necessarily require assistance with binding the muscle fibers together, due to the extraction of soluble proteins with the use of salt. However, the binding or management of *added water* in a poultry product is more challenging, thus the need to investigate the functionality of water-managing ingredients, such as METHOCEL® Food Gums. MC is considered GRAS (generally recognized as safe) by the Food and Drug Administration (FDA) (21CFR 182.1480) and is already allowed in meat and poultry products up to 0.15%, based on the total product, to assist with binding and increasing water holding capacity [9CFR 318.7(c)(4)] (USDA, 2001). HPMC is a food additive (21CFR 172.874), and "may be safely used in food, except standardized foods, as an emulsifier, film former, protective colloid, stabilizer, suspending agent, or thickener, in accordance with good manufacturing practice" (FDA, 2001). Use of HPMC in poultry products is very limited, and must be approved on an individual basis (USDA, 1998).

MC and HPMC have been studied to some extent in meat and poultry products, particularly in coated and fried poultry products, where a film to block out absorption of frying oils and increase moisture retention in the meat is desired (U.S. Patent 4,900,573). Recent research has shown that MC, when combined with starch, can form a barrier in microwaved foods that reduce moisture migration and increases crispiness (Zhang, 2001).

HPMC has been shown to reduce migration of acetic acid, a pro-oxidant, from a marinated chicken product into frying oil, thus reducing the tocopherol loss in peanut oil (Holownia *et al.*, 2001). This was demonstrated by HPMC's ability to form a film or barrier, thus keeping the marinade with acetic acid inside the product rather than seeping into the frying oil (Anonymous, 1999c). Foegeding and Ramsey (1986) investigated the functionality of 0.2% methylcellulose (METHOCEL® A4M Food Grade) in lowfat meat batters (for lowfat frankfurters).

Early in the study, A4M showed an increase in weight loss between 60° and 70°C, while treatments with other gums (carrageenan, guar, locust bean, and xanthan) remained similar throughout heating. Speculation as to why so much moisture was lost during cooking of the emulsion plug revolves around the fact that MC was the only hydrocolloid that gels when it is heated compared to the other gums in the study. This gelling phenomenon results in a tight network, subsequently squeezing out liquid (syneresis) (Anonymous, 1999c). The researchers reported that the molecular basis for the observed effect of MC was not investigated, which could in fact provide different results. It is the belief of the author of this research that the use of MC and HPMC in processed meat and poultry products has been stagnated due to these negative results, plus lack of understanding of the gum being studied.

Recently, supergelling MC became available (The Dow Chemical Company, Midland, MI). SGMC is improving cooked yields and enhancing textures in processed meats in Latin America, Europe and Asia (U.S. Patents 6,228,416 and 6,235,893). These new supergelling MC's are being used and tested extensively in formed food products, particularly seafood, vegetarian patties and other meat analogs, where binding is critical to retain shape during processing and provide cohesiveness. The supergelling MC's not only provide significant gelling during the cooking process (like conventional MC's), but also maintain a gelled network as the cooked product cools to a tolerable eating temperature; in fact, even down to room temperature. These gums also lock in moisture, but it is released in greater quantities in the mouth during chewing due to reduced and organoleptically optimal binding (Conklin, J. R., The Dow Chemical Company, personal communication, 2001).

Supergelling and conventional MC's are made by different processes, and have different resulting carbohydrate polymer structures. Conventional MC (like METHOCEL A4M Food Grade), when in aqueous solution, is known to thermally gel when heated to 50-55°C, reverting back to the original liquid state upon cooling to room temperature, i.e. forms heat activated reversible gels. As with conventional MC, supergelling MC also exhibits reversible thermal gelation, but exhibit 300-400% more gel strength as measured by the dynamic elastic modulus (G'). The gel temperature is 38-44°C, which enables a more rapid gelling response in the early stages of cooking for many applications. This in turn provides better binding during formed food processing. Importantly, supergelling MC enables reheated formed foods to retain their firm texture and juiciness longer due to slower "melting" of the thermal gel (Conklin, 2000).

Research by Xiong and Blanchard (1993) suggests that although polysaccharides exhibit remarkable water-binding potential themselves, they may tend to diminish the gelling and emulsifying ability of meat proteins. This can cause weakening of the texture of restructured meats by competing for water and disrupting protein-protein and protein-lipid interactions. With the introduction of supergelling methylcellulose, perhaps gelation and water binding of proteins will be enhanced in processed meat and poultry.

VALUE ADDED POULTRY PRODUCTS

Chicken patties are becoming a popular alternative to beef patties in both retail and foodservice industries. Tyson Foods has recently promoted their chicken burgers as "America's favorite protein in America's favorite form" (Anonymous, 1999b). Consumers desire value-added products that reduce preparation time, enhance the flavor of the final product, or provide new shapes and sizes of familiar meat and poultry products. Examples of value-added poultry products include restructured chicken rolls, fully cooked, breaded and formed nuggets, and marinated breast fillets, which come individually frozen (Friesen, 2001). Restructuring of meat and poultry adds value in several ways, including portion control and transforming low-value carcass trimmings into high-value finished products (Frank, 2000). Providing convenience, variety, a desirable dining experience, and less risk (i.e. more safety) bring value to consumers today. Products are processed further to reduce the amount of time needed to prepare the finished product before being served in a restaurant, or consumed at home (Sams, 2001).

In the past, raw poultry products have been marinated, battered and breaded at the point-of-sale. Recently, following the further processed trend and increased desire for convenience, many of these functions are being performed in the food processing plants, rather than at the store, to enhance efficiency and improve process control (Young and Lyon, 1997).

Perdue Farms has developed a turkey burger as an answer to several of these desirable attributes. The turkey burgers are ready to cook from the frozen state, which aids in safe storage and preparation. They also come in uniform “unique natural shapes” for a “hand formed” look, and expand the burger category by providing a healthier, low fat alternative to traditional beef burgers. They come in several gourmet seasoned flavors, including jambalaya, woodfire grille, beef flavor, and Mediterranean Tuscany. The ingredient list includes turkey, salt, dextrose, hamburger-type flavor (contains no beef), and flavorings (Product Showcase, 2001). No binders or extenders are in this particular product, and may not be needed. However, if products such as this require additional shape retention, binding of moisture, enhanced succulence or bite and/or improved texture, perhaps the inclusion of non-meat ingredients is warranted in such value-added products.

SUMMARY

Several conditions, such as processing, cooking, and storage, and ingredients, such as phosphates, soy proteins and hydrocolloids, can affect the moisture management and texture enhancement of meat and poultry products. Binding water during processing and cooking is critical so as to not lose value, but releasing moisture during consumption is also critical to enhance the eating experience. The same holds true for textural qualities. Water-holding capacity of muscle can affect texture and color, while processing conditions can affect the functions of the muscle proteins by disrupting the muscle tissues (Smith, 2001). Non-meat ingredients, other than salt, phosphates, alginates and crosslinking enzymes, bind water rather than proteins, and sometimes actually diminish the binding function of the proteins. Retention of water either by absorption or adsorption phenomena, or reducing protein binding by additional ingredients can also soften a processed meat or poultry product. Researching the effectiveness of supergelling and conventional MC, and their potential for managing water and enhancing texture in poultry products is warranted due to their water binding and thermal gelation properties. With this in mind, the poultry industry must continue to research the use of meat and non-meat ingredients in processed meat and poultry products for the continued and creative output of value-added products.

MATERIALS AND METHODS

EARLIER RELATED RESEARCH

Several preliminary rangefinding studies were conducted at The Dow Chemical Company (Larkin Lab, Midland, MI) over the course of two years on chicken patties with various types of MC and HPMC to determine functionality at the bench top. The intent was to validate protocols and formulations, verify operating parameters, and narrow the scope of gum choices before scaling up to pilot plant runs at the Michigan State University (MSU) Meat Processing Pilot Plant (E. Lansing, MI). The results of the rangefinding study suggested that MC functionality could provide poultry processors with a new functional ingredient for water binding, or more broadly, moisture management. Additionally, texture enhancements in processed poultry products, particularly chicken patties, could perhaps be accomplished in a cost-effective manner.

EXPERIMENTAL DESIGN

Studies were conducted to determine the effects of MC on moisture management issues and textural changes in formed chicken patties. A two by two factorial with augmented control provided five levels for comparison (SAS Institute, Inc., 2001). Two types of MC at two different concentrations (0.25% and 0.5%) were compared to a control without MC. Chicken patties were formulated, molded, and "crust frozen", which means freezing the outer surface of the pattie to avoid deformation during packaging. The patties were vacuum packaged for frozen (-18°C) storage until ready for cooking and analysis. A commercial steam-injected combitherm oven (ALTO-SHAMM, INC., Menomonee Falls, WI) was used for cooking the patties, and various analyses were performed. These included texture (shear force), trained sensory evaluations, cooked yields, color (raw), pH (raw and cooked), TBA (lipid oxidation); and moisture, fat, and protein (MFP) tests, following AOAC (1990) procedures. A consumer sensory panel was also conducted, following AMSA guidelines for sample preparation, cooking (pan fry), and presentation to panelists (AMSA, 1995).

Boneless, skinless ground chicken meat was utilized (rather than larger pieces of poultry) to obtain a uniform system for evaluating the functional ingredients. Friesen commented that larger pieces of meat connected with glue-like interfaces would reduce the homogeneity of the test samples, thus testing the differences between the muscle fibers in the large meat pieces rather than the homogeneous network of ingredients (Friesen, 2001). A ground chicken pattie was chosen as the substrate due to its homogeneity and uniform shape. A typical chicken pattie formulation provided by a large poultry processor was followed, including skin emulsion, to mimic current products. An outer coating of batter/breading was eliminated to simplify the process and subsequent sensory evaluations.

FORMULATION AND PROCESSING

Ingredient Procurement

Boneless, skinless, fresh (never frozen) chicken breast and thigh meat were obtained from Tyson Foods (Springdale, AR), from birds of uniform size that were harvested on the same date. Production of chicken patties occurred within one week at MSU, so approximately 1588kg (720#) of chicken (50:50 breast to thigh) were shipped overnight via Federal Express in insulated coolers with refrigerant packs to the Michigan State University Meat Lab. Fresh chicken skin [176.4kg (80#)] was also shipped for production of a chicken skin emulsion. The insulated containers of chicken meat and skin remained refrigerated (1.1°C; 34°F). The chicken was used within three days of packaging and shipping.

The skin emulsion contained chicken skins, SPC (Promine® HV Functional Concentrate) from Central Soya (Ft. Wayne, IN), and ice water. Salt, onion powder, and cracked black pepper were purchased at Gordon Food Service (GFS). The Dow Chemical Company (Midland, MI) supplied the conventional [a 17,000 centipoise (cps) food grade of conventional methylcellulose] and supergelling (METHOCEL® SG A16M Food Grade) MCs, trademarked as METHOCEL® Food Gums. Both MC products were of similar viscosity, but SG exhibited >300% gel strength when compared to Bohlin Rheometer gel strength readings of 1.5% solutions of conventional MC (Conklin, 2000).

Chicken pattie processing

The chicken patties were processed in the Meat Processing Pilot Plant, at the Department of Food Science and Human Nutrition, Michigan State University. Figure 1 illustrates the chicken pattie production process.

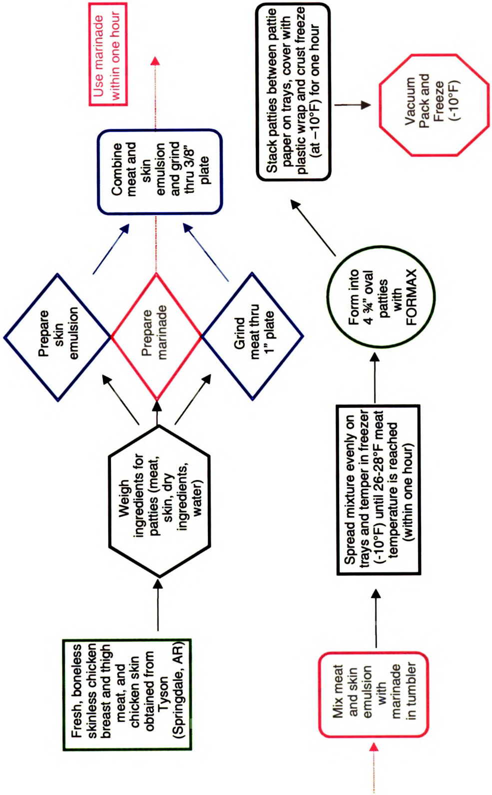

Figure 1: Chicken pattie production process with and without methylcellulose

Five treatments were prepared with three repetitions for each treatment group conducted on separate consecutive days.

Control – contained no methylcellulose

Treatment 1 – 0.25% supergelling methylcellulose (SG at 0.25)

Treatment 2 – 0.50% supergelling methylcellulose (SG at 0.50)

Treatment 3 – 0.25% conventional methylcellulose (CM at 0.25)

Treatment 4 – 0.50% conventional methylcellulose (CM at 0.50)

Ingredients and amounts are listed in Table 4. Water, salt, STPP, skin emulsion and seasonings were constant. A 50:50 ratio of chicken breast to chicken thigh meat made up the meat block.

Skin can be added up to 20% in boneless chicken products, which is considered a natural proportion of chicken skin (USDA, 2001). Pearson and Gillett (1996) state that the use of 0.45% carrageenan and 8.97% water can substitute for skin typically used in poultry patties, especially when fat reduction is desired. The current research focuses on the effects of methylcellulose, rather than skin emulsions, and the inclusion of a skin emulsion containing SPC was included across the board to mimic current poultry pattie formulations. Skin is typically added to shaped poultry products to add flavor and moisture (Friesen, 2001). Future consideration of reducing skin and/or skin emulsions may be warranted when adding methylcellulose, but was not a primary objective of this study.

TABLE 4: Quantification of ingredients (% and Kg) for chicken patties with and without methylcellulose

INGREDIENTS	TREATMENTS CONTROL		0.25% MC		0.5% MC	
Meat Base	%	kg	%	kg	%	kg
Chicken Breast	**38.20**	**8.67**	**38.08**	**8.66**	**37.95**	**8.65**
Chicken Thigh	**38.20**	**8.67**	**38.08**	**8.66**	**37.95**	**8.65**
Skin Emulsion	**10.00**	**2.27**	**10.00**	**2.27**	**10.00**	**2.27**
Skin	*5.70*	*1.29*	*5.70*	*1.29*	*5.70*	*1.29*
Water	*3.80*	*0.85*	*3.80*	*0.85*	*3.80*	*0.85*
SPC	*0.50*	*0.13*	*0.50*	*0.13*	*0.50*	*0.13*
Meat Block Total	*86.40*	*19.61*	*86.15*	*19.59*	*85.90*	*19.57*
Marinade						
Salt	**0.75**	**0.08**	**0.75**	**0.08**	**0.75**	**0.08**
Water	**12.00**	**1.36**	**12.00**	**1.36**	**12.00**	**1.36**
Phosphate (STPP)	**0.35**	**0.04**	**0.35**	**0.04**	**0.35**	**0.04**
Black pepper	**0.25**	**0.03**	**0.25**	**0.03**	**0.25**	**0.03**
Onion powder	**0.25**	**0.03**	**0.25**	**0.03**	**0.25**	**0.03**
Methylcellulose (MC)	**0.00**	**0.00**	**0.25**	**0.03**	**0.50**	**0.06**
Non-meat Ingredients Total	*13.60*	*1.54*	*13.85*	*1.57*	*14.10*	*1.60*
TOTAL	100.00	21.15	100.00	21.16	100.00	21.17

Natural proportions for chicken equal 50-65% for breast (white) meat and 35-50% for thigh (dark) meat (Friesen, 2001). Chicken pattie formulations included 50% breast meat and 50% thigh meat for the study. The 50:50 fixed ratio of white-to-dark meat is within natural proportions for chicken.

Two different MC's were evaluated. They come from the same chemistry family (methylcellulose), but are made by different processes as noted earlier.

These products have similar viscosity and molecular weight profiles, but their "hot gel" (thermal gelation) characteristics are significantly different, with SG providing >300% more gel strength, when compared to the gel strength of CM. The hot gelling characteristics may produce different effects on overall cooked yields and eating qualities, such as succulence and texture, of the chicken products. Gum concentrations of 0.25% and 0.5% for each type of MC were evaluated in the chicken pattie formulation, along with a control without MC, and were produced in triplicate. It is important to note that MC is currently allowed only up to 0.15% (raw, total formulation) as a binder and/or extender in meat and poultry products (USDA, 2001). The higher levels of MC used in this study were for research purposes, and will be used as supporting data for petitioning for extended usage level approval with the USDA.

Equipment

A HOBART 4146 (Troy, OH) meat grinder was used to grind the chicken breast and thigh meat separately through a 25mm (1") plate. The skin emulsion was prepared separately, using a Seydelmann Micro 112 (Germany) bowl chopper with vacuum; see Table 5 for the formulation and procedure. The appropriate quantities of ground chicken breast and thigh meat, along with skin emulsion, were weighed, then mixed by hand to ensure semi-homogeneity. This mixture was re-ground through a 10mm (3/8") plate, then the appropriate amount of marinade was added.

TABLE 5: *Chicken skin emulsion formulation and mixing procedure*

INGREDIENT	% IN FORMULA	% IN EMULSION
Fresh Chicken Skins	5.70	57.0
Water	3.80	38.0
Promine HV	0.50	5.0

Procedure:

1) Combine 60:40 ice: water with SPC (PROMINE HV, Central Soya, Ft. Wayne, IN) in bowl chopper, Speed 2, Vacuum 50, 90s mix. Stop and scrape bowl.
2) Add chicken skins. Mix on Speed 4, Vacuum 50, 300s mix. Temperature 6.0°C +/- 0.5°C.

Marinades were prepared by weighing the appropriate amounts of seasonings and methylcellulose in a gallon plastic bag. The phosphate was weighed in a separate bag. The first bag of ingredients was mixed thoroughly to disperse the methylcellulose powder. A mixture of water and ice [1.7°C (35°F)] was weighed in a plastic bucket, and the phosphate was dissolved in it. The remaining marinade ingredients were poured into the water, with continuous stirring, to ensure the ingredients were properly dispersed, and the methylcellulose was fully hydrated (five minute mix time). Marinades were used within an hour of preparation.

The ground poultry/skin emulsion mixture was combined with the marinade in a Röscherwerke (West Germany) MM-80 tumbler (see Figure 2), which operates at 20 revolutions per minute. The mixture was initially mixed for 30 seconds (10 revolutions), then allowed to rest for one minute, followed by another minute of mixing. This mix/rest sequence was repeated a total of four times, completed with a 30 second mix time, resulting in 5 minutes of mix time (total process time equaled 9 minutes per treatment). According to Pearson and

Gillett (1996), alternating between tumbling and rest periods actually speeds up extraction of the muscle proteins and absorption of the salt and phosphates, due to the relaxation of the muscle structures. Final temperatures of the tumbled ground chicken/marinade combination were -2.2° to -1.1°C (28-30°F).

FIGURE 2: Röscherwerke MM-80 Tumbler

The ground chicken/skin/marinade mixture was spread evenly on two stainless steel trays lined with butcher paper, covered with plastic wrap and placed in a walk-in freezer to temper to -3.3 to -2.2°C (26-28°F) before forming into patties in the FORMAX F6 Molding Machine (Formax, Inc., Mokena, IL) (see Figure 3). Spreading a thin layer of the meat mixture on trays eliminated the need for stirring. Trays were stored for approximately one hour before molding into patties. Upon removal from the freezer, the meat mixture was emptied into the hopper of the FORMAX F6, and the molding machine was adjusted and operated to stamp out patties. The warmer the product, the lower the pressure needed to form the patties in the FORMAX. If the meat mixture is too warm, smearing occurs, which is undesirable. Pressure for pattie formation ran between 80 and 110 psi, and was potentially dictated by the viscosity of the mixture, affected either by the temperature of the mixture or the addition of MC. If the meat temperature is uniform [i.e. reduced hard (frozen) and soft (not frozen) pockets], the forming pressure can be raised, which is desired to minimize shape differences. The speed of the FORMAX was 60 to 65 strokes per minute, which was proportional to the thickness of the plate and the viscosity of the product. Inside dimensions of the pattie mold were approximately 120mm (4 ¾") oval with 10mm (3/8") thickness.

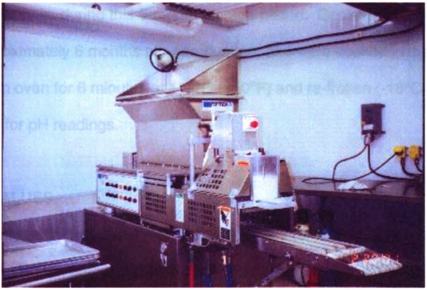

FIGURE 3: FORMAX F6 Forming Machine

PROXIMATE COMPOSITION AND pH

Chicken pattie samples, both raw and cooked, were analyzed in triplicate for proximate composition, including moisture, fat, and protein (AOAC, 1990 and 1997). See Appendix A for the description of the methods. For pH readings, 10 grams of each pattie treatment, both raw and cooked, were combined with 100 ml of distilled deionized water. This mixture was blended for one minute using a high shear Polytron mixer (Model PT10-35, 710 Watt, 60 Hz, 110 volts) until homogeneous. A pH/ATC Calomel electrode (Fisher Scientific, Cat. #13-620-531; polypropylene body, liquid-filled combination electrode) attached to an Accumet pH meter (Model AB15, Fisher Scientific) was used to read the pH values. The pH meter was standardized and calibrated with pH 7 buffer before taking readings. Samples were analyzed in duplicate. Raw pH measurements were obtained on days 1, 14, 28, 42, and 56 of storage. Patties were stored frozen in vac paks during this 6-month storage period. Cooked pH was analyzed once, approximately 6 months after production, and were cooked in the combitherm oven for 6 minutes at 117°C (350°F) and re-frozen (-18°C or 0°F) until ready for pH readings.

COLOR VALUES

Lightness (L*), redness (a*), and yellowness (b*) values were determined on four raw chicken patties per treatment, thawing to 3°C (37.4°F) before reading with a Minolta chromameter CR-310 [Commission International D'Eclairerage (CIE) L*a*b*, Ramsey, NJ]. The meter was previously calibrated with a standard white tile. Settings for the CIELab chromameter were L*, a*, b*, D65 (daylight illuminator), 2° standard observer, with a 50mm reading orifice. Samples were tested on days 1, 14, 28, 42, and 56 of storage to determine whether color changed during frozen storage. Three observations of the L*, a*, and b* values were measured on the surface of each pattie, with the Minolta chromameter averaging the readings to obtain the four color values per treatment. The scales for lightness is zero (no light or black) to 100 (white). Redness and yellowness have no scale, and can go from zero to infinity on both a positive and negative scale.

LIPID OXIDATION DETERMINATION

Thiobarbituric acid values (TBA) were determined on samples from four raw chicken patties per treatment on days 1, 14, 28, 42, and 56 of frozen storage (-18°C; 0°F) to monitor oxidative rancidity. Two replicates were run for each sample, using a macrodistillation unit. See Appendix B for details on the procedure (Tarladgis *et al.*, 1960; Zipser and Watts, 1962).

COOKED YIELD DETERMINATION

A commercial (ALTO-SHAAM Inc., Menomonee Falls, WI) steam-injected combitherm oven was used at The Dow Chemical Company (Larkin Lab, Midland, MI) for cooking the patties for all evaluations, including trained sensory, Kramer Shear values, cooked proximate analysis, and cooked yields. Murphy *et al.* (2001) reported that during cooking in air-steam impingement ovens (similar to steam-injected combitherm ovens), product yields were affected by product temperature and cooking conditions.

The combitherm oven was set to operate on the "superheated steam and convection" program with oven temperature at 177°C (350°F). This program electronically balances the amount of both steam and convection heat during the entire cooking process, which enables shorter cooking times, less product shrinkage, and more moisture retention than in standard convection ovens (Alto Shaam, 1999). The oven was preheated for 30 minutes before cooking the patties. Six frozen (-18°C; 0°F) patties were cooked at one time. A stainless steel rack (with ½" grid-like design and elevated with wire "feet") was placed within the stainless steel tray, to elevate the patties approximately ½" from the tray. This would eliminate resorption of the cooked-out juices upon removal of the patties from the oven.

Patties were cooked for 6 minutes or until an internal temperature of 74°C (165°F) was obtained, via a temperature probe inserted into the geometric center. The surface of the patties was lightly blotted with a paper towel to collect pooling juices and fat, then immediately weighed for cooked yields and measured for dimensional changes. Cooked yield measurements were obtained while the patties were still hot (70°-72°C), to analyze the effects of the hot thermal gel from methylcellulose. This is also standard procedure when pan-broiling frozen beef patties per AMSA guidelines (AMSA, 1995). Cooked yields were determined by the following formula:

$$\text{Cooked Yield} = \frac{\text{weight of blotted cooked chicken pattie}}{\text{weight of raw frozen chicken pattie}} \times 100$$

The temperature probe was inserted into the center of one pattie per tray to determine finished cooked temperature. Oven temperature uniformity was tested to determine potential "hot" and "cold" spots, a key point in standardizing the cooked yield determinations. Results showed that oven temperatures were uniform (within +/- 2°C).

DIMENSIONAL CHANGES

Typically, meat and poultry patties shrink and/or cup upon cooking, which can lead to reduced portion size along with increased bun exposure for sandwiches. This may cause the consumer to believe their chicken pattie weighs less than the advertised portion. Meat can shrink in all three dimensions, length, width, and thickness, and often does. Severe or inconsistent shrinkage and/or deformation are a valid quality concern in food service operations.

The chicken patties were formed using a standard 4oz. mold used in the FORMAX F6 forming machine. Typically, each pattie is approximately 120mm (4 ¾") long, 110mm (4 3/8") wide, and 10mm (3/8") thick. For each treatment and repetition, the length, width, and thickness of four frozen patties were measured using a ruler (mm) before cooking. Upon reaching the targeted internal temperature, the patties were removed from the oven, and the dimensions were measured again to determine the changes after cooking.

SHEAR FORCE DETERMINATION

Ground chicken patties were analyzed at The Dow Chemical Company (Larkin Lab, Midland, MI) using the Kramer Shear 5-blade shear force test method, using a TA.XT2i texturometer (Textured Technologies, Hamilton, MA). Three patties were cooked in the combitherm oven to an internal temperature of 74°C (165°F), immediately removed from the rack, stacked on a heat-resistant plate, and covered with foil. Two rectangular samples (25 x 70mm) were cut from the center of each pattie, resulting in six samples per treatment. Thickness of samples was not measured at this point, but assume they varied slightly, depending on which treatment was being evaluated. Internal pattie temperature was monitored to maintain a temperature range of 63°C to 74°C (145° to 165°F) during shear force analysis.

A 25kg load cell was used to measure the peak force in Newtons (N) required to shear the chicken pattie sample with the Kramer Shear 5-blade cell apparatus. See Appendix C for the TA.XT2 settings. The 5-blade shear apparatus was applied perpendicular to the sample axis, and the peak force (N) was determined as the maximum force during shearing (see Figure 4). The blades penetrated the sample completely as they traveled through the bottom of the Kramer shear box. The peak force required to shear through the cooked chicken pattie was reported in force per unit mass of sample (N/g) (Troy *et al.,* 1999), which normalizes the values by accounting for the weight (g) of the pre-cut sample.

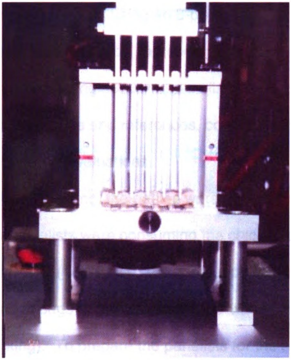

FIGURE 4: Kramer Shear 5-blade cell attached to a TA.XT2 Texturometer

TRAINED SENSORY PANEL

A seven-member trained sensory panel at The Dow Chemical Company (Larkin Lab, Midland, MI) was used to develop sensory procedures and terms used to characterize tenderness and juiciness attributes of the cooked chicken patties (Meilgaard *et al.*, 1999). Panelists were trained during four sessions, acclimating their palettes and senses to the extremes of tenderness and juiciness (AMSA, 1995). Reference foods were used throughout the sessions to assist panelists in determining tenderness and juiciness of the cooked patties. Tenderness was determined when biting into the product with incisors, making sure the bite was from the center point of the pattie. Juiciness was rated on the amount of juice released during mastication (10 chews). Scores for each attribute were assigned by panelists using an 8-point scale, 1 = extremely tough or dry and 8 = extremely tender or juicy, for tenderness and juiciness ratings respectively. During these training sessions, panelists conducted roundtable discussions regarding the patties and references, coming to agreement to ensure compatibility during the actual evaluations.

Upon completion of cooking, the patties were cut into quarters and served immediately to ensure panelists were consuming the chicken pattie at a typical serving temperature of 60°C (140°F). To ensure samples remained at or above 60°C, they were placed in bags and stored in a 60°C-water bath until consumed (within 10 mins of cooking). To prepare the panelists for the actual evaluations, a well-done (82°C; 180°F) (also uncoated) retail chicken burger was served to exemplify "moderately tough and dry", which would rate a "3" on the sensory scale for both attributes. Another retail chicken burger was cooked (73°C; 163°F) to exemplify "very juicy and moderately tender", rating a "7" and "6", respectively, on the sensory scale. The panelists agreed upon the ratings for these "benchmark" patties before proceeding. Panelists were confined to individual booths, separated by partitions and illuminated with white fluorescent lighting (see Figure 5). Unsalted crackers, room temperature water and apple juice was provided between samples. Sensory sessions were held mid-morning to ensure similar states of hunger amongst panelists. Patties were assigned random numbers to eliminate any biases. See Appendix D for the evaluation form used during the trained sensory testing, which also includes a list of the references and how they correlated with the rating systems.

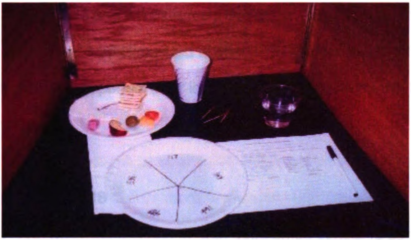

FIGURE 5: Trained Sensory Panel Set-up (includes rating sheet and reference foods)

CONSUMER SENSORY PANEL

AMSA guidelines (AMSA, 1995) were followed for sample preparation and presentation to consumer sensory panelists at Michigan State University (East Lansing, MI) on three consecutive days one month after production. Frozen patties were cooked using an electric fry pan, cooking for 3 minutes on each side, for a total of 6 minutes cook time, to reach an internal temperature of 71°C (160°F). A thermocouple was placed in the geometric center of the patties while cooking. Cooked patties were placed on a cutting board, and cut into six wedges per pattie for sampling. Wedge-shaped samples were placed in small plastic bags, and held in Pyrex® double boilers heated to 140°F. Samples not evaluated within 15 minutes were discarded and replaced with new samples. The consumer panel evaluations were conducted as two-hour sessions between 10am and noon on three consecutive days, collecting data from 60 panelists.

Panelists were asked to determine desirability of juiciness, texture, flavor, and overall acceptability of the chicken patties. A hedonic scale was used, with 1

= extremely undesirable and 8 = extremely desirable. The neutral category of "neither like nor dislike" was eliminated to effectively remove the "sitting on the fence" response. See Appendix E for instructions to the taste panelists and score sheet.

STATISTICAL ANALYSIS

A two-level two variable factorial with augmented control (a control level added) experimental design provided five treatments for comparison: 1) control (no gum), 2) SG at 0.25%, 3) SG at 0.5%, 4) CM at 0.25%, and 5) CM at 0.5%. The "Fit Model" platform within JMP was implemented (JMP statistical software, SAS Institute, Inc., Cary, NC) for all five treatments, and effects of the variables were evaluated. Least square means were calculated and compared using the Tukey Studentized Range (HSD) test ($P < 0.05$). Least square means were used so that a fair comparison between the five treatments available could be made in light of the significant differences identified among the replicates provided (Sweeney, J., The Dow Chemical Company, personal communication, 2001).

RESULTS AND DISCUSSION

PROCESSING AND FORMULATION DATA

This section includes observations made during the processing of the chicken patties and should not be considered "fact" due to lack of formal statistical analysis of these observations. However, reporting the observations provides insight and consideration for future research.

During preparation of the marinades, the dryblend of salt, onion powder, black pepper, and MC dispersed easily, especially at the 0.25% usage level of MC (based on total formulation). Adding all dry ingredients quickly, with agitation, aided in mixing due to the lower initial viscosity. Once the marinade started to thicken (due to gum hydration) it became more difficult to disperse the dry mix.

Based on the marinade alone, the phosphate level was 2.6%, salt was 5.5%, the onion powder and black pepper were both 1.8%, and the MC concentration was 1.8% or 3.6%. Based on the finished raw chicken pattie, the phosphate level was 0.35%, salt was 0.75%, the onion powder and black pepper were both 0.25%, and the MC concentration was 0.25% or 0.5%. Formulations containing >6% salt have inhibited the hydration of methylcellulose (Bellekom, 2001). Bellekom also reported that high phosphate contents (>1.0%) can make MC gels synerese when heated. However, these marinades were well dispersed with the ground chicken, which reduced the concentration of the salt and phosphate, thereby allowing the MC to adequately hydrate and function in the environment of the pattie formulation. Also, the low temperatures reduce the chemical activity (hence antagonistic effects) of the salt and phosphate, and promote better MC hydration (Conklin, J. R., The Dow Chemical Company, personal communication, 2001).

Marinades containing 0.5% MC were more viscous than the marinade containing 0.25%, however, they were all still pourable. The supergelling methylcellulose appeared to disperse more readily in the cold water, compared to the conventional methylcellulose. Particle sizes of the two types of MC were similar and neither was granular in morphology. The control marinade had a low viscosity, allowing particles of onion powder and black pepper to settle to the bottom of the bucket between stirrings.

During mixing in the tumbler, all MC treatments appeared to increase the cohesiveness of the mixture, with 0.5% gum concentration providing a firmer meat mixture. Treatments containing 0.5% MC also improved the efficiency of the clean-up out of the tumbler. This could be attributed to increased matrix cohesion and apparent slipperiness of the mixture on the wall of the tumbler, thus making it easier to scoop the mixture out of the tumbler, into the awaiting lugs.

During the shaping of the patties, treatments containing MC appeared to provide more defined shape, especially at the higher concentration of 0.5%. This is probably due to the increase in binding/cohesion of the meat/marinade mixture. Patties containing MC also released from the mold easier. This may be due to the increased lubricity from the hydrocolloid.

PROXIMATE COMPOSITION, pH, COLOR, and LIPID OXIDATION

Table 6 provides the least square mean values for moisture, fat, and protein (both raw and cooked), plus the pH of raw and cooked patties. Table 7 provides the least square mean color values for lightness, redness, and yellowness, plus the TBA (lipid oxidation) results.

Moisture, fat, protein and pH

For raw proximate composition, there were no significant differences in percent moisture. Raw fat contents were slightly higher than the 5.7% skin content added in the formulation, possibly due to the small (1.6-4.3%) additional fat from the meat. CM at 0.5% was significantly lower in fat content compared to the other three MC treatments, with the control intermediate. Percent raw protein was significantly higher for the control, compared to the treated patties. This difference may be attributed to the "dilution factor" from the reduction of meat when the hydrocolloids were added to the treatments, but the difference is so slight it may not be a factor.

For cooked proximate composition, CM at 0.25% and the control contained significantly more moisture than CM at 0.5%, with the SG treatments falling in-between. This agreed with cooked yield data, with the exception of CM at 0.5%, which obtained higher cooked yields compared to the SG treatments. However, from a practical standpoint, the differences in % cooked moisture were only slightly different, as was also noted with the cooked yields. The MC treatments appear to be managing moisture similarly to the control, which is different from "prior art" as noted by Foegeding and Ramsey (1986) and Shand *et al.* (1993).

CM at 0.5% was significantly higher in fat compared to the other four treatments, which makes sense since it was lowest in percent moisture. When comparing the percent cooked moisture to percent cooked fat, it appears that when moisture goes up, the fat level goes down, and vice versa. This agrees with the inverse relationship between moisture and fat content (Barbut, 2002). The protein content is not affected as much by this change, with no significant difference noted for any of the five treatments.

The treatments did not significantly affect either the raw or cooked pH values, which would be predicted because MC is nonionic (Anonymous, 1999c). Overall, the total percent proximate composition, both raw and cooked, was not significantly different between the five treatments, which would also be expected because composition should equal 100%.

TABLE 6: ***Proximate composition and pH of chicken patties manufactured with different types and concentrations of methylcellulose***

Attributes	Control	Methylcellulose Type: SG 0.25	SG 0.50	CM 0.25	CM 0.50	SEM [c]
		Concentration (%)				
Raw Moisture, % [NS]	75.68	75.97	76.28	75.65	76.21	0.33
Raw Fat, %	7.46 [ab]	8.06 [a]	8.06 [a]	8.26 [a]	6.94 [b]	0.21
Raw Protein, %	16.33 [a]	15.50 [b]	15.88 [ab]	15.91 [ab]	15.99 [ab]	0.18
Raw Total, % [NS]	99.47	99.53	100.21	98.09	99.14	0.91
Raw pH [NS]	6.54	6.55	6.55	6.53	6.56	0.02
Cooked Moisture, %	65.31 [a]	64.42 [ab]	64.24 [ab]	65.67 [a]	62.67 [b]	0.39
Cooked Fat, %	9.37 [b]	9.44 [b]	9.57 [b]	8.68 [b]	11.12 [a]	0.23
Cooked Protein, % [NS]	24.28	23.69	24.38	23.47	24.79	0.36
Cooked Total, % [NS]	98.96	96.48	98.19	97.82	98.58	0.70
Cooked pH [NS]	6.59	6.63	6.57	6.63	6.59	0.02

[ab] Least square means having different superscripts within rows are significantly different ($P<0.05$)
[c] SEM = Standard error of the means
[NS] Model is not significant

Color

There were significant differences for lightness, redness, and yellowness in the raw chicken patties (Table 7). Variation in measured color values could be the result of where the sample reading was taken on the surface of the pattie. The homogeneity of a coarsely ground chicken pattie containing breast and thigh meat, plus a skin emulsion is very diverse, compared to an emulsified product like frankfurters. The color value depends on what type of meat (dark or light) was populating that particular region of the pattie. Thigh meat is typically darker and sometimes more red due to higher myoglobin content, in comparison to breast meat, which is substantially lighter.

For lightness, there were statistically significant differences between the five treatments, with control patties very slightly darker than those containing MC. This agrees with the fact that MC entrains air, which can form very tiny bubbles and reflect light differently compared to materials with no bubbles present (Anonymous, 1999c). Air entrainment increases lightness in a product, such as whipped toppings. However, from a practical standpoint, differences between values of 57 and 59, based on a scale of zero to 100, are not very different. The instrument is very precise at reading the color values, as is noted by the very small errors involved ($P < 0.0001$).

Table 8 lists the least square means of L*, a*, b* based on day of storage. Significant differences for lightness were also noted between days of storage ($P < 0.0012$). Color varies more often in ground products compared to emulsified products, such as frankfurters, due to less breakdown of the different muscle components during processing. Therefore, larger pieces of muscle are dispersed throughout the pattie, and can cause the variation in the color readings noted from the chromameter analysis.

Redness values were not significantly different when comparing the five treatments. There were significant differences noted between days of storage, with day 56 having the highest redness values ($P < 0.0001$). Considering the redness scale has no beginning or end, practically speaking, these differences are probably insignificant.

Yellowness results indicate significant differences between the five treatments ($P < 0.0180$) and the days of storage ($P < 0.0001$). However, considering the infinite scale of yellowness, and the fact that each least square means value is nearly identical to two significant figures, the significance is not important, from a practical standpoint.

TABLE 7: Objective raw color (L, a*, b*) and lipid oxidation (TBA) assessment of chicken patties manufactured with different types and concentrations of MC*

Attributes	Control	Methylcellulose Type: SG, Concentration (%) 0.25	Methylcellulose Type: SG, Concentration (%) 0.50	Methylcellulose Type: CM, Concentration (%) 0.25	Methylcellulose Type: CM, Concentration (%) 0.50	SEM [c]
Lightness (L*) [e]	55.87 [c]	57.80 [a]	56.35 [bc]	57.05 [abc]	57.61 [ab]	0.34
Redness (a*) [e NS]	8.54	8.04	8.32	8.05	8.41	0.15
Yellowness (b*) [e NS]	17.09	17.95	17.48	17.61	17.60	0.18
TBA [f NS]	1.18	1.08	1.12	1.19	1.02	0.05

[ab] Least square means having different superscripts within rows are significantly different (P<0.05)
[c] SEM = Standard error of the means
[e] Measurements of L*, a*, and b* via chromameter of raw thawed chicken patties.
[f] Lipid oxidation (TBA) measured in mg, then converted to mg/kg of sample.
[NS] Model is not significant

Lipid oxidation

When comparing the least square mean TBA values for the five treatments, there was no significant differences noted (Table 7). TBA values (Table 8) indicated a significant difference between day of storage when comparing the five treatments ($P < 0.0001$). As the day of storage increases from 1 to 56, TBA values increased. Days 1 and 14 were similar, followed by days 28 and 42 increasing slightly, with day 56 substantially higher than the previous four test days. This would be expected, since lipid oxidation increases with time as food products age, even if they are vacuum-packed and frozen. However, this does not mean that these chicken patties were rancid after the 56 day storage period. The overall storage life of a food product depends on the ingredients added and the inclusion of antioxidants (Barbut, 2002).

TABLE 8: Effect of frozen (0°F) storage time (1 to 56 days) on raw color and lipid oxidation (TBA) values of chicken patties manufactured with and without methylcellulose

Attributes	Day of Storage					
	Day 1	Day 14	Day 28	Day 42	Day 56	SEM [c]
Lightness (L^*) [e]	58.14 [a]	56.36 [b]	56.97 [ab]	56.82 [ab]	56.40 [b]	0.34
Redness (a^*) [e]	8.30 [b]	7.50 [c]	7.72 [bc]	7.66 [c]	10.18 [a]	0.15
Yellowness (b^*) [e]	17.74 [b]	16.51 [c]	18.65 [a]	18.34 [ab]	16.50 [c]	0.18
TBA [f]	0.40 [c]	0.55 [c]	1.12 [b]	1.09 [b]	2.43 [a]	0.05

[ab] Least square means having different superscripts within rows are significantly different ($p<0.05$)

[c] SEM = Standard error of the means

[e] Measurements of L^*, a^*, and b^* via chromameter of raw thawed chicken patties.

[f] Lipid oxidation (TBA) measured in mg, then converted to mg/kg of sample.

COOKED YIELDS

Least square means of the cooked yields are reported in Table 9. Statistical analysis of the six patties cooked per treatment indicates a significant difference between the five treatments. CM at 0.25% had the highest cooked yield, followed by the control, CM at 0.5%, and SG at 0.25% (which were all similar), and finally SG at 0.5% exhibited the lowest cooked yield. However, practically speaking, these differences were small. A greater number of patties (> 20 per treatment) for future studies may be useful to yield a more meaningful difference in cooked yields. Processors may not see a significant difference in cooked yields at the bench or in pilot plant scale-ups, but can realize substantial savings (i.e. 5% improvement) once in production for a month.

Murphy *et al.* (2001) reported moisture losses in cooked chicken patties increased 10 to 14% with increasing product temperature from 55° to 80°C (131° to 176°F) during air-steam impingement cooking. They also found that increasing product temperatures from 70° to 80°C actually decreased the product yield by 7 to 8%. So, cooking *conditions* are just as important as the ingredient functionality.

TABLE 9: Cooked yields and dimensional changes of chicken patties manufactured with different types and concentrations of methylcellulose

		Methylcellulose Type				
	Control	SG		CM		
Attributes		Concentration (%)				
		0.25	0.50	0.25	0.50	SEM [c]
Raw Length [d NS]	127.75	127.92	127.50	128.08	128.92	0.89
Raw Width [d NS]	117.08	116.67	117.08	117.75	116.67	0.77
Raw Depth [d NS]	9.50	9.33	9.42	9.25	9.33	0.20
Cooked Yield, % [e]	74.66 [ab]	74.10 [ab]	73.06 [b]	75.58 [a]	74.26 [ab]	0.42
Cooked Length [f NS]	105.58	105.33	104.17	106.17	106.42	1.04
Cooked Width [f]	100.08 [ab]	100.08 [ab]	98.67 [ab]	101.33 [a]	97.17 [b]	1.04
Cooked Depth [f]	7.17 [b]	7.75 [ab]	7.92 [a]	8.25 [a]	8.17 [a]	0.18
% Length [g NS]	82.66	82.37	81.75	82.93	82.61	0.84
% Width [g NS]	85.49	85.82	84.28	86.07	83.65	0.84
% Depth [g]	75.74 [b]	83.45 [ab]	84.26 [ab]	89.13 [a]	87.78 [a]	2.47

[ab] Least square means having different superscripts within rows are significantly different ($p<0.05$)
[c] SEM = Standard error of the means
[d] Actual raw measurements (mm) of length, width, and depth of original frozen chicken pattie.
[e] Cooked Yield = Cooked weight/Raw weight x 100. Pattie cooked to an internal temperature of 71°C (160°F)
[f] Cooked length, width, and depth measurements (mm) of frozen chicken pattie. Pattie cooked to internal temperature of 71°C (160°F).
[g] Changes from original dimension of pattie after cooking to an internal temperature of 71°C.
[NS] Model is not significant

Foegeding and Ramsey (1986) determined that conventionally made MC (4000-cps food grade) significantly reduced the cooked yields of model lowfat frankfurter systems when cooked to between 60° and 70°C. Shand *et al.* (1993)

also determined that MC in a salt/phosphate beef roll-up resulted in a substantial loss in cooked yields. This was not the case for all the MCs in the current study. Contrary to "prior art", use of MC did not cause a major reduction in cooked yields, based on this study. In fact, it was about the same as the control (73.1% for SG vs. 74.7% for control). However, cooked yields are just one of many variables to analyze. While this can be important to poultry processors and their operating costs, it does not directly concern consumers.

DIMENSIONAL STABILITY

The least square means of the raw, cooked, and cooked percentage of dimensional changes are reported in Table 9. The five treatments did not cause any significant differences in raw chicken pattie dimensions.

Cooked chicken pattie dimensions demonstrated significant differences only for depth (or thickness) measurements. The control patties were significantly thinner than patties containing MC, especially CM. One might speculate that these thinner patties would hold less water, but this was not the case. Control patties received the second highest value for cooked yields and percent cooked moisture. Chicken patties containing supergelling MC, which were at least 7% thicker than cooked control patties, had actually slightly lower cooked yields.

When comparing the mean values of raw thickness (depth) to cooked thickness, there are remarkable differences between the control and treatments with MC. The control patties had a 25% reduction in thickness, while the SG and

CM patties were only reduced by 16-17%, and 11-12% respectively. This is a very interesting point to consider, and one might speculate that the MC's were somehow better able to maintain a swollen hydrated pattie structure in spite of reduced available moisture.

Cooked percent dimensions (or % retention) had similar results to cooked dimension results. Length and width were not significantly affected by the five treatments in the study. Chicken patties made with CM at 0.25% were 15% thicker than the control, and also had the greatest cooked yields. Importantly, the patties with MC all retained 83.4% to 89.1% of their raw thickness compared to the control, which shrunk to 75.7% of its raw thickness. Control patties (0% gum conc) were significantly thinner compared to any of the patties containing MC. Reduced thickness or shrinkage is very important in foodservice, where sandwich height and meat portion thickness are readily apparent to consumers. This may also be perceived as "plumpness", a positive attribute for "center-of-the-plate" entrees.

SHEAR FORCE

Table 10 reports the least square means for shear force. Generally, it appears that MC tenderized the cooked chicken patties based on the reduced "force to penetrate" values obtained when using the Kramer Shear 5-blade cell on hot (63° to 74°C) chicken patties. Control chicken patties were significantly less tender than all MC treatments. This may be the result of two phenomena. First, the thickness of the patties or density may be causing the difference.

Thinner patties, as was seen with the controls, mean more protein per millimeter of distance traveled that is encountered by the sensor. The same total amount of protein is within each pattie, but is more compressed or concentrated in the control patties because they are thinner. This could cause an increase in force to cut through the sample since the thinner pattie would be tougher to penetrate. Second, the addition of MC to the formulation may be diluting the protein network, thus reducing the ability of the proteins to find each other and crosslink. This may also cause the reduction in firmness of the MC patties. Both gum concentrations of 0.25% and 0.5% demonstrated similar tenderness ratings.

Shand *et al.* (1993) also saw this phenomena in beef rolls, where the inclusion of conventionally made MC lowered the bind and texture values, indicating a general softening effect even with the increased protein concentration due to water loss. Hydrocolloids such as blends of carrageenan with starches, pectin, and other binders (Troy *et al.*, 1999) or carrageenan alone (Blackmer, 1992) reduced shear force values in low-fat beef patties. They both concluded that the addition of water and the ability of the hydrocolloids to hold water by gelling would tenderize the beef patties.

Pearson and Gillett (1996) reported proper cooling is required for the maximum binding strength of the coagulated proteins. Troy *et al.* (1999) also cooled cooked patties for at least one hour before conducting mechanical texture analysis. The chicken patties in this research were kept hot (63° to 74°C) to evaluate the texture of the gel formed by the MC and to better approximate actual panelist consumption temperatures. The temperature range during testing did not appear to cause significant differences in actual shear force values within the treatments, nor was the difference in hot gel strengths (between CM and SG) apparent from this analysis.

TABLE 10: Shear force values, trained sensory (juiciness and tenderness), and consumer sensory (juiciness, texture, flavor, and overall acceptability) panel ratings of chicken patties manufactured with different types and concentrations of methylcellulose

Attributes	Control	Methylcellulose Type				
		SG		CM		
		Concentration (%)				
		0.25	0.50	0.25	0.50	SEM [c]
Shear Force [d]	3.94 [b]	2.74 [a]	2.76 [a]	2.96 [a]	2.76 [a]	0.10
Trained Juiciness [e NS]	5.79	5.95	6.18	5.86	6.27	0.22
Trained Tenderness [e]	4.90 [b]	4.98 [ab]	5.66 [a]	5.18 [ab]	5.55 [ab]	0.22
Consumer Juiciness [f NS]	6.34	6.24	6.09	6.14	6.00	0.10
Consumer Texture [f]	5.75 [ab]	5.86 [a]	5.76 [ab]	5.77 [ab]	5.40 [b]	0.11
Consumer Flavor [f]	5.68 [a]	5.59 [ab]	5.50 [ab]	5.45 [ab]	5.20 [b]	0.11
Overall Acceptability [f]	5.87 [a]	5.74 [ab]	5.72 [ab]	5.57 [ab]	5.39 [b]	0.10

[ab] Least square means having different superscripts within rows are significantly different (p<0.05)

[c] SEM = Standard error of the means

[d] Peak force (N) to shear through 25x70mm sample, using a TA.XT2 texturometer. Reported as peak force per sample mass (N/g). Temperature range: 63°-74°C.

[e] Scores by trained sensory panel based on reference foods, including chicken patties cooked to varying degrees of doneness to exemplify extreme conditions for juiciness and tenderness. Eating temperature = 60°-63°C.

[f] Scores by consumer sensory panel based on rating scale, where 1 = extremely undesirable and 8 = extremely desirable. Eating temperature = 60°-63°C.

[NS] Model is not significant

SENSORY EVALUATIONS

Trained Sensory Panel

Table 10 reports the least square mean values for objective sensory tenderness and juiciness. Tenderness was significantly different (P<0.05), where 0.5% SG was 13% more tender than the control. The 0.5% gum concentration exemplified the most tenderness. Shand *et al.* (1993) also saw this tenderizing effect from MC in beef rolls. This increase in tenderness for the MC patties may be attributed to the dilution of the proteins, due to the addition of the hydrocolloid and its ability to retain moisture within the cooked patties.

There were no significant differences noted for juiciness when comparing the five treatments ($P<0.50$). When comparing the actual means of the five treatments, the control patties were perceived the least juicy (5.76) with 0.5% SG at 6.14 and 0.5% CM at 6.31, indicating higher "juiciness" values. Although perceived juiciness was not significantly different between treatments, patties containing MC, especially SG, which actually lost slightly more juices during cooking, were *still* perceived to be as juicy as those which held on to juices during the cooking process. This has also been noted with soy-based and veggie-based formed patties, where succulence is substantially increased with the use of supergelling MCs (Conklin, 2000). One would speculate that those patties that had higher cooked yields would be juicier during sensory tests, but these results demonstrate that the relationship is more complex than that.

Consumer Sensory Panel

Table 10 also reports the least square means for juiciness, texture, flavor, and overall acceptance from the consumer sensory panelists at Michigan State University. The rating scale for these four attributes was the same, with "1" equal to "extremely undesirable" and "8" equal to "extremely desirable", with six slight increments of these two extremes within these endpoints (See Appendix E for rating scale). To put the trained sensory and consumer sensory results in perspective, one must keep in mind that the trained panel was taught the definitions of the terminology used in these evaluations. Consumers, on the other hand, came in "untrained", with different impressions and viewpoints. Each individual had a different perspective on "juicy", "texture", and "flavor", plus individual likes and dislikes, and this must be accounted for when analyzing the results.

The panelists were asked whether the chicken pattie juiciness was desirable, or was it too dry. The panelists determined no significant difference in juiciness between the treatments, as was also noted by the trained sensory panel. For texture, the panelists were to determine how desirable they thought the texture of the chicken patties was, i.e. was it too soft, too hard, too mushy, or too brittle. Panelists desired the texture of SG at 0.25% the most, and disliked CM at 0.5% the most.

Panelists were instructed to rate whether flavor was desirable, or whether it was too bland or too spicy. This particular rating can be very subjective, since individuals are very different when it comes to preferred tastes and tolerance to spicy foods. The panelists determined the control to have the most desirable flavor, followed by SG at 0.25% and 0.5%, with CM the least desirable for flavor, especially CM at 0.5%. Overall, consumer acceptability was based on the panelist's reaction to the overall satisfaction derived from the consumption of the chicken pattie. Panelists liked the control patties the best, followed by SG at 0.25% and 0.5%, with CM the least liked, especially CM at 0.5%.

Figure 5 compares the texture results from both trained and consumer sensory panels. Although the rating scales were different, it is interesting to note the graphical representation of the data. The trained panel indicated a significant increase in tenderness ($P<0.05$)) with 0.5% MC. One might conclude with this data alone that either MC at increased concentrations might be beneficial for tenderizing, but further evaluations would be necessary to quantify that conclusion. However, the consumer panel clearly, and very significantly ($P<0.02$), indicated an 8% reduction in desirability between SG at 0.25% and CM at 0.5%. Although the trained panel may have indicated increased tenderness with CM at 0.5%, clearly the consumer panel did not *like* that texture, when compared to the other treatments. Other factors, such as flavor and juiciness, may also factor into that overall "likeness" factor, but it is clear from this data set that increased tenderness does not always mean consumers desire to eat the product. Collecting both trained and consumer sensory panel data is critical in understanding both the quantitative and qualitative organoleptic aspects of the finished products.

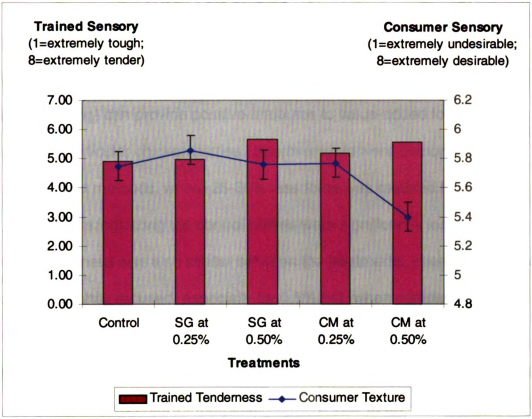

FIGURE 5: Relationship of Sensory – Trained "Tenderness" and Consumer "Texture"

SUMMARY AND CONCLUSIONS

The results of this study indicate the addition of MC (both conventional and supergelling) can provide positive attributes to value-added formed chicken products, in particular chicken patties. Improvements were demonstrated by mechanical test methods, where 25-30% less force was required to penetrate the MC patties, thus indicating the control patties were significantly less tender. Perceived juiciness was also similar between the treatments, even when cooked yields were slightly reduced, especially for 0.5% SG, when compared to the control. In addition, shape retention was improved upon cooking, including a 15% increase in thickness with MC, which can be perceived as "plumpness", a positive attribute for "center-of-the-plate" entrees. Based on these results, a concentration of 0.5% or less of MC is recommended to obtain the positive attributes noted in this study. Future studies are recommended to elaborate the apparent positive contributions from MC and potentially HPMC in processed poultry.

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RECOMMENDATIONS FOR FUTURE RESEARCH

This research was conducted to determine the performance of methylcellulose on the moisture management and textural attributes of chicken patties to provide a homogenous model system to track the effects of the food additive. Throughout this study, several other ideas and avenues of research were discussed for future consideration:

1) Evaluate the effectiveness of methylcellulose, hydroxypropyl methylcellulose and other hydrocolloids on moisture binding and improved texture when phosphates are reduced or eliminated in a poultry product. Replacing part or all of the phosphate with MC or HPMC may provide similar binding characteristics plus possibly better moisture control during cooking and storing under heatlamps due to the unique thermal gelation which helps lock in moisture.
2) Evaluate effectiveness of MC and HPMC on moisture binding and textural attributes in 100% dark (thigh/leg) chicken meat, 100% white (breast/wing/back) chicken meat, and variations of blended white/dark chicken meat. Does MC or HPMC make "dark meat eat like white meat"? (Friesen, 2001).
3) Evaluate effectiveness of MC and HPMC in injection marinades to determine effects on flavor retention, cooked yields, and juiciness/texture enhancement.
4) Evaluate MC and HPMC in combination with other hydrocolloids, particularly carrageenan, in meat/poultry systems to determine whether there is any synergism and/or whether qualities of both gums are significant in the finished

product. Preliminary investigations at The Dow Chemical Company (Midland, MI, August, 2001) demonstrated that when kappa carrageenan and methylcellulose were combined in model systems (hydrocolloids in water), an increase in cold gel strength occurred, compared to kappa carrageenan alone. The brittleness of the carrageenan gel was also reduced when combined with methylcellulose, with both hydrocolloids at 1% in the model system. Upon heating, the carrageenan lost its gelling capabilities, while the methylcellulose thermally gelled. This combination could prove useful in processed meats and poultry where both cold and hot gels are desired (Moseley, 2001).

Shand *et al.* (1993) determined that kappa-carrageenan actually improved cooked yields and maintained or improved bind and texture of raw and cooked beef roll-up samples, in both algin/calcium and salt/phosphate systems. Carrageenan was added dry to the meat system, and required heating to 75°C for solubility. This suggests that the carrageenan was taking up the excess water in the meat system during cooking, since it was gaining solubility. Upon cooling, the carrageenan gels, thus improving the bind and firmness of the beef roll-ups. However, when carrageenan is alone in solution in a model water system, and subsequently heated, the polysaccharide does not bind the water, as noted above by the melting characteristics of the model system when combined with methylcellulose (Guiseley et al, 1980).

5) Investigate combinations of functional soy protein concentrates, textured soy protein concentrates, MC and HPMC in ground and formed poultry products.

Evaluate for synergism and contributing factors from both raw materials, regarding moisture control, texture enhancement, and succulence upon cooking and reconstitution.

6) Evaluate effects of completely cooling cooked chicken patties on final texture and sensory attributes. Determine whether room temperature gelling from supergelling MC positively influences the texture of the properly coagulated proteins.

7) Evaluate varying levels of marinade addition to ground poultry patties, optimizing added water level for optimum cooked yields and sensory attributes.

8) In “Processed Meats” (Pearson and Gillett, 1996) on pg. 370, the use of 0.45% carrageenan and 8.97% water substitutes for the chicken skin which is typically used in poultry patties. Based on this, evaluate the addition of MC and HPMC in the absence of skin, but with the addition of skin flavoring. Compare to controls containing skin but no hydrocolloids. Also, reduce the skin emulsion a predetermined percentage when adding the MC or HPMC and determine the effect of that variable. Finally, determine whether MC or HPMC can replace soy protein concentrate in a skin emulsion, and keep the emulsion stable.

9) Evaluate MC and HPMC added dry with other seasoning ingredients to determine if partial hydration provides enough or better functionality in the finished product.

10) Determine whether “softer” or more tender is actually more desirable in a meat and poultry product. Additional discussions with Dr. Jim Steffe (Professor, MSU, E. Lansing, MI, 2001) following the analysis of these results highlighted several other options to consider to normalize the data, including compensating for changes in density upon cooking, and will be considered for future research.

11) Investigate freeze/thaw behavior of MC and HPMC in meat and poultry products.

APPENDICES

APPENDIX A

PROXIMATE ANALYSIS PROCEDURES

Michigan State University
Meat Processing Laboratory
Written August 2001
(These analyses are based on official AOAC (1990; 1997) methods)

MOISTURE ANALYSIS (Air drying method)
Sample preparation and moisture determination have some modifications when compared to the official methods.

Sample Preparation (modified from Section 983.18 – Meat and Meat Products)
Section meat into very small (<1 cm squares) pieces. If already frozen, crush samples with a hammer to decrease size of sample for ease of grinding. Add sample to Tekmar grinder, filling grinding chamber half full. Then add small pieces of dry ice (<2 – 3 cm) to fill chamber. Grind 2 to 3 minutes until sample is ground into a fine powder. It may be necessary to stop in the middle of grinding and manually stir the sample and dry ice for uniform grinding. Transfer finely ground powder to labeled Whirlpack bags. Loosely close bag so that dry ice can evaporate and dissipate. This takes about 2 days. Place in freezer immediately to prevent melting of powder.

Moisture Analysis (Modified from Section 950.46B – Air drying for determination of moisture in meats)
Clean and level the analytical balance before using. Place a medium weigh boat on scale and zero the balance; this is to keep the balance clean. Add paper labeled with sample ID and paperclip. Record the weight then tare the scale. Add 2 grams (+/- 0.03g) of well-mixed sample to the paper with a spatula. Once the desired weight is obtained, record weight and fold over the top, securing with paper clip. Weigh out each sample in triplicate. Do not stack samples on tray as this hinders the drying process. Once the tray is full of samples, place the tray in the drying oven set at 100°C for 18hrs. Transfer the samples directly to the dessicator and allow to cool completely before weighing. Wear dry latex gloves or use tongs when handling the samples so moisture from hands does not transfer to the sample. The dry samples will absorb moisture very quickly and increase experimental error. Weigh and record the dried weight of the samples. This weight is the final weight for moisture and the initial weight for fat analysis. Determine the percent moisture with the following calculation:

$$\text{Moisture (\%)} = \frac{\text{wet sample weight} - \text{dry sample weight}}{\text{wet sample weight}} \times 100$$

FAT ANALYSIS USING SOXHLET ETHER EXTRACTION
(Modified from Section 960.39 – Meat and Meat Products)

SAFETY NOTE: Fat extraction must be conducted in a ventilated hood with proper hand and eye protection (latex gloves and goggles) to avoid petroleum ether vapors from being inhaled or coming in contact with eyes and skin.

Place the samples from the moisture determination into the Soxhlet extraction tubes, making sure sample levels are below the level where the ether drains off (curved glass on outside of tube). Add petroleum ether to clean boiling flasks until ~3/4 full. Add 2-3 glass beads as boiling aids. Connect the extraction flask to the boiling flask, and place parafilm on the joint to minimize leaks (do not use joint grease). Make sure no residual petroleum ether remains on the outside of the boiling flask, to prevent flashes when the rheostat is turned on. Mount extraction and boiling flasks to the Soxhlet apparatus securely with clamps present. Place condensing units on top of extraction flasks and secure with clamps present. Place parafilm around this joint as well. Turn on condensing water so it runs at a steady stream without too many air bubbles. Rheostats are set on high and ready to use. Turn the matching rheostats on for samples (do not turn on rheostats that do not have samples connected). Run for 24 hours. Cool system down completely before disassembling apparatus. Unhook all parts and pour ether soaked samples separately onto a tray in another hood (other than where the Soxhlet extraction unit resides) and allow petroleum ether to dissipate. Once ether is dissipated, (no odor remains), place samples in drying oven for 5 to 10 mins. to remove any possible moisture. Using latex gloves or tongs, transfer samples to a desiccator to cool completely. Weigh and record the weight of samples. To determine percent fat in samples use the following equation:

$$\text{Fat (\%)} = \frac{\text{dry sample weight} - \text{extracted sample weight}}{\text{wet sample weight}} \times 100$$

Dry sample weight equals the dry sample weight from moisture analysis and wet sample weight is the original weight of the wet samples before drying. Extracted weight is the last weight taken after the petroleum ether extraction.

PROTEIN ANALYSIS (Combustion Method)
(Modified from Method 992.15: Crude Protein in Meat and Meat Products)

Principle: Combustion Method determines nitrogen released at high temperature into pure oxygen and measured by thermal conductivity. Nitrogen is converted to protein equivalent by using appropriate factor, 6.25, for meat and meat products including pet food.

Obtain crucible boats from MSU proximate lab by the Leco analyzer. Weigh out approximately 1 gram of powdered meat (from moisture analysis; stored in freezer until used) into the tared crucible. Write the weight and sample ID on the side of the crucible with pencil. This sample ID and wet weight is entered into the Leco computer. After weighing out samples, dry for 18 to 20 hours in the drying oven. This removes most of the moisture that can cause internal malfunctions with the Leco Protein Analyzer. No need to reweigh samples. Enter wet weight into computer. Prepare the Leco analyzer for use.

Procedures for the LECO FP-2000 Nitrogen Analyzer (St. Joseph, MI)

1. Open valves completely on oxygen, helium and compressed air tanks located by the wall. Make sure tanks have adequate levels of gas (gauge on right should read >100psi) and that the pressure out of the tanks are set at 40 psi (gauge on left). This should never change unless they have been tampered with.

2. Press "escape" on upper left-hand corner of touchscreen until "front panel" comes up and then press it. On right hand side of screen, a section labeled "analysis gas" can be found. Push the "on" button to turn gasses on to the machine. Check to see that the furnace temperature is 1050°F (located on left part of screen).

3. Wait about 5 minutes for all gasses to equilibrate then start leak tests. These must be done daily. Press "escape" from the front panel located in upper left corner. A screen with several icons will appear. Press "maintenance". This will bring up helium leak test, combustion leak test and ballast leak test icons. Press the helium leak test. If it passes, move onto the combustion leak test. If it does not pass, stop and obtain assistance from Dr. Jamie Sue Willard (3365 Anthony Hall). If helium test passes then move to the combustion test. If this passes, you are finished and can start running blanks. No need to run a ballast test as it is part of the combustion system. If the combustion leak fails, try the ballast leak test. If it passes, the leak is not in the ballast. If it fails, it is located in the ballast and again you must obtain assistance.

4. If all the leak tests pass then you can move onto your analyses. You must run several air blanks thru to purge the system. To do this, "escape" from the "maintenance" section and push the "analyze" icon. On the bottom of the screen are several commands. Push "select ID code". Toggle the highlighted line using the arrows to "blanks". Then push "exit" on bottom. Then push "manual weight". This will bring up a touch screen with 0.2000000 on it. Push the "enter" button at least 10 times to bring up 10 rows of 0.20000.

Then push "analyze". The machine will run thru these ten samples. Nothing is done to the machine while it is running the blanks. Numbers should come down to about <0.30% protein. A negative number indicates the machine is cleaner than the calibrated curve. If ten samples do not bring the numbers down, enter five more blanks in, using the "manual weight" button. Do this until your numbers reach your goal. If you have entered 20 blanks and the numbers will not come down, obtain assistance.

5. Once blanks are at an acceptable number, run 4 to 5 EDTA (chelating agent) samples (approximately 0.5g) to see if the machine is running appropriately. Weigh samples out in the ceramic boats and write the weight on the side in pencil (at least three decimal places). Select ID code again and toggle until "Meats/Meats" is illuminated. Push "exit". Select "manual weight" and enter weight into the machine pushing "enter" after each entry. Once weights are in, push "analyze". Follow the directions on the touchscreen. The door to the combustion chamber will open. Check to see that no boats are in the chamber from previous tests. Remove any boats that are in the chamber. Push first sample into the chamber about one half inch so the door does not catch the boat. Push "okay" on the screen when it asks for the sample to be placed in the chamber. The next message will say to "wait" because the system is purging. Then the machine will indicate to push the boat into the chamber. Make sure the pushrod is pulled all the way out or it will jam the door. The machine will combust and analyze the sample in approximately 3 minutes. If error messages appear, obtain assistance. The EDTA should read 59.94% protein. If numbers are scattered and inconsistent, obtain assistance. If they read the same number or very close (but is not 59.94% $\pm$ 0.20), then a "drift correction" is needed. If they read 59.94% $\pm$ 0.20 then the machine is ready to analyze samples. To "drift correct", obtain assistance.

6. Analyzing samples: ID code will still be "meats/meats". Select "manual weight" and enter sample weights as was done with the EDTA samples. Push "analyze" and follow same steps as was done with the EDTA samples. If error messages appear, obtain assistance. A printout provides a hardcopy of the results as the samples run. If results are inconsistent, run them again to make sure the samples were uniform. If they continue to be inconsistent, obtain assistance.

7. Upon completion of running all the samples for the day, go back to the "front panel" screen and turn off "analysis gas". Also, turn each gas off at the tank. Analysis may start up the next day following these same procedures; however, other daily maintenance procedures must also be conducted before startup so be sure to schedule the Leco with Dr. Willard.

CRUDE PROTEIN, % = % NITROGEN X 6.25   Results reported as % Protein

APPENDIX B

LIPID OXIDATION PROCEDURE

(Tarladgis *et al.*, 1960; Zipser and Watts, 1962)

Dissolve 0.5766 grams of Thiobarbituric Acid (TBA) (Mw = 144.1) (Eastman Organic Chemicals) into 220 ml of distilled water. Place flask with mixture in a sonic cleaner for several minutes and shake periodically until the TBA is dissolved. Store in cooler until ready to use (may be kept for 2 days). Prepare an hydrochloric acid (HCl) solution by combining one part HCl to two parts water (v/v). Dow Corning Food Grade "200 fluid" antifoam is used to diminish foaming from products containing fish and eggs, but typically not necessary for poultry. However, due to the foaming characteristics of methylcellulose, the antifoam was used for these samples. Need separate flasks for extraction and homogenization.

1) Assemble connecting tube (spouts) and graduated cylinders
2) Turn on condenser water
3) Into 500-ml extraction flask, add glass beads, 2.5 ml HCl solution, and antifoam; set aside.
4) Weigh 10g of chicken pattie sample directly into homogenizer flask.
5) Add 50 ml distilled water with a graduated cylinder.
6) Homogenize for 1 minute, using a large centrifuge bottle.
7) Quantitatively transfer homogenate into 500-ml extracting flask and rinse with distilled water to bring total volume to 100 ml.
   * Total volume = 50 ml (meat & water) + 2.5 ml HCl + 47.5 ml = 100 ml
8) Turn powerstats to line voltage (setting 85) and heat flasks rapidly.
9) Distill and collect 50 ml of the distillate.
10) Transfer distillate into culture tubes, cap and hold in refrigerator for TBA reaction.

<u>TBA Reaction / Spectrophotometric Determination (perform within 18 hours)</u>

11) Invert each test tube containing the 50 ml distillate and pipette 5 ml into each of two tubes. Pipette 5 ml distilled water into two blank tubes.

12) Add 5 ml of TBA Reagent into each tube containing 5 ml of sample. Thoroughly mix each tube on a Vortex Genie shaker.

13) Immerse tube support containing tubes into boiling water bath for 35 mins.

14) Turn Spectrophotometer to IDLE (after warming up for at least 20 mins.)

15) When the tubes are done heating in the water bath, cool them in cold water for 10 mins.

16) Turn Spectrophotometer to ON: Manual adjust, just closed
Narrow slit control
Wavelength 532 nm (for poultry)

* Read within one hour *

17) Subtract blank averages from readings then multiply by 7.6 (from standard curve):

[Sample observance$_{532}$ – blank] x 7.6 = TBA number (mg malonaldehyde)

<u>Report</u>: $\frac{\text{mg malonaldehyde}}{\text{1000gm sample}}$ = mg/kg

APPENDIX C

TA.XT2I TEXTUROMETER SETTINGS

The TA.XT2I Texturometer (Stable Micro Systems Texture Expert, Version 07.12) from Textured Technologies (Hamilton, MA) was used to mechanically analyze the texture of the cooked chicken patties. The peak force is the maximum amount of force needed to shear through the cooked chicken pattie and typically is recorded in N/g. The settings used are as follows:

Mode:	Measure Force in Compression
Option:	Return to start
Pre-speed:	10.0mm/sec
Test speed:	2.0mm/sec
Post-speed:	10.0mm/sec
Distance:	40.0mm
Trigger:	Button
Probe:	HDP/KS5 Kramer Shear Cell 5 Blade
Load cell:	25Kg

APPENDIX D

TRAINED SENSORY EVALUATION FORM

Texture Profile Panel for Chicken Patties

Judge ______________________ Date __________ Time of Day __________

SAMPLE: One-fourth (1/4) wedge of chicken pattie, consumed at ~140°F.

A) **TENDERNESS**: Bite into product with incisors, making sure bite is from center point of pattie. Evaluate for amount of force required to bite through sample.

B) **JUICINESS**: Amount of juice released during mastication (10 chews).

TENDERNESS (Overall Impression)	*Reference*		JUICINESS (Overall Impression)	*Reference*
8 Extremely tender	(Cream cheese)		8 Extremely juicy	(Watermelon)
7 Very tender			7 Very juicy	(Apple) RCB
6 Moderately tender	(Colby cheese)	RCB	6 Moderately juicy	
5 Slightly tender	(Egg white)		5 Slightly juicy	(Ham)
4 Slightly tough	(Frankfurter)		4 Slightly dry	(Carrot)
3 Moderately tough	(Olive)	------------------------------	3 Moderately dry --------------	Well-done RCB
2 Very tough			2 Very dry	(Soft tortilla)
1 Extremely tough	(Peanut)		1 Extremely dry	(Saltine cracker)

SAMPLE	TENDERNESS	JUICINESS	COMMENTS
652			
891			
211			
703			
420			

RCB = Retail chicken burger

APPENDIX E

CONSUMER SENSORY EVALUATION FORM

INSTRUCTIONS: You will evaluate five chicken pattie samples for four characteristics, including **juiciness, texture, flavor and overall acceptability**. The following definitions may help you understand the terms:

JUICINESS: Is the chicken pattie juiciness desirable, or is it too dry?

TEXTURE: How desirable is the texture of the chicken pattie? Is it too soft, too hard, too mushy, or too brittle?

FLAVOR: Is the flavor desirable, or is it too bland or too spicy?

OVERALL ACCEPTABILITY: Your reaction to the overall satisfaction derived from the consumption of the chicken pattie.

SAMPLING PROCEDURES:
Please chew each sample 10-15 times. Using the rating scale below, write the number listed that best describes each characteristic for that sample in the boxes provided, then proceed to the next sample. A cup is provided for expectoration of samples and saltines and water are provided to cleanse and rinse the palette between samples. We encourage you to make comments about each sample in the appropriate space.

RATING SCALE:

8 **Extremely Desirable**
7 **Very Desirable**
6 **Moderately Desirable**
5 **Slightly Desirable**
4 **Slightly Undesirable**
3 **Moderately Undesirable**
2 **Very Undesirable**
1 **Extremely Undesirable**

SAMPLE NUMBER	JUICINESS	TEXTURE	FLAVOR	OVERALL ACCEPTABILITY
719				
261				
956				
358				
873				

Comments: ____

____

APPENDIX F

Moisture Management and Texture Enhancement in Chicken Patties Containing Methylcellulose

Linda Steinke

MS Defense
Michigan State University
November 30, 2001

Outline

- Introduction
  - Objective of research
  - Definitions
  - Non-meat ingredients - binders/extenders
    - Protein-based
    - Carbohydrate-based

11/01 2

Outline (continued)

- Materials and Methods
  - Experimental Design
  - Formulation
  - Chicken Pattie Process - Flowchart
  - Analyses
    - Proximate composition, pH, color, TBA
    - Cooked Yield
    - Dimensions
    - Shear Force
    - Sensory - trained and consumer

11/01 3

Outline (continued)

- Results and Discussion
  - Proximate composition, pH, color, TBA
  - Cooked Yields
  - Dimensions
  - Shear Force
  - Sensory - trained and consumer
- Conclusions
- Future Studies

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Objective

Determine the Effects of Methylcellulose on Moisture Management and Texture Enhancement in Chicken Patties

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What is Methylcellulose (MC)?

- Water soluble polymer - cellulose (trees)
- Binder, thickener, film former, fat replacer
- Unique Property - Gels when it's HOT
  - Thermally Reversible
    - Conventional (CM) - 50-55°C (122-131°F)
    - Supergelling (SG) - 38-44°C (100-111°F)
- MC limited to 0.15% in meat and poultry
  - Petitioning with USDA to expand approval

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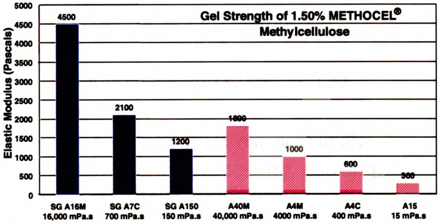
Supergelling vs. Conventional



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What is Moisture Management?

- Water holding capacity
- Matrix binding (cohesion)
- Syneresis & gel "tightening"
- Moisture retention
  - Cooked Yields
  - Package Purge
- Sensory - juiciness
  - Mechanical release from chewing

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What is Texture Enhancement?

- Tenderness vs. Toughness
- Firmness vs. Softness
- Springiness and Cohesiveness
- Juiciness
  - Juicy meat perceived more tender
- Ingredients, processing, cooking, and storage conditions

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What is a Chicken Pattie?

- 100% Ground Poultry within "natural proportions"
  - White (50-65%) and Dark (35-50%)
- Can be breaded or unbreaded
- Perceived as lower fat alternative to beef patties
- Salt, phosphate, water, spices, skin emulsion, and non-meat ingredients
  - Extend product, Manage moisture, or Enhance texture
- Products containing binders/extenders will be called "chicken patties" (USDA, 2001)

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Non-meat Ingredients

- Protein-based
  - Soy Proteins
    - Soy protein concentrate
    - Isolated soy protein
  - Milk Proteins
    - Whey Protein Conc
    - Sodium Caseinate
  - Hydrolyzed Proteins
  - Transglutaminase
  - Gelatin
- Carbohydrate-based
  - Starches
  - Hydrocolloids
    - Alginates
    - Carrageenan
    - Xanthan
    - MC and HPMC

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Materials and Methods

- Experimental Design
  - Two-level two-variable factorial with augmented Control = five treatments
    - Control - no gum
    - SG at 0.25%
    - SG at 0.50%
    - CM at 0.25%
    - CM at 0.50%
  - Statistically analyzed, reporting least square means
  - Three repetitions of the five treatments

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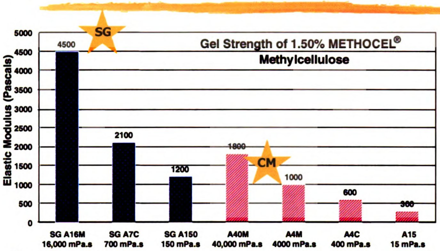
Supergelling vs. Conventional



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Formulation for Chicken Patties

	CONTROL		0.25% MC		0.5% MC	
INGREDIENTS	%	Kg	%	Kg	%	Kg
Chicken Breast	38.20	8.67	38.08	8.66	37.95	8.65
Chicken Thigh	38.20	8.67	38.08	8.66	37.95	8.65
Skin Emulsion	10.00	2.27	10.00	2.27	10.00	2.27
Skin	*5.70*	*1.29*	*5.70*	*1.29*	*5.70*	*1.29*
Water	*3.80*	*0.85*	*3.80*	*0.85*	*3.80*	*0.85*
SPC	*0.50*	*0.13*	*0.50*	*0.13*	*0.50*	*0.13*
Meat Block Total	*86.40*	*19.61*	*86.15*	*19.59*	*85.90*	*19.57*
Marinade						
Salt	0.75	0.08	0.75	0.08	0.75	0.08
Water	12.00	1.36	12.00	1.36	12.00	1.36
Phosphate (STPP)	0.35	0.04	0.35	0.04	0.35	0.04
Black pepper	0.25	0.03	0.25	0.03	0.25	0.03
Onion powder	0.25	0.03	0.25	0.03	0.25	0.03
Methylcellulose (MC)	0.00	0.00	0.25	0.03	0.50	0.06
Non-meat Ingredients Total	*13.60*	*1.54*	*13.85*	*1.57*	*14.10*	*1.60*
TOTAL	100.00%	21.15Kg	100.00%	21.16Kg	100.00%	21.17Kg

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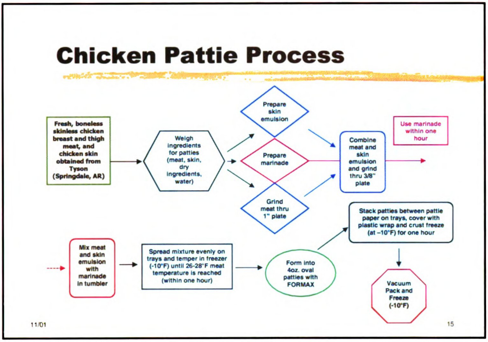
Chicken Pattie Process
Fresh, boneless skinless chicken breast and thigh meat, and chicken skin obtained from Tyson (Springdale, AR)
Weigh ingredients for patties (meat, skin, dry ingredients, water)
Prepare skin emulsion
Prepare marinade
Grind meat thru 1" plate
Combine meat and skin emulsion and grind thru 3/8" plate
Use marinade within one hour
Mix meat and skin emulsion with marinade in tumbler
Spread mixture evenly on trays and temper in freezer (-10°F) until 26-28°F meat temperature is reached (within one hour)
Form into 4oz. oval patties with FORMAX
Stack patties between pattie paper on trays, cover with plastic wrap and crust freeze (at –10°F) for one hour
Vacuum Pack and Freeze (-10°F)
11/01
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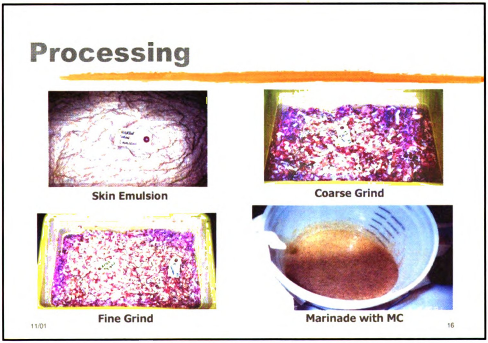
Processing
Skin Emulsion
Coarse Grind
Fine Grind
Marinade with MC
11/01
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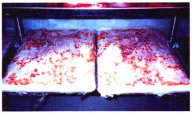
Processing

Tumbler

Mixing poultry & marinade



Chilling before forming

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Processing

FORMAX F6

Making patties

11/01

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Analyses

- Proximate Composition, pH, Color, TBA
  - Moisture, Fat, and Protein (MFP)
- Cooked Yields
- Dimensions
- Shear Force
- Sensory - Trained and Consumer

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Proximate Composition, etc.

- % Moisture *
- % Fat *
- % Protein *
- pH
  - Raw
  - Cooked
- Color (raw)
  - Lightness
  - Redness
  - Yellowness
- TBA (Thiobarbituric Acid)
  - Effect of treatment
  - Effect of storage (56 days)

* AOAC methods followed

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Cooked Yield

- 350°F steam-injected convection oven
- 6 minute cook (165°F internal)
- Blot excess surface moisture
- Weigh before and immediately after

Raw patties

Cooked patties

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Shear Force

- Three patties/treatment
- Cooked to 165°F internal in steam/convection oven
- Two 25 x 70mm samples per pattie
- Tested hot (145-165°F)
  - Measure MC HOT Gel
  - Correspond with Sensory
- Force to penetrate measured in Newtons/g

TA.XT2 Texturometer

Kramer Shear 5-blade cell

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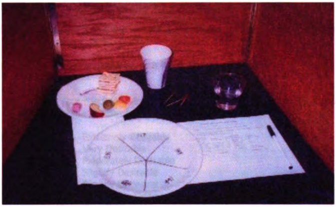
Trained Sensory Set-up



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Trained Texture Profile for Chicken Patties

Judge ____________ Date ________ Time of Day ________

SAMPLE: One-fourth (1/4) wedge of chicken pattie, consumed at ~140°F.

A) **TENDERNESS:** Bite into product with incisors, making sure bite is from center point of pattie. Evaluate for amount of force required to bite through sample.

B) **JUICINESS:** Amount of juice released following 10 chews.

	TENDERNESS (Overall Impression)	Reference		JUICINESS (Overall Impression)	Reference
8	Extremely tender	(Cream cheese)	8	Extremely juicy	(Fresh watermelon)
7	Very tender		7	Very juicy	(Apple) Retail chicken burger
6	Moderately tender	(Colby cheese)	6	Moderately juicy	
5	Slightly tender	(Egg white)	5	Slightly juicy	(Ham)
4	Slightly tough	(Frankfurter)	4	Slightly dry	(Carrot)
3	Moderately tough	(Olive)	3	Moderately dry	Well-done retail chicken burger
2	Very tough		2	Very dry	(Soft tortilla)
1	Extremely tough	(Peanut)	1	Extremely dry	(Saltine cracker)

SAMPLE	TENDERNESS	JUICINESS	COMMENTS
652			
891			
211			
703			
420			

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Consumer Sensory Panel

JUICINESS: Is the chicken pattie juiciness desirable, or is it too dry?

TEXTURE: How desirable is the texture of the chicken pattie? Is it too soft, too hard, too mushy, or too brittle?

FLAVOR: Is the flavor desirable, or is it too bland or too spicy?

OVERALL ACCEPTABILITY: Your reaction to the overall satisfaction derived from the consumption of the chicken pattie.

RATING SCALE:

8 Extremely Desirable
7 Very Desirable
6 Moderately Desirable
5 Slightly Desirable
4 Slightly Undesirable
3 Moderately Undesirable
2 Very Undesirable
1 Extremely Undesirable

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Results and Discussion

- Proximate Composition, pH, Color, TBA
- Cooked Yield
- Dimensions
- Shear Force
- Sensory - Trained and Consumer

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Results and Discussion

- Proximate Composition
  - Raw MFP
    - % Protein - Control > MC
  - Cooked MFP
    - % Moisture
      - CM at 0.25% & Control
      - Agrees w/ Cooked yields
  - pH - raw and cooked
    - NSD - MC is nonionic
- Color
  - Lightness
    - Control slightly darker
  - Redness - NSD
  - Yellowness - NSD
- TBA
  - Effect of treatments - NSD
  - Effect of storage
    - Oxidative rancidity increased over 56 days for all five treatments

NSD = Not significantly different

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Results and Discussion

- COOKED YIELD
  - Similar results within the five treatments
    - 3% difference between the least square means
  - "Prior art" indicates substantial losses w/ MC
    - MC did NOT cause a critical reduction in cooked yield in these chicken patties
  - May consider cooking more patties (>20) next time to realize full potential (ex. Large poultry processor)

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Results and Discussion

- DIMENSIONAL CHANGES
  - Raw - NSD
  - Cooked
    - Length and width - NSD
    - Thickness of patties significantly different
      - Control - 25% reduction - thinnest patties!
      - SG - 16-17% reduction
      - CM - 11-12% reduction - thickest patties!
  - Dimensions readily apparent to consumers
    - Sandwich height and meat portion thickness

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Results and Discussion

Dimensional Changes and Cooked Yield

	Methylcellulose Type					
	Control	SG		CM		
		Concentration (%)				
		0.25	0.50	0.25	0.50	SEM [c]
Raw Thickness [NS]	9.5	9.3	9.4	9.3	9.3	0.2
Cooked Thickness	7.2 [b]	7.8 [ab]	7.9 [a]	8.3 [a]	8.2 [a]	0.2
% Retention	75.7 [b]	83.5 [ab]	84.3 [ab]	89.1 [a]	87.8 [a]	2.5
% Cooked Yield	74.7 [ab]	74.1 [ab]	73.1 [b]	75.6 [a]	74.3 [ab]	0.4

[ab] Least square means having different superscripts within rows are significantly different ($P<0.05$)
[c] SEM = Standard error of the means
[NS] Model not significant

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Results and Discussion

- SHEAR FORCE
  - Less force to penetrate MC patties
    - Thickness of patties - density
      - Control patties thinnest - ↑ force to penetrate
      - MC patties more plump - ↓ force to penetrate
    - Dilution of protein network by MC
  - 0.25% and 0.5% MC gave similar results
  - Gel strength difference between SG and CM appears not to be a factor

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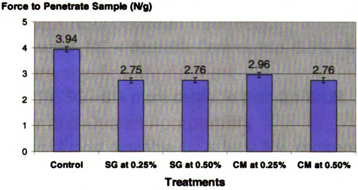
Results and Discussion

25-30% less force to penetrate MC patties



Least square means with standard error of the mean

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Results and Discussion

- TRAINED SENSORY
  - Juiciness NSD between treatments (P<0.50)
    - However, 0.5% MC > Control
  - Tenderness was significantly different (P<0.05)
    - SG at 0.5% was 13% more tender than the Control
  - Higher cooked yields do not necessarily mean patties are perceived to be more juicy

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Results and Discussion

- CONSUMER SENSORY
  - Juiciness NSD between treatments
    - However, MC < desirable Control, esp. 0.5% MC
  - Texture significantly different
    - 0.25% SG ~8% more desirable than 0.5% CM
  - Flavor and Overall Acceptability
    - Control most desirable, by at least 8%, compared to CM
    - 0.25% SG next most desirable
    - 0.5% CM least desirable

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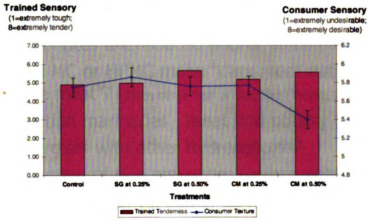
Sensory - Tenderness vs. Texture



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Conclusions

- 25-30% less force to penetrate MC patties
  - Trained tenderness results similar, yet NSD
- Perceived Juiciness similar, even when cooked yields were slightly reduced
- 15% ↑ in thickness with MC = "plumpness" for center-of-plate entrees
- 0.5% or less of MC recommended for these positive attributes

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Future Studies

- Determine functionality of MC and HPMC when phosphates are reduced and/or eliminated
- Does MC or HPMC make "dark meat eat like white meat"? Utilize other half of the bird (Tyson, 2001)
- Injection marinades - meat and poultry (USDA)
- Synergism with other hydrocolloids?
- Reduction of skin emulsion; replace w/MC?
- Effect of partial vs. complete hydration of MC

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Thank you!

- Colleagues at MSU
  - Dr. Mark Uebersax
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  - Dr. Don Coffey
  - Jerry Conklin
  - Stephanie Lynch
  - Diane Brown
  - Jeff Sweeney
  - The Food Lab

Together Each Achieves More!

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