AN ABSTRACT OF THE THESIS OF

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Replacer in a Ground Meat System.

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A.M. Pearson

The effect of adding a high moisture gel manufactured from a combination

of konjac flour (2%) and kappa carrageenan (1%) to a reduced fat ground beef

system was evaluated. Lean beef (95-10) and 50-50 fat beef trimmings were used

to manufacture reduced fat ground beef patties containing konjac flour/carrageenan

(K/C) gel at varying levels (5% fat/15% K/C gel; 10% fat/10% K/C gel; 15% fat/5%

K/C gel) and compared to a 20% fat (0% K/C gel) control.

With experienced panelists, the addition of 5% K/C gel did not significantly

effect mean scores for the palatability characteristics (aroma, juiciness,

texture/mouthfeel), although it did significantly ($p \leq 0.05$) change mean scores for the

visual characteristics (cooked color, visible gel and overall appearance). Increasing

the amount of K/C gel to 10% did not result in any significant difference in mean

scores of the various palatability characteristics. There were, however, significant

differences ($p \leq 0.05$) in mean scores of the visual traits when compared to control

patties. Mean scores for both the visual and palatability characteristics for the 15%

added K/C gel treatment were significantly lower (p≤ 0.05) than either the 5% or 10% fat K/C gels or the control.

A similar trend existed in consumer acceptability and purchase intent sensory tests. Results indicated that the K/C gel could be utilized to reduce fat levels from 20% to 10 and 15% without any significant effect upon acceptability. Further reduction of fat level to 5% by adding 15% K/C gel, however, resulted in a significant reduction (p≤ 0.05) in consumer acceptability and desire to purchase.

There were no significant differences (p>0.05) in cooking yields between the control (20% fat) and the reduced fat treatments (5, 10 and 15% fat). Mean surface area, however, was increased significantly (p≤0.05) as the level of K/C gel was increased.

There were no significant differences for Hunter colorimeter L-values for reflectance between treatments or the control. However, mean scores for both the a-value (redness) and the b-value (yellowness) were significantly lower in all treatments than in the control patties indicating a shift towards a gray (neutral) color as the amount of K/C gel increased. There was no significant difference between the 10% (10% K/C gel) and 15% fat (5% K/C gel) for either redness (a-value) or yellowness (b-value).

Konjac Flour/Carrageenan Gel as a Suitable
Fat Replacer in a Ground Meat System

by

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Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Robert L. Dickson, Author

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Dedicated in the memory

of

Mike and Sue Lawrence

and

Chet Munson

They passed so quickly through our lives, but while

they were here, they made such a difference.

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INTRODUCTION

Consuming diets containing high levels of fats have been linked to higher risks of colon cancer, cardiovascular diseases and several other dietary related disorders (NCI, 1984; Giese. 1992). As the general population became more concerned about reducing these risks, per capita consumption of animal fats and red meats have declined (USDA, 1984; Anonymous, 1985).

The desire by consumers for reduced fat products has driven the meat processors and retailers to try and meet the demand by simply removing the fat from ground meat systems (Sweeten et al. 1990; Taki, 1991). Some processors have utilized non-digestible, zero calorie bulking agents to replace as many high calorie ingredients as possible (Best, 1987; Summerkamp and Hesser, 1990). Typically, ground beef contains between 20 and 30% fat (Huffman et al., 1991). As the fat content is reduced below the 20% level down to 10% or less, there have been noted declines in tenderness, flavor, juiciness, satiety and overall acceptability (Egbert et al. 1991; Taki, 1991).

Since fat is a reservoir for flavor components and is a direct contributor to product texture and juiciness, altering the amount of fat in the initial formulation can lead to adverse affects on the final product (Foegeding and Ramsey, 1986; Taki, 1991; Miller *et al.*, 1993). For example, lowering the fat content in products such as wieners has been reported to increase toughness (Sofos and Allen, 1977; Paul and Foget, 1983). To compensate for decreases in the favorable palatability characteristics of meat products as the fat level goes down, reduced fat ground meat systems have been extended using non-meat ingredients, such as hydrocolloids, or gums as they are referred to more commonly. The term gum refers to a wide variety of products from both plant and microbial origin, certain proteins of animal origin, and some chemical derivatives from cellulose (Andres, 1975).

Hydrocolloids function by retaining moisture in the final product, thereby enhancing texture, tenderness and juiciness. Because of their creaminess, smoothness and lubricating effects, hydrocolloids tend to mimic the organoleptic characteristics found in fat (Glicksman, 1991). Many may even function as dietary fiber, providing health benefits normally attributed to products containing high levels of soluble and insoluble fibers (Best, 1987).

The use of a hydrocolloid gel made from a mixture of konjac flour and carrageenan was investigated in this study. The objective was to evaluate the feasibility of incorporating varying levels of a gel made from konjac flour and

carrageenan into a reduced fat ground meat system, and to determine the physical and organoleptic characteristics of the final product.

LITERATURE REVIEW

DIETARY FATS

Consumption of fat in the United States has become a major issue to consumers wishing to lead a healthy lifestyle (Briggs and Schweigert, 1990; Taki, 1991). On one hand, fats make a significant contribution to product palatability, smoothness, mouthfeel and as a source of energy in the diet, supplying 9 kcal/g of fat consumed (Dziezak, 1989). Fat also aids in the transfer of heat during the cooking process, provides a feeling of fullness or satiety after eating, acts as a carrier for fat soluble vitamins, and provides a source of essential fatty acids (Dziezak, 1989; Kennedy, 1991; Swanson et al., 1994).

On the negative side, much attention has been focused on the relationship of diets rich in animal fats, specifically to the intake of certain fatty acids, blood cholesterol levels, and certain diseases (Breidenstein, 1988; Sweeten et al., 1990). High levels of fat in the diet and sedentary life style habits have been identified as potential risk factors, and a significant link has been demonstrated between over consumption of fats and hypercholesterolemia, stroke, heart disease and some forms of cancer (Cohen,

1985; Cronin and Shaw, 1988; McNamara, 1985; Lewis, 1988; Sweeten *et al.*, 1990; Gerrietts, 1992). It is estimated that Americans consumer approximately 37% of their total calories as fat, much higher than the 30% recommended by health professionals (Cronin and Shaw, 1988; Summerkamp and Hesser, 1990).

CHOLESTEROL AND FATTY ACIDS

The significance of raising or lowering blood plasma cholesterol levels was demonstrated by Kannel *et al.* (1971). Their results indicated a corresponding 2% increase or decrease in coronary heart disease as blood plasma cholesterol levels were increased or decreased by 1%, respectively.

There is evidence that the longer chain fatty acids, such as oleic (C18:1) and stearic (C18:0), have no effect in raising serum cholesterol levels (Grundy, 1986; Bonanome and Grundy, 1987: Bonanome and Grundy, 1988). On the other hand, the shorter saturated fatty acids, such as lauric (C12:0), myrisitc (C14:0) and palmitic (C16:0), result in elevated levels of serum cholesterol (Hegsted *et al.* 1965). Saturated fatty acids shorter than 12 carbons in length have been demonstrated to have no effect on increasing serum cholesterol levels, as they are metabolized by different metabolic pathways than the longer chain fatty acids. Keys *et al.* (1965) demonstrated that fatty acids are absorbed via intestinal capillaries into the portal blood stream. However, once in the

liver, the shorter chain fatty acids were, for the most part, oxidized rather than elongated. Thus, the short chain fatty acids have no effect on increasing serum cholesterol levels (Grande, 1962). Because of these relationships, health care professionals have recommended reducing the amount of red meat consumed as a way of reducing saturated fats and cholesterol in the diet, and increasing the use of foods, which are higher in both monounsaturated and polyunsaturated fatty acids (Breidenstein, 1988.)

Trends indicate that consumers have increased the amount of reduced or low-fat animal products, such as lean meats, low fat milk, poultry and fish in an effort to reduce total fat consumption (NRC, 1988; Summerkamp and Hesser, 1990).

PALATABILITY CHARACTERISTICS

In spite of these health related issues, consumers have found it difficult to give up the desirable characteristics found in higher fat foods. Ground beef typically contains between 20 and 30% fat. As the fat level is reduced below the 20% level, there is a corresponding decline in taste panel scores for tenderness, juiciness, texture, flavor, appearance and overall acceptability (Mize, 1972; Berry and Leddy, 1984). This is especially true when fat levels are decreased below the 5% level as demonstrated by Troutt *et al.* (1992). Fats are essential to the overall eating satisfaction by consumers as they contribute

to the feeling of fullness or satiety (Schneeman, 1987; Pearson *et al.*, 1987). Fat contributes to mouthfeel and provides lubrication for the mastication process (Gaddis *et al.* 1950; Weir, 1960; Dikeman, 1987; Hedrick *et al.*, 1994).

JUICINESS IN MEAT

Juiciness in meat is a highly subjective, complex and personal sensory experience based upon individual perceptions and physical responses derived from mastication (Christensen, 1984). Although current evaluation of juiciness is made as a single measurement (Harris *et al.*, 1972; Dransfield *et al.*, 1984), most contend that two factors are involved in the sensation of juiciness in meat (Bratzler, 1971; Cover *et al.*, 1962; Cross, 1987; Weir, 1960). The first, is the initial impression of wetness generated by the early, rapid release of fluid from the meat during the first few chews (Cover *et al.*, 1962; Bratzler, 1971). The second, is the sustained sensation of moistness created by the release of serum from the meat and stimulation of the salivary glands by fat during continued chewing (Bratzler, 1971).

Because juiciness is so important to the overall acceptability and eating quality of meat, there has been an effort to correlate mechanical measures of juiciness with those achieved from sensory evaluation (Szczesniak, 1963; Jowitt, 1974; Dransfield *et al.*, 1984). Although initial juiciness is important, most studies have shown a closer correlation between juiciness and mechanical

measurements (Cross, 1987). It also has been indicated that initial fluid release is affected by the degree of doneness and method of cooking, while the impression of sustained juiciness is related intramuscular fat Cross (1987). Smith *et al.* (1982) suggested that more mature animals with higher intramuscular fat levels had higher panel scores for juiciness than younger animals. Meat from younger animals with little intramuscular fat (e.g. veal) gives an initial perception of juiciness, while have a dry mouthfeel for sustained juiciness (Cross, 1987). As the amount of true intramuscular fat in trim used for ground bee goes up or down, there may be more juiciness, flavor and less shrinkage because this type of fat is heat-extracted less readily than added fat even when the fat percentages are the same prior to cooking (Kaufmann and Marsh, 1987). Because of these factors, any correlation between subjective and objective measurements of juiciness in meat remains relatively low (Cross, 1987; Hamm, 1960).

MUSCLE STRUCTURE

According to Cassens (1987), skeletal muscle is made of long, multinucleated thread-like fibers arranged in a parallel manner to form muscle bundles. He further stated, fiber diameter can be as small as 1 μm and as large

as 100 μm, while length may be as short as 1 mm to as long as 40 mm. Muscle fibers normally do not, however, extend the full length of the muscle (Cassens (1987).

The myofibril is the basic component of the muscle fiber, and is composed of long, thin, cylindrical rod-shaped filaments (Hultin, 1985). The long axis of the myofibril lies parallel to the long axis of the muscle fiber, and is traversed by the Z-line, which divides the myofibril into regular repeating units called sarcomeres (Hultin, 1985; Bechtel, 1986; Cassens, 1987). The sarcomere, which is the contractile unit of the myofibril, is composed of both myosin (thick) and actin (thin) myofilaments aligned parallel to the axis of the myofibril (Bechtel, 1986). Actin myofilaments are anchored at the Z-line and extend towards opposing Z-lines overlapping the myosin myofilaments at specific regions of the sarcomere (Hultin, 1985). This arrangement is often referred to as the sliding filament structure of the myofibril (Bechtel, 1986).

Each region of the sarcomere can be differentiated under the light microscope using polarized light depending on overlapping of the thick and thin myofilaments (Cassens, 1987). Where there is overlapping, the region appears darker and is anisotropic, while those lighter regions where only actin myofilaments are present are isotropic (Hultin, 1985). As a result of these properties, the anisotropic and isotropic regions have been termed the A-band and I-Band, respectively (Hultin 1985; Cassens, 1987). A narrow, light colored area in the center of the sarcomere, which occurs when the actin does not

completely overlap the myosin myofilament, is termed the H-band (Cassens, 1987). The banding of each sarcomere, as well as the alignment of the myofibrils and muscle fibers give the appearance of cross striations to the muscle fiber, hence the appearance of striated muscle (Cassens, 1987).

THE STATE OF WATER IN MEAT

The myofibrillar substructure described above is responsible for retention of the majority of water in muscle tissue (Honikel and Hamm, 1994). The ability of meat or meat systems to retain moisture is called water holding capacity or WHC (Hamm, 1960; Honikel and Hamm, 1994). At slaughter, lean muscle contains between 70 and 75% water (Offer and Trinick, 1983). Furthermore, any reduction in total water retained by meat may adversely affect consumer satisfaction as it may cause a marked reduction in tenderness, juiciness and overall eating satisfaction (Hamm, 1960; Hamm, 1975).

It is apparent that proteins play a central role in the mechanism of water binding in meat (Hamm, 1960; Wismer-Pedersen, 1987). This is especially true of the myofibrillar proteins because of both their chemical and physical nature (Wismer-Pedersen, 1987; Offer and Trinick, 1983). Of major importance are myosin and tropomyosin, which are composed of both acidic and basic (amphoteric) amino acids, and thus depending on the pH of the meat confer an increased charge (group-dipole) on the protein molecules (Busk, 1984; Wismer-

Pedersen, 1987). This dipole causes binding of water to the proteins, and since water is a good insulator, water to water binding occurs in concentric regions or hydration shells around the proteins (Wismer-Pedersen, 1987). The hydration shells may be characterized as constitutional or interfacial water depending on the protein composition, proximity of the water to the protein molecule and the orientation of the water molecules (Hamm, 1986; Wismer-Pedersen, 1987; Honikel and Hamm, 1994). Both constitutional and interfacial water make up a very small amount of total tissue moisture, averaging less than 0.1% for constitutional and between 5 and 15% for interfacial water (Hamm, 1986; Honikel and Hamm, 1994). The largest proportion of water in the muscle cell is termed bulk phase or free water, which is held within the cellular structure, but is not directly influenced by charge from the myofibrillar proteins (Hamm, 1986; Honikel and Hamm, 1994).

In addition, a small amount of moisture ($\simeq$ 10% of the total in living muscle) exists within the extracellular space of muscle (Hamm, 1960). The amount of extracellular water depends on the degree of swelling, or lack thereof in the muscle fibers (Hamm, 1986).

The final pH of muscle after slaughter has a direct effect on the ability of the muscle tissue to hold water (Hamm, 1986). As the pH of the meat approaches 5.0, the net charge of the myofibrillar proteins nears its isoelectric point (pI) where the net charge of the proteins equals zero (Hamm, 1986). Because of the attraction between the myofibrillar proteins, there is only limited

space that can be occupied by water (Hamm, 1986). Changing the pH of the meat, either slightly above or below it's pI, causes a change in the charge on the proteins, such that an electrostatic repulsion of the proteins occurs enlarging the area of the myofibril that water may occupy (Hamm, 1986; Honikel and Hamm, 1994).

Work done by Offer and Trinick (1993) using myofibrils from rabbit psoas muscle further supported the idea that water is held within the myofibrils. They pointed out that the amount of water held can be increased by changing the net charge of the protein molecules and increasing the interstital space of the myofibrils.

FAT REPLACERS

According to Swanson and Akoh (1994), fat replacers are chemically similar to carbohydrates, proteins and/or fats, and can be grouped in two categories: (1) fat mimetics, and (2) fat substitutes. In their review, fat mimetics are defined as "Compounds that replace the mouthfeel, body and bulk of fats, but do not replace fat on one to one basis. . .', while they define fat substitutes as "-compounds that physically and chemically resemble triglycerides, and can theoretically replace fat on a one to one, gram for gram basis." They further divide the two groups by the fact that fat mimetics imbibe high levels of moisture

and are not considered to be heat stable, while fat substitutes are stable at cooking and frying temperatures.

Fat mimetics can be divided further into constituent categories such as starch based, cellulose based, pectin based, protein based and hydrocolloids. Their main functions are to reduce fat and thus reduce total caloric intake (Swanson and Akoh, 1994). Some categories may be beneficial to consumers by adding potentially healthful fiber to the diet as well as decreasing the amount of caloric intake (Best, 1987; Todd et al., 1989).

There is also evidence that product yields can be increased when using certain cellulose based mimetics, while use of some soluble gums were as effective in holding moisture during the cooking process (Todd et al., 1989).

Hydrocolloids have been mainly used as texture modifying agents and have only recently gained acceptance in fresh and processed meat production (Mandigo and Eilert, 1994). Within This category, each component has different structural, textural and water retaining capacities that make each valuable when used either by itself, or in combination with other hydrocolloids (Wallingford and Labuza, 1983; Foegeding and Ramsey, 1986).

MOISTURE RETENTION IN HYDROCOLLOIDS

As is the case when considering water binding by muscle, water enclosed in the three dimensional structure of a gel can be considered to be either in a

free form on in some way bound or entrapped by the gel structure (Labuza and Busk, 1979). The amount of water held by the gel is normally considered to be the Water Holding Capacity (WHC) of the gel, although the term Water Binding Capacity (WBC) has been employed interchangeably in the literature (Labuza and Busk, 1979; Rey and Labuza, 1981; Wallingford and Labuza, 1983). Both terms refer to the ability of the hydrocolloid to hold water under certain conditions (Wallingford and Labuza, 1983).

More specifically, the WHC of a hydrocolloid may be considered to be the amount of water which is picked up and held or retained within the boundaries of the gel such that exudate is prevented, and is, thus, directly related to the moisture content of the gel (Fennema, 1985; Rey and Labuza, 1981). The WBC refers to the ability of the hydrocolloid to retain water when physical stress such as centrifugation is applied (Rey and Labuza, 1981; Wallingford and Labuza, 1983).

The term "bound" water has also been used describe water held in a gel that has properties differing from that of free or bulk water (Wallingford and Labuza, 1983). Since many hydrocolloids have the ability to form gels at very low concentrations (0.5-1-0%) and physically bind water into three-dimensional structures, the water held by these gels exhibits characteristics very similar to those of free water (Whitney, 1977). This water, however, is not easily removed when stressed or in some cases by heating (Labuza and Busk, 1979; Wallingford and Labuza, 1983; FMC, 1994).

CARRAGEENAN

Carrageenan is the name applied to a group of linear, high molecular weight galactan polysaccharides derived from the red seaweeds of the *Gigartinacae, Hypneaceae, Solieriaceae, Phllophoraceae* and *Furcellariaceae* families (Glicksman, 1979; FMC, 1993; Therkelsen, 1993). Carrageenans are characterized by repeating galactose units, joined together by alternating (1-3) alpha-ᴅ and (1-4) beta-ᴅ-glycosidic linkages, and depending on the fraction, an ester sulfate content of between 15 and 40% (Glicksman, 1983; FMC, 1988b; FMC, 1993; Therkelsen, 1993). The basic disaccharide backbone structure exists in all forms of carrageenan, but solubility and functionality are altered by (1) the degree and position of the sulfate ester, (2) the presence or absence of a 3-6 anhydrogalactose (3-6 AG) unit, and, (3) the species from which the carrageenan is extracted (Moirano, 1977; Glicksman, 1983; Therkelsen, 1993).

Three major carrageenan fractions have been identified are listed with their respective structures in Figure 1. Four minor carrageenan fractions (Figure 1) have been identified, and it is apparent from their structures that they are precursors of the major fractions (Rees, 1977; Glicksman, 1983). The kappa and iota fractions may further be differentiated by the presence of a half sulfate ester at the 2-O position on the anhydrogalactopyronosyl unit in the iota

fraction, and the lack of the sulfate ester at the 2-O position in the kappa fraction (Glicksman, 1983; Therkelsen, 1993).

Normally, the D-galactopyronosyl units of carrageenan would assume the chair conformation ($^4C_1$), since this reduces steric repulsion to a minimum by placing all substituents in the axial position (Rees, 1977). In the kappa and iota carrageenan fractions, the formation of a 3-6 anhydro ring on the beta-D-galactopyronosyl unit changes the residue conformation to the $^1C_4$ configuration, allowing for greater rotation about the equatorially aligned glycosidic bonds (Rees, 1977; Therkelsen, 1993). Because of these changes, the carrageenan polymer now has the capability to form helical structures (Rees, 1977).

Although considered to be a repeating disaccharide, the basic residues of the carrageenan structure indicated above, can alternate changing the structure of the polymer into regions with repeating regularity separated by areas with either a different type of regularity or no regularity at all (Rees, 1977; Therkelsen, 1993). This type of arrangement is termed and "interrupted sequence" and is illustrated by the presence of the galactose 2,6-sulphate residue in place of the 3,6-anhydrogalactose 2-sulphate residue as shown in Figure 2 (Rees, 1977). The presence of the 2,6-sulphate residue in place of the 3,6-anhydro rings has a profound affect on the orientations that can be achieved by the polymer and its ability to form the helix required to form a gel (Rees, 1977; Morris, 1979).
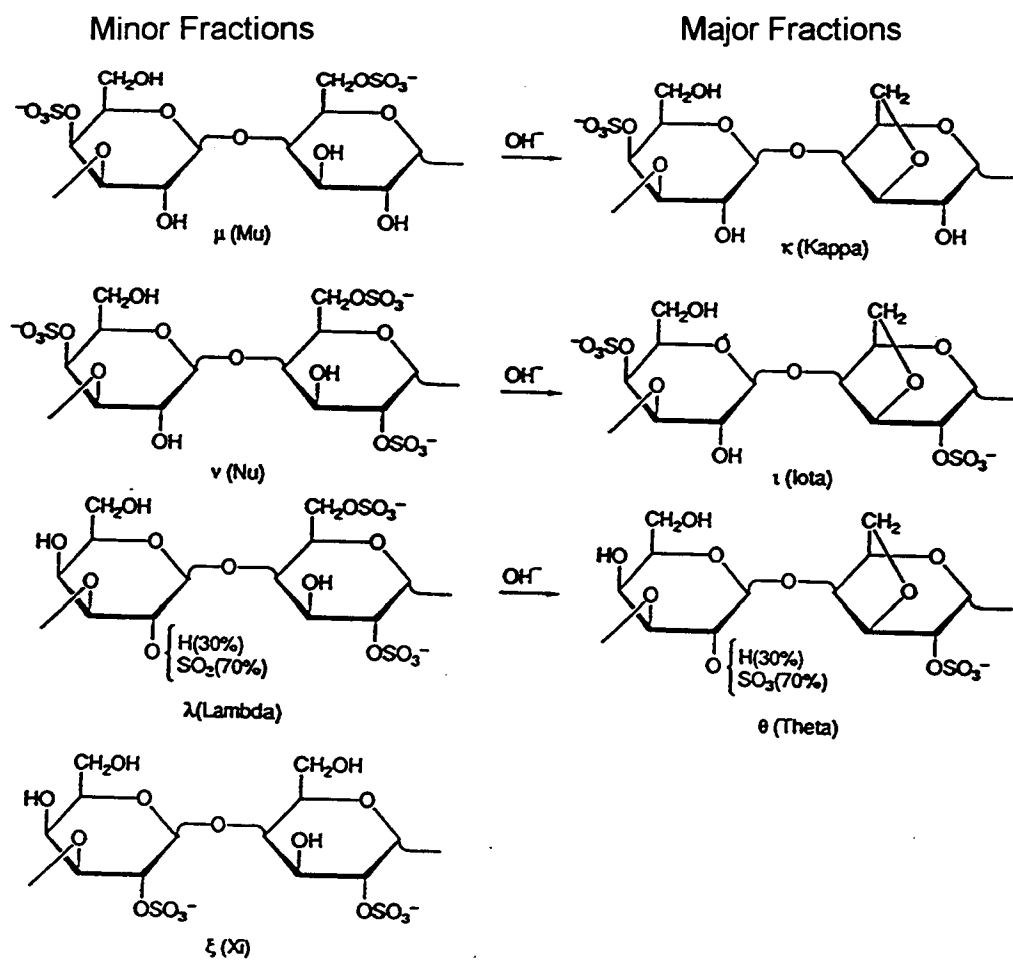
Figure 1. Minor and major structures of the basic carrageenan repeating units (Therkelsen, 1993).

κ Carrageenan

4-O-Sulfato-β-D-galactopyranosyl unit   3,6-Anhydro-α-D-galactopyranosyl unit

ι Carrageenan

4-O-Sulfato-β-D-galactopyranosyl unit   3,6-Anhydro-2-O-sulfato-α-D-galactopyranosyl unit

λ Carrageenan

2-O-Sulfato-β-D-galactopyranosyl unit

2,6-Di-O-sulfato-α-D-galactopyranosyl unit
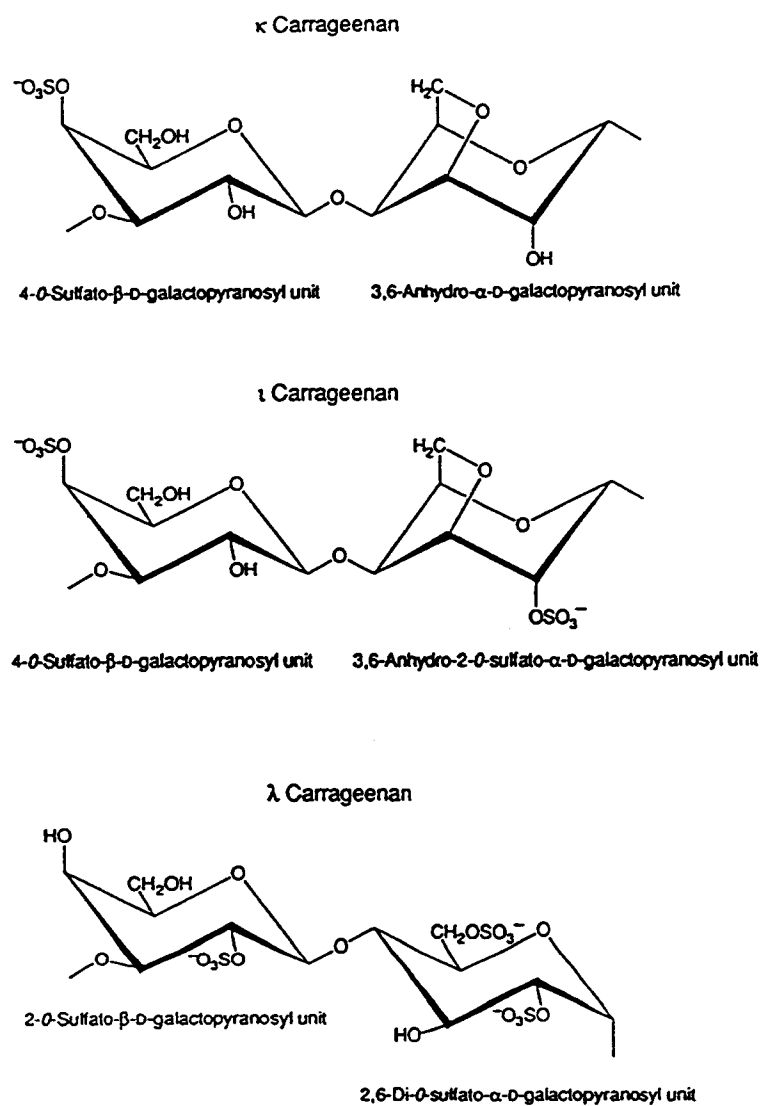
Figure 2. Stereochemical representation of the basic carrageenan repeating units and their conformation changes (Therkelsen, 1993).

Both kappa and iota carrageenan are insoluble in cold water and must be heated to above 70° C. in order to be solubilized (Glicksman, 1983; FMC 1993). In solution, the carrageenan polymers exist in random coils with no distinct orientation as to polymer structure (Rees, 1977; FMC, 1990; Therkelsen, 1993). Each polymer contains several helix forming regions, with a typical chain containing between 8 and 10 such areas (Rees, 1977). In order for conversion from the random coil to the helical arrangement to proceed after heating, the solution must cool, allowing the helix forming areas to align and nucleate with other helix forming regions (Figure 3), but not necessarily involving the same chain, and cross-link forming junction zones (Dea et al., 1972; Rees, 1977). Additional cooling leads to aggregation of these junctional zones and formation of a three-dimensional cross-linked structure (Glicksman, 1983).

As indicated above, the presence of the 2,6-sulphate residue in place of the anhydro ring residue causes a kink in the helical area of the polymer, preventing helix formation (Rees, 1977). Preparations of carrageenan can be manufactured such that there are no 2,6-sulphate residues present, but because they form a continuous helical structure, there is no gel formation (Rees, 1977). These kinks represent a biological system in which multiple carrageenan residues interact with one another to form a three dimensional structure of pores and channels in which water may be held (Rees, 1977). Properties of the gel like pore size, strength, rigidity and brittleness are determined by the placement of the 2, 6-sulphate residues (Rees, 1969;
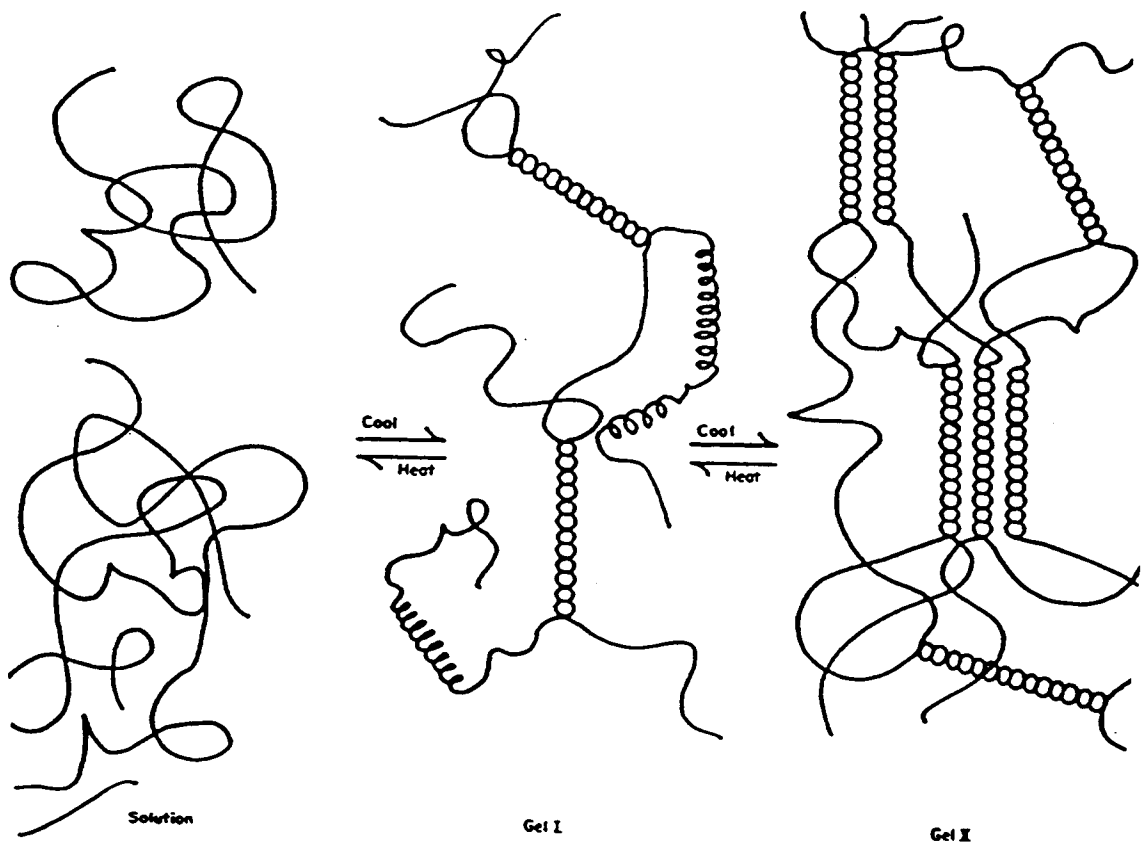
Figure 3. Proposed gelation mechanism for carrageenan (Rees, 1969)

Rees, 1977). Models of the double helix structures of both the iota and kappa fractions demonstrate that the strands of the helix are bound together by hydrogen bonding between the 0-2 and O-6 of the respective units (Rees, 1977; Therkelsen, 1993).

Of the major fractions, only kappa and iota carrageenans have the ability to form gels (Rees, 1969; Therkelsen, 1993). The presence of a sulphate moiety on the C_2 of the 1,3-linked galactose units (Figure 2) acts as a wedging unit, inhibiting helix formation in lambda carrageenan, and, therefore gel formation as well (Moirano, 1977; Glicksman, 1983; FMC, 1988a; FMC, 1991). The sulfate on the C_2 of the 3,6-anhydrogalactose residue and sulfate on the C_4 of the 1,3-galactose residue project outward, and therefore do little to sterically interfere with the formation of the double helix (Moirano, 1977; Glicksman, 1983).

Both the kappa and iota carrageenan fractions require positively charged counterions in order to form a gel, although neither one will form a gel in the presence of Na^+ (Therkelsen, 1993). These cations may be associated either with the carrageenan or constituents of the system that the carrageenan is used in, but their presence is essential (Moirano, 1977). It has been suggested that the cations provide a screening of the sulfate group charge, and therefore, stabilize the formation of the helically aggregated units of the final gel (Therkelsen, 1993). Increasing the screening charge of the ionic sites causes the polymer chains to coil as a result of decreasing interchain electrostatic

repulsion (Therkelsen, 1993). It also has been reported that the kappa fraction is K^+ sensitive, while the iota fraction is Ca^{++} sensitive (Moirano, 1977;, Glicksman, 1993;, FMC, 1993). It is clear that the cations are site specific to helix formation, but presently, no single explanation has gained general acceptance (Therkelsen, 1993).

KONJAC FLOUR

Konjac flour is produced from the Amorphopallus konjac (elephant yam) plant, which is a perennial cultivated mainly in Japan, but grows wild in other Far Eastern countries such as China, Burma, Indonesia, Thailand and Indo-China (Kiriyama et al., 1972; Tye, 1991). Historically, the Japanese have used gels made form konjac flour (1) to produce noodles that are stable in boiling water, (2) as an intestinal purging agent for good health, and (3) for the production of "konnyaku", which is used for food products ranging from desserts to soup dumplings (Dekker, 1979; Tye, 1991).

The flour consists of small, white, oval sacs ranging in size from 100 to 500 microns (Tye, 1991). Each sac contains the linear glucomannan molecule consisting of repeating chains of mannose and glucose in a molar ratio of approximately 1.6:1, respectively, linked by beta-1,4-linkages (Tye, 1991; Williams et al, 1991; FMC, 1994). The molecular weight of the linear molecule ranges between 200,000 and 2 million daltons, but usually averages around 1
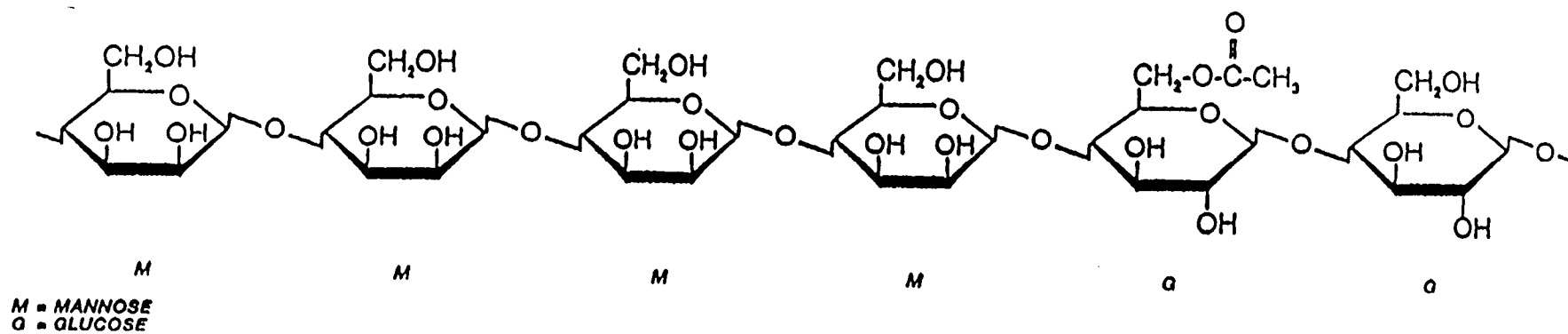
Figure 4. Linear glucomannan structure of konjac flour (FMC, 1994).

M = MANNOSE
G = GLUCOSE

along the linear molecule (Maeda *et al.*, 1979; Tye, 1991; Williams *et al.*1991;

FMC, 1994). Although the side branches may occur at any residue, it has been

suggested that the branches occur more frequently on the mannose than on the

glucose residues (Maeda *et al.*, 1979). This may be due to chance since there

are higher numbers of manes sugar residues in konjac flour, and the sequence

of mannose and glucose residues are arranged in a less definite order (Smith,

1959; Maeda *et al.*, 1979).

The acetyl groups range from one per six sugar units to one per 19 sugar

units (Tye, 1991; FMC, 1994). The acetyl groups act to (1) impart water

solubility to an otherwise amylose-like molecule, and (2) it is theorized they

prevent premature hydrogen bonding between linear molecules and thus

formation of a gel network (Tye, 1991; FMC, 1994). Use of a mild alkali to

cleave the acetyl groups form the glucomannan molecule and application of

heat results in the formation of a three-dimensional, hydrogen bonded gel that

is heat stable (Tye, 1991; FMC, 1994).

As water is added to konjac flour, the small sacs of glucomannan begin to

swell, increasing the viscosity of the dispersion analogous to when starch is

added to a liquid (Tye, 1991). As the swelling continues, the sacs burst,

releasing the glucomannan (Tye, 1991). Konjac flour hydrates at room

temperature on application of low shear force, but the rate of hydration can be

enhanced by increasing both temperature and shear without affecting the ability

to form gels during subsequent processing (FMC, 1994).

Because of its resistance to digestion by enzymes of the human gastrointestinal tract, konjac glucomannan is classified as a dietary fiber (Dekker, 1979). As mentioned previously, incorporation of dietary fiber has a positive impact by reducing the frequency of heart disease, cancer, and other diseases associated with the colon (Dekker, 1979). Incorporation of konjac flour glucomannan in hypercholesterolemic diets of adult rats has been shown to reduce the levels of both serum and liver cholesterol (Dekker, 1979). The glucomannan is believe to inhibit transport of cholesterol in the jejunum and bile acids in the ileum (Dekker, 1979; Truswell, 1977). It has also been reported that effectiveness of konjac glucomannan as a cholesterol scavenger is related to its structural and physical features, specifically to its high molecular weight, viscosity and water solubility (Dekker, 1979). Kiriyama *et al.* (1972) determined that extensive purification of the konjac glucomannan did not effect its hypocholesterolemic activity, but the beneficial effects of konjac glucomannan were eliminated with the addition of cellulase enzymes or a mild alkali.

SYNERGISMS OF HYDROCOLLOIDS

The effects of combining hydrocolloids to improve or modify the gelling or functional characteristics has been reported by Therkelsen (1993) and FMC (1994). Kappa carrageenan forms a very brittle, rigid, and synerating gel, while the iota fraction forms a cohesive, soft, highly resilient gel which does not sweat

under normal conditions (Therkelsen, 1993; FMC, 1994). By blending the two

forms of carrageenan together, the gel can be modified to attain the desired

texture, resilience and water retaining characteristics desired by the food

processor (Therkelsen, 1993).

Other hydrocolloids such as locust bean gum and konjac flour are highly

synergistic with carrageenan, especially those containing a higher 3,6-anhydro

ring content, such as the kappa fraction (Moirano, 1977; Therkelsen, 1993;

FMC, 1993). The exact mechanism of the interaction between konjac flour and

carrageenan, however, has not been explained.

MATERIALS AND METHODS

GEL MANUFACTURE

The konjac flour/carrageenan (K/C) gel (Table 1) was formulated

containing water, Nurticol K80V konjac flour (FMC Marine Colloids Div.,

Philadelphia, PA.) and Gelcarin XP 8007 carrageenan (FMC Marine Collids

Div., Philadelphia, PA.). Prior to blending, the water was preheated to 80° C.

and placed in a preheated Kitchen Aid (Hobart Inc., Troy, OH) stainless steel

mixing bowl. The konjac flour and carrageenan were mixed together in dry form

and slowly added to the heated water while mixing at high speed for seven

minutes with a wire whip attachment. Following mixing, the gel was ground

through a 0.32 cm plate, placed in the Kitchen Aid stainless steel mixing bowl,

and using the mixing attachment at medium speed, 7.5 mls of potassium

carbonate were added to the gel and mixed for two minutes. The gel was

poured into one quart glass jars, sealed and heated under pressure (10 psi) for

15 minutes. After cooling, the gel was ground through a 0.32 cm plate and the

appropriate amounts added to each meat block during patty formulation.

PATTY FORMULATION

Ground beef patties were formulated from lean and fat beef trim obtained from frozen U.S. commercial cow trim (95% lean), and U.S. Select and Choice lean and fat trim inventories at the Clark Meat Science Center. Lean and fat meats were ground separately through a 1 cm plate using a Butcher Boy Model-52 meat grinder (Lasear Manufacturing Inc., Los Angeles, CA.). Six random samples of each component were collected, homogenized and ground two times through a 0.32 cm plate. Four two ounce subsamples of each component were analyzed for fat content using a Hobart Ground Beef Fat Analyzer Model F-101 (The Hobart Mfg. Co., Troy, OH). Values were averaged and the mean value of each component used for further formulation using Pearson Square. Lean trim, fat trim and konjac/carrageenan (K/C) gel were blended to formulate meat blocks containing varying levels of lean, fat and K/C gel as outlined in Table 2. Batches were hand mixed for two minutes, ground through a .32 cm plate, and processed into patties ($\simeq$ 110 g patties) using a Hollymatic super, Model 54 patty machine (Hollymatic corporation, Park Forest, Illinois). After forming, patties were individually stacked on aluminum trays and placed in a -20° C. for 1 hour until firm. Patties were then vacuum packed in stacks of 4 and stored at -20° C. until further evaluation.

Table 1. Formulation for the konjac/carrageenan gel added to ground beef patties.

Ingredients	Amount
Water	970 g
Konjac Flour*	20 g
Carrageenan**	10 g
Total Gel	1000 g

* Nutricol K80V Konjac Flour (FMC Marine colloids, Div.)
** Gelcarin XP 8007 Carrageenan (FMC Marine colloids, Div.)

Table 2. Control and treatment formulations by percent for ground beef patties.

	Treatments*			
Ingredients	Control	1	2	3
Lean	80	80	80	80
Fat	20	15	10	5
K/C Gel	0	5	10	15

* Control and all treatments formulated from common lean, fat and gel blocks.

COOKING METHODOLOGY

Yield/Sensory Panel Testing

Patties were thawed (2° C., 24 hr.) and cooked on a preheated (178° C.) electric griddle (The West Bend Co., West Bend, WI.). Each patty was weighed immediately before and again after cooking to an endpoint temperature of 71° C. to determine yield (weight of cooked/blotted patty / weight of raw patty X 100). Once cooked, patties were allowed to sit for one minute and blotted dry on each side before weighting. Endpoint temperatures were monitored using a hypodermic probe-type thermocouple attached to a Speedomax W Recorder (Leeds & Northrup Co., North Wales, PA).

Patty diameter was determined by tracing the patty on acetate paper both prior to and after cooking. Surface are was determined using a Bruning planimeter No. 80-510 and was reported in square centimeters.

Consumer Testing

Patties were cooked on a preheated electric griddle (The West Bend co., West Bend, WI.) at a setting of 178° C for five minutes on one side, turned and cooked for another one minute and forty-five seconds on the second side. Final

patty temperature (69-71° C) was measured using a hypodermic probe-type thermometer at the geometric center of each patty.

SENSORY EVALUATION

An 11-member semi-trained experienced consumer panel was formed from staff and students of the Clark Meat Science Center and the department of Nutrition and Food Management to evaluate the cooked ground beef patties for general appearance and palatability. Each panelist was introduced to the characteristics being evaluated during training sessions prior to product evaluations being made. Panelists were instructed to evaluate each patty for external cooked color, the presence of visible konjac gel particles, overall patty appearance, cooked aroma, texture/mouthfeel and initial juiciness. A sample ballot is shown in Figure 5. Sensory sessions were held daily, with four samples evaluated during each session. Patties were assigned random three digit identification numbers and order of presentation to panelists was randomized as well.

PROXIMATE ANALYSIS

Representative samples (2 patties) from each treatment, were selected for proximate analysis. Prior to analysis, each sample was homogenized in a

Name:_____

Date:_____

Directions: Please taste and evaluate each sample based on the characteristics below. Place an X in the blank that corresponds with your opinion of the sample.

COOKED APPEARANCE

COLOR	618	925	869	132
7-Bleached/white				
6				
5				
4-Tan				
3				
2				
1-Caramel/brown				

VISIBLE GEL PARTICLES	618	925	869	132
7-Abundant gel particles				
6				
5				
4				
3				
2				
1-No gel particles				

OVERALL APPEARANCE	618	925	869	132
7-High quality/Standard				
6				
5				
4				
3				
2				
1-Not usual/Below standard				

AROMA

AROMA	659	841	466	932
7-Strong beef aroma				
6-Moderate beef aroma				
5-Mild beef aroma				
4-No aroma				
3-Mild fishy aroma				
2-Moderate fish aroma				
1-Strong fishy aroma				

TEXTURE/MOUTHFEEL

TEXTURE/ MOUTHFEEL	659	841	466	932
7-Mealy/Breaks apart easily				
6				
5				
4				
3				
2				
1-Rubbery/Cohesive				

INITIAL JUICINESS	659	841	466	932
7-Very juicy				
6				
5				
4-Neither juicy nor dry				
3				
2				
1-Dry				

Figure 5. Sensory ballot for semi-trained panel evaluation.

Cuisinart DLC-10 Food Processor. Samples were analyzed in triplicate for moisture (oven air-drying method), fat (ether extractable component) and protein (Kjeldahl nitrogen) following AOAC (1990) procedures.

CONSUMER TESTING

A consumer panel (n = 53) made up of students and staff from various departments on the Oregon State University campus were asked to evaluate acceptability of cooked ground beef patties. Panelists were instructed to rate each sample using a 9-point hedonic scale for acceptability and purchase intent (Meilgaard et al., 1991). A sample ballot is provided in Figure 6. Panelists were also asked to rate the potential purchase intent of the control and each treatment. Sample ballots for acceptability and purchase intent are provided in Figure 6 and Figure 7, respectively.

For serving, each patty was divided into four approximately 20 gram samples and served hot to panelists. Patties from the treatment combinations were assigned random presentation order and numbers within the session.

MEASUREMENT OF pH

Measurement of pH was done using a Corning digital pH meter (Model 125) with a Sensorex sealed epoxy body reference combination electrode

INSTRUCTIONS:

1. Please fill in the code numbers (located on on the serving cups) of each sample from left to right as they appear on your tray.

2. Taste the sample on the far left and place an X on the line that best describes how well you liked the sample. Please ensure the X is in the column beneath the sample code.

3. Continue in this manner until all the samples have been identified.

SAMPLE#	——	——	——	——
LIKE EXTREMELY	——	——	——	——
LIKE VERY MUCH	——	——	——	——
LIKE MODERATELY	——	——	——	——
LIKE SLIGHTLY	——	——	——	——
NEITHER LIKE NOR DISLIKE	——	——	——	——
DISLIKE SLIGHTLY	——	——	——	——
DISLIKE MODERATELY	——	——	——	——
DISLIKE VERY MUCH	——	——	——	——
DISLIKE EXTREMELY	——	——	——	——

Thanks!

Figure 6. Consumer acceptance sensory ballot.

INSTRUCTIONS:

1. Please fill in the code numbers (located on the serving cups) of each sample from left to right as they appear on your tray.

2. Taste the sample on the far left and place an X on the line that best describes how well you liked the sample. Please ensure the X is in the column beneath the sample code.

3. Continue in this manner until all the samples have been identified.

SAMPLE#	——	——	——	——
Definitely would buy	——	——	——	——
Probably would buy	——	——	——	——
Maybe / maybe not	——	——	——	——
Probably would not buy	——	——	——	——
Definitely would not buy	——	——	——	——

Thanks!

Figure 7. Purchase intent ballot for consumer panel evaluation.

attached. Pre-measurement standardization was accomplished using pH 4.0 and 7.0 buffers at ambient room temperature. The pH meter was restandardized between each sample to compensate for any changes in temperature.

Two patties from each treatment and the control were randomly selected and homogenized into a single sample. From each newly formed sample, four ten gram subsamples were taken for pH measurement. Individual samples were place in a Waring blender with 100 mls of distilled water and mixed at high speed for one minute to make a meat slurry. After initial blending, the slurry was allowed to rest for one minute, then blended for another thirty seconds. After blending, the slurry was placed in a 100 ml glass beaker and the pH measured by inserting the electrode into the slurry while stirring until the reading from the pH meter stabilized (Koniecko, 1985).

HUNTER COLORIMETER VALUES

External raw patty color was evaluated using a Hunter Lab Scan model LS-5100 spectrocolorimeter (Hunter Associates Laboratory, Reston, VA.) where L = reflectance of light, a = redness and b = yellowness (Pomeranz and Meloan, 1978). The colorimeter was standardized using a white blank (CIE no. 15, x = 78.2, y = 82.81, z = 85.68) with a 30 mm aperture.

Twelve patties from each of the three treatments and the control were placed on aluminum trays, covered by clear plastic sheeting and stored 24 hours in a $0°$ C. walk-in cooler. Color measurement of each patty was taken as close to the geometric center as possible. Measurements were always made on the light exposed surface of the patty.

STATISTICAL ANALYSIS

Data were analyzed using analysis of variance and mean separations determined by the General Linear Models (GLM) procedures of the Statistical Analysis System (SAS, 1988) as a randomized complete block design with treatment (fat and added konjac/carrageenan gel) as the main effect. Where treatment variable effect was significant, the means were separated using Least Square Means Procedures (SAS, 1988).

RESULTS AND DISCUSSION

SENSORY EVALUATION FOR VISUAL APPEARANCE

Panelists were asked to rate ground beef patties for external cooked color, presence of visible gel and overall appearance. The results for these evaluations are presented in Table 3.

Color

Preliminary observations suggested that replacement of the fat with high levels of moisture caused a reduction in surface browning, giving boiled meat appearance to the patty surface. It was observed that as the level of K/C gel increased, a reduction in surface browning occurred during the cooking process. Even though the amount of browning was not deemed as having a negative effect upon appearance, it may effect final consumer acceptance of patties containing high amounts of the K/C gel. Although mean values for treatments 1 (5% gel) and 3 (15% gel) were significantly different from the control and treatment 2 (10% gel), all scores fell within a range of 1 to 4 (1=Caramel/brown and 4=Tan), indicating there was not enough surface bleaching among treatments to be of concern to panelists. This is verified further by the fact that

panelists rated treatment 1 (5% gel addition) higher (lighter) than treatment 2 (10% gel).

Visible Gel

As the percentage of gel increased, mean panelist scores for visible gel increased significantly ($p < 0.05$). The control (added gel) and all treatments were scored significantly different ($p < 0.05$) from each other for the amount of visible gel. This demonstrates that the panelists could recognize visible gel differences between all treatments, with the scores being significantly higher (more gel) between each succeeding increase in the level of added gel ($p < 0.05$). Similar results were noted in studies by Osburn and Keeton (1994) using pork sausage.

Overall Appearance

For overall appearance, the panelists rated the control patties significantly higher ($p < 0.05$) than all other treatments, while treatment 3 (15% gel) was rated lower than either treatment 1 (5% gel) or 2 (10% gel). There was no significant difference for overall appearance of the cooked patties between treatments 1 and 2. This suggests that the presence of gel at the higher levels may effect the overall acceptance of the patties due to visible gel particles, while

Table 3. Least square mean scores for experienced sensory panelist evaluations.

	Treatments				
	Control	1	2	3	SEM[k]
Color[a]	3.17^g	3.59^h	3.18^g	3.45^i	.125
Visible Gel[b]	2.38^g	3.91^h	4.40^i	4.85^j	.126
Appearance[c]	5.46^g	5.00^h	4.95^h	4.73^i	.095
Aroma[d]	5.52^g	5.35^{gh}	5.34^{gh}	5.13^h	.094
Texture/Mouthfeel[e]	4.84^g	4.94^g	4.66^g	4.31^h	.117
Juiciness[f]	5.14^g	5.11^g	4.53^h	4.41^h	.114

[a] 1=Carmel/brown, 7=Bleached/white
[b] 1=No gel, 7=Abundant gel
[c] 1=Below standard, 7=High standard
[d] 1=Strong fishy aroma, 7=Strong beefy aroma
[e] 1=Rubbery/cohesive, 7=Mealy
[f] 1=Dry, 7=Very juicy
[g-h] Means in the same row followed by different letters are significantly different ($p \leq 0.05$).
[k] Standard error for the means

the observed difference in color may have little influence on the acceptance of the cooked patties.

SENSORY EVALUATION FOR PALATABILITY CHARACTERISTICS

Panelists rated the ground beef patties for aroma, texture/mouthfeel and for juiciness attributes. The data for each of the attributes is found in Table 3.

Aroma

When considering consumption characteristics, aroma of the final product may be of great importance due to the presence of a fishy aroma in the manufactured konjac gel. Table 3 shows that there were significant differences ($p<0.05$) between mean scores for aroma between the control and treatment 3 (15% gel), but not between the control and treatments 1 (5% gel) and 2 (10% gel). Treatment 3 was not significantly different from either treatments 1 or 2. Since mean scores tended to be rated higher for beefy aroma, this suggests that the fishy aroma was not a factor in the final product as initially was suggested. Reduction in mean values as K/C gel percentages increases also indicates there may be some dilution effect for aroma. However, panelists scores suggested that the levels of gel added in the current study were not high enough to seriously effect aroma.

Texture/Mouthfeel

When considering texture/mouthfeel panel scores, mean scores for the control were not significantly different from either treatments 1 (5% gel) or 2 (10% gel), but were significantly different (p<0.05) from treatments 3 (15% gel) as shown in table 3. Only treatment 3 was significantly different (p<0.05) from all other treatments. Even though the mean score for treatment 3 was significantly lower, it was still within the acceptable range. Thus, treatment 1 and 2 were quite acceptable, which indicates that levels of 5% or 10% of the gel had but little effect upon the texture/mouthfeel of the ground beef patties.

Juiciness

Mean scores for juiciness between the control and treatment 1 (5% gel) were not significantly different, nor were treatments 2 (10% gel) and 3 (15% gel) significantly different from each other as shown by the data in table 3. Treatments 2 and 3, however, both were scored significantly lower for juiciness (p<0.05) than either the control or treatment 1. This indicates that even with the addition of high moisture gels to replace fat, as the fat level approached and dropped below the 10% fat level, there is a significant decrease in consumer acceptance as has been found in other studies (Mize, 1972; Egbert *et al.* 1991; Troutt *et al.* 1992; Berry and Leddy, 1984).

CONSUMER ACCEPTABILITY

Consumers were asked to rate the acceptability and the likelihood of whether or not they would purchase each of the treatments. The results are presented in Table 4.

Consumer Acceptance Scores

Mean values for consumer acceptance, which are presented in Table 4, reveled no significant differences ($p < 0.05$) in acceptability between the control, and treatment 1 (5% K/C gel) and treatment 2 (10% K/C gel). This was apparently due to the moisture retention during cooking in treatments 1 and 2, and is supported by cooking yield data as presented in Table 6. Mean values for treatment 3 (15% K/C gel) were significantly lower in acceptability than either the control or treatments 1 or 2 ($p < 0.05$).

One factor that may contribute to the reduced acceptance of the 15% K/C gel treatment is that fat provides lubrication during mastication (Hedrick *et al.*, 1994). Therefore, consumers may get the perception that the meat is dryer than it really is. Other studies (Cross *et al.*, 1980; Berry and Leddy, 1984; Troutt *et al.*, 1992), in which ground beef patties were manufactured with less than 10% fat content found than to be less palatable and satisfying than those with fat levels above 10% fat.

Table 4. Consumer panel (n=53) least square mean scores for consumer acceptance and purchase intent.

	Treatment				
	Control	1	2	3	SEM[d]
Consumer Acceptance	7.11[a]	6.66[a]	6.58[a]	5.81[b]	.192
Purchase Intent[f]	3.94[a]	3.53[b]	3.49[b]	3.00[c]	.147

[a-c] Means in the same row followed by different letters are significantly different (p≤0.05).
[d] Standard error
[e] 1=Dislike extremely, 9=Like extremely
[f] 1=Definitely would not buy, 5=Definitely would buy

Purchase Intent

Analysis of purchase intent (Table 4) revealed mean values for treatment 3 (15% K/C gel) to be significantly lower ($p<0.05$) than either treatments 1 (5% K/C gel) or 2 (10% K/C gel), while purchase intent for the control was significantly higher ($p<0.05$) than that of all other samples. There was no significant difference in purchase intent between treatments 1 and 2.

PHYSICAL EVALUATIONS

Each treatment was evaluated for, and compared against the control, using Hunter colorimeter, yield and surface area measurements. The results are shown in tables 5 and 6.

Hunter Color Scores

Mean values for hunter color scores are shown in Table 5. There was no significant differences in Hunter L-color (reflectance) values for either the control or any of the other treatment groups. This indicates that the presence of the K/C gel in the treatment groups had neither a positive nor negative effect on either absorption or reflectance of light. There were, however, significant

differences (p<0.05) in both Hunter a and b values (Table 5). Hunter a-color (redness) means scores for control patties were significantly higher (p<0.05) than patties in all other treatments, while the mean value for patties in treatment 3 (15% K/C gel) was significantly lower than those in either treatments 1 (5% K/C gel) or 2 (10% K/C gel). There were no significant differences in mean scores between treatments 1 and 2.

Mean scores for Hunter b-color (yellowness) values followed the same trends as the a color values. As demonstrated by the data in Table 4, mean scores for control patties were significantly higher (p,0.05) than those in all other treatments, while mean scores for patties in treatment 3 (15% K/C gel) were significantly lower (p<0.05) than those in either treatments 1 (5% K/C gel) or 2 (10% K/C gel). Once again, there were no significant differences between mean scores for either treatments 1 or 2.

Thus, results indicated that as the percentage of K/C gel in the patty formulation increased, there was a notable decrease in both redness and yellowness towards neutral or gray values. This was especially apparent between the control patties and treatments 1 (5% K/C gel) and 2 (10% K/C gel), and treatments 2 and 3 (15% K/C gel). Apparently, there is a plateau between the 5% and 10% K/C gel addition where the color values did not change. It is not possible to explain the reason for this phenomenon at the present time.

Table 5. Least square mean scores for Hunter colorimeter values.

	Treatments				
	Control	1	2	3	SEM[d]
L-Color[e]	33.12[a]	31.57[a]	33.81[a]	32.63[a]	.817
a-Color[f]	9.01[a]	8.07[b]	7.89[b]	6.91[c]	.252
b-Color[g]	8.75[a]	7.96[b]	7.83[b]	7.27[c]	.206

[a-c] Means in the same row followed by different letters are significantly different (p≤0.05).
[d] Standard error for the means.
[e] Hunter value for reflectance
[f] Hunter value for redness
[g] Hunter value for yellowness

Cooking Yields/Surface Area

There were no significant differences in cooked yields ($p < 0.05$) between treatments or between the treated samples and the control (Table 6). Studies by Berry (1992) and Troutt *et al.* (1992) showed that as fat levels decreased, cooking times increased. This was not the case with the K/C gel substitution. All patties in all treatments achieved the minimum temperature in the allotted cooking time. Due to the thermal stability of K/C gels (Tye, 1991), it may be theorized that the patties containing higher levels of gel may cook at a faster rate than those containing lesser amounts of gel.

Although cooking yields between treatments were not significantly different, mean values for surface area were significantly different ($p < 0.05$) between all treatments and the control. As the amount of K/C gel increased, there were significant increases ($p < 0.05$) in surface area mean values (Table 6). As was the case when considering patty yields, the thermal stability of the gel (Tye, 1991) may have a major impact on overall shrinkage of the patty during cooking. In cooking beef patties normally there is subsequent losses of moisture and rendered fat due to the effects of heating reducing surface area. Since the K/C gels were thermally stable during the cooking process, there was not any reduction of surface area during cooking. (Table 6).

Proximate Analysis and pH Values

Results of the proximate and pH measurements of the control and each treatment are shown in Table 7. There was not any variation in the values for percent protein between either the control or sample patties, indicating that the addition of the K/C gel did not effect protein content. However, as the percent K/C gel increased and the percent fat decreased, there was a corresponding increase in the percent water in each treatment.

Although actual values of fat for the control (20% fat/0% K/C gel) and treatment 1 (15% fat/5% K/C gel) were slightly less than their targeted values, and treatment 2 (10% fat/10% K/C gel) was slightly higher than its targeted value, it was determined that these values were within acceptable range.

As shown in Table 7, addition of the K/C gel did not have an affect on the pH as the amount of gel increased.

Table 6. Least square mean scores for surface area and percentage yield of cooked patties.

	Treatments				
	Control	1	2	3	SEM[e]
Surface Area (cm^2)	68.19[a]	70.15[b]	71.41[c]	71.48[c]	.094
Yield (%)	60.00[a]	60.30[a]	59.00[a]	59.20[a]	.005

[a-d] Means in the same row followed by different letters are significantly different ($p \leq 0.05$).

[e] Standard error for the means.

Table 7. Proximate analysis and pH values for the control and treatment ground beef patties.

	Treatments			
	Control	1	2	3
Moisture (%)	62.3	65.7	70.1	76.4
Protein (%)	18.2	18.2	18.1	18.1
Fat (%)	18.9	14.3	10.4	5.0
pH	5.68	5.58	5.68	5.72

CONCLUSIONS

Sensory evaluation indicated that K/C gels added to ground beef made a satisfactory fat replacer as long as the fat levels did not fall below 10% fat.

The presence of the K/C gel at the 5% and 10% levels did not significantly decrease mean scores for either consumer panel or a semi-trained panel evaluating the patties for acceptability or palatability (aroma, texture/mouthfeel, juiciness). Both the consumer and semi-trained panel found the 15% K/C gel patties to be significantly ($p<0.05$) less palatable than the control or either of the other two treatments (% or 10%). This is consistent with the results of other studies (Cross *et al.*, 1980; Berry and Leddy, 1994) in which ground beef patties manufactured with less than 10% fat were found to be less desirable than those having fat levels above 10%. Although the K/C gels bound high levels of moisture, the data suggests that the gel is unable to duplicate the characteristics of fat when level falls below 10% fat.

Although mean scores for visual appearance (cooked patty color, visible gel, overall appearance) were significantly lower ($p<0.05$) for all treatments than for the control, both cooked patty color and overall appearance were within acceptable range. The reduction ($p<0.05$) in mean scores for visible gel increases directly with the percentage of K/C gel increases. This suggests that consumers may find patties containing the K/C gel particles to be unappealing.

For this reason, further research on incorporation of K/C gels into coarse ground products is needed.

There were no significant differences in cooking yields between the control (20% fat) and the reduced fat treatments (5, 10 and 15% fat) containing the added K/C gel. Mean surface area, however, was significantly higher ($p<0.05$) as the level of K/C gels increased. Thus, results demonstrated that the K/C gels were effective in binding and holding water during cooking. In contrast to earlier studies using meat systems without added water binders, the K/C gel did not alter cooking rates.

Hunter L-values for reflectance in raw patties were not significantly different between treatments or the control, but a-values for redness and b-values for yellowness were significantly lower ($p<0.05$) There was some diffusion of a-values and b-values toward gray as the amount of K/C gel increased from the control to 5% added gel. There was no significant difference between the 5% and 10% added gel, but mean score for the 15% added gel was significantly lower ($p<0.05$).

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