APPLICATION OF CORN GERM PROTEIN IN BEEF PATTIES

by

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INTRODUCTION

Due to the increasing shortages of food, proteins essential for growth and good health are needed throughout the world. Meat is one of the most preferred sources of protein; however, it is becoming increasingly more expensive to produce. Increased prices combined with the current health concerns about cholesterol, have caused many American families to restrict the use of meat in their diets.

Through the years there have been numerous efforts to increase the use of non-meat proteins in meat products based on their potential to lower production costs. Increased use of soy-based products, including soy flours, concentrates, and isolates, is well known. Other oilseeds including peanuts, cottonseed, sunflower seeds and sesame seeds also have been processed into food-grade ingredients of high protein content. However, the use of high protein food ingredients derived from cereal grains is less common.

The germ portion of cereals has long been known for its high nutritional value. Corn germ is a source of many valuable nutrients including proteins, vitamins, and minerals. Despite this great potential, corn germ protein has not been adequately utilized in the food industry.

One potential use for corn germ protein in the food industry is as an extender of ground beef. However, little information is available as to the actual effects this additive would have on the quality characteristics of the meat product. It is common knowledge that the way an additive reacts in a model system, is not necessarily the way it will function in a food system. Therefore, this study was designed to investigate the functional properties of defatted corn germ protein added to beef patties.

REVIEW OF LITERATURE

Availability and Production of Corn Germ Protein

Corn is the most important grain produced in the United States in terms of acreage planted, quantity produced, and value of production. The United States is the world's principal producer and exporter of corn, accounting for approximately one-half of world production and 80% of world export (U.S. International Trade Commission, 1982).

Corn germ is a by-product of both the wet- and dry-milling corn industries. Only the corn germ resulting from the dry milling process can be utilized for human consumption since the steeping process in the wet milling industry alters the germ proteins. This alteration leads to the deterioration of both the sensory and nutritional qualities of the corn germ proteins, making them unsuitable for food uses (Neilson et al., 1973a; Barbieri and Casiraghi, 1983).

The major food products of the corn dry milling industry come from the endosperm portion of the corn kernel, resulting in 65-70% of the industry's output. In this processing technique, the germ portion of the kernel is an important intermediate product since it undergoes further processing for oil extraction. After the oil has been removed, defatted corn germ (generally referred to as corn germ meal) usually is combined with the remaining dry mill streams and sold as hominy feed for animals. However, the residue which remains following oil extraction also can be finely ground into a defatted corn germ flour. Corn germ flour is a white to cream-colored powder containing approximately 25% protein. Because of its relatively high protein content, the resulting flour is also referred to in this text as corn germ protein (CGP).

Most of the dry milling industry expells oil from corn germ with screw presses. This process subjects the germ to high temperatures (120-130^{o}C) which causes a loss of approximately one-third of the available lysine (Cluskey et al., 1978). Exposure to heat in the defatting process also results in a sharp decrease in the protein solubility of corn germ flour (Barbieri and Casiraghi, 1983). An alternative procedure of oil recovery utilizes solvent extraction to remove the oil from the germ. Solvent extraction is considered better than expeller processing (Wall et al., 1971). Presently there are two methods of solvent extraction: low-temperature hexane and supercritical carbon dioxide (SC-CO_2). These processing techniques result in higher yields of oil, while retaining the nutritional value of the corn germ proteins.

The degree to which the fat is extracted is important not only in the yield of corn oil but also for the storage stability of the resulting flour. Lipids in the flour will either auto- or enzymically oxidize into off-flavor compounds during storage, which will reduce the flavor and nutritional quality of the product (Christianson et al., 1984). Conventional hexane extraction leaves residual lipids in the flour, which reduces its quality (Phillips and Sternberg, 1979; Christianson et al., 1984). SC-CO_2 extraction is more efficient than hexane extraction for the removal of triglycerides and bitter constituents (bound lipids), as well as for the inactivation of peroxidase enzymes, therefore contributing to the excellent flavor and storage stability of the germ flour (Christianson et al., 1982 and 1984).

Traditional hexane extraction has several disadvantages. In addition to its escalating cost, hexane is highly flammable and explosive. Because hexane is a petroleum fraction, it contains traces of higher boiling fractions that could be left in the oil and flour. These contaminants pose a potential health hazard. Carbon dioxide, on the other hand, is nontoxic, nonflammable, nonexplosive, inexpensive, and easily separated from both oil and flour (Christianson et al., 1982).

Method of solvent extraction also has an influence on the color of the resulting flour. A SC-CO_2-defatted corn germ protein was found to be whiter, less red and less yellow in color than a hexane-defatted product. The high fat content and its resulting oxidation are thought to contribute to the yellow color of hexane-defatted corn germ protein (Lin and Zayas, 1987c).

However, a modified process for hexane-extraction of oil from corn germ meal has been developed. This method significantly improved the sensory characteristics of flavor and color in the resulting corn germ flour. The modified fat extraction technique was effective in producing corn germ protein with a low fat content (0.2% and less) and high storage stability (Zayas and Lin, 1988).

Nutritional Quality of Corn Germ Protein

In the 1940's, researchers found that corn germ extracted with low temperature solvents to remove the oil exhibited a high digestibility and biological value when fed to rats (Mitchell and Beadles, 1944). Colorimetric assay methods also illustrated an excellent balance of essential amino acids in corn germ (Block and Bolling, 1944). Therefore, it was suggested to reserve corn germ as a protein food for human consumption.

Corn germ represents approximately 12% of the total corn kernel (Blessin et al., 1972). It contains approximately 22% protein, while the corn seed itself only averages about 9-10% protein (Johnson et al., 1978). Proteins in corn germ are primarily albumins (water soluble and heat coagulable) and globulins (soluble in dilute salt solutions) (Paulis and Wall, 1969; Hoseney, 1986).

Feeding studies have found the protein in whole corn germ to be almost as nutritious as animal proteins. Mitchell and Beadles (1944) found the protein of corn germ to be 85% as digestible as that in beef round steak. The PER value of 2.2 for corn germ protein is comparable to that of casein and soya protein (Wells, 1975; Cluskey et al., 1978). Wall et al. (1971) demonstrated that the protein quality of corn germ was better retained if oil was removed by solvent rather than expeller processing.

Numerous studies on the upgrading of defatted dry-milled corn germ flour into a food-grade product have been conducted since Wall et al. (1971) demonstrated the nutritional value of the proteins contained in the germ. The mineral and fiber content of germ also contribute to its value as a food supplement. Gardner et al. (1971), reviewed and summarized compositional data and earlier nutritional studies on corn germ. Commercially available dry-milled corn germ was examined by Blessin et al. (1974) using hexane to remove the oil. Preparation and properties of corn germ flours from dry-milled germ of yellow, white, and high-lysine corns using hexane extraction were reported by Blessin et al. (1979).

Composition of a defatted corn germ flour studied by Blessin et al. (1972) was reported on a moisture-free basis (%) as follows: Protein 25.3, Fiber 4.2, Starch 24.7, Sugars 13.8, Pentosans 11.7, Fat 0.5 and Ash 10.3. The high protein and ash contents indicate that corn germ flour could be a valuable supplemental source of nutrients in food products. Phosphorus, potassium and magnesium are the major mineral elements in defatted corn germ; while sodium, calcium, iron, zinc and copper are minor constituents (Tsen, 1975). The composition and properties of corn germ protein will vary with the corn type (Wu and Sexson, 1976).

If cereal proteins are to be used as meat extenders, one important concern is the nutritive value of the proteins. Chemical scores indicate that the essential amino acid pattern of defatted corn germ flour closely resembles that recommended by the World Health Organization (Tsen, 1975). Blessin et al. (1973) reported that the essential amino acid patterns of defatted corn germ flour compare favorably to that of hen's egg proteins.

The predominant cereal proteins differ greatly from oil-seed proteins in composition. Generally, oilseed proteins are rich in lysine and limiting in methionine and cystine, whereas, cereal proteins usually are limiting in lysine but contain adequate amounts of the sulfur amino acids (Phillips and Sternberg, 1979). The lysine deficiency in corn occurs primarily in the endosperm portion of the kernel, but the amino acid pattern of the corn germ is much better nutritionally. Nielson et al. (1973a) found that the protein in a dialyzed corn germ isolate contained 6% lysine with a good balance of other essential amino acids.

The distribution of amino acids in the protein component of two defatted corn germ protein products are reported in the following table (Table 1). Levels of essential amino acids in defatted corn germ protein are compared to those of hen's egg protein, soybean protein, and the FAO required amino acid pattern.

On the basis of grams of amino acid per 100g of protein, defatted corn germ protein proves equal or higher in all essential amino acids (except isoleucine) to the FAO provisional amino acid pattern. CGP is higher than FAO requirements for leucine, tyrosine, phenylalanine and lysine. Lysine levels in corn germ protein are higher than for any other fraction of the corn kernel. Lysine content in corn germ protein is 5.35-5.88 g/100 g protein (Zayas and Lin, 1988).

Functional Properties of Corn Germ Protein

Utilization of food ingredients, especially high protein materials, depends to a great extent on functional properties (Kinsella, 1976). Industry's selection of a

Table 1. Amino acid composition of corn germ protein.[a]

Amino Acid	Amino acid composition of corn germ protein, g/100g				
	$SC\text{-}CO_2$ defatted[1] CGP	FAO Amino Acid Pattern[2]	Essential Amino Acids in hen's egg[3]	Hexane defatted CGP	Soybean Protein[5]
Asp	9.32			10.57	
Thr	4.35	2.8	5.1	4.82	3.6
Ser	5.62			5.95	
Glu	14.15			15.82	
Prol	3.98			4.04	
Gly	6.14			6.60	
Ala	6.93			7.11	
Cys	1.88	2.0	2.4	1.68	0.9
Val	4.21	4.2	7.3	4.28	4.3
Met	2.63	2.2	3.1	2.23	1.2
Isoleu	2.59	4.2	6.6	2.42	4.2
Leu	6.76	4.8	8.8	6.99	7.4
Tyr	4.33	2.8	4.2	3.51	3.4
Phe	4.91	2.8	5.8	3.95	4.5
His	5.69			5.62	
Lys	5.88	4.2	6.4	5.38	6.4
NH_4	1.18			1.59	
Arg	9.49			9.98	

[a]Tryptophan was not determined.

[1]Sample of $SC\text{-}CO_2$-defatted corn germ protein was obtained from USDA Research Center, Peoria.

[2]FAO/WHO. Protein requirements. FAO nutrition meeting report series 37, p. 36. FAO:Rome (1965).

[3]C.W. Blessin et al. 1973. Composition of three food products containing defatted corn germ flour. J. Food Sci. 38:602.

[4]Sample of hexane-defatted corn germ protein was obtained from the Lauhoff Grain Company, Danville, IL.

[5]Evans and Bendemer 1967. J. Agric. Food Chem. 15:439.

Table adapted from J.F. Zayas and C.S. Lin 1988. Submitted for publication in J. Food Quality.

protein raw material is based on data measuring its functional properties. Manufacturers use this data both in establishing how these protein materials can be utilized in existing products to replace the more expensive proteins traditionally used, and also, in the development of new product formulations.

Production of protein materials with desirable functional properties is of particular interest to the food industry. The quality characteristics of juiciness, texture, and structural binding, as well as, the finished yield of a meat product are determined by the ability of the proteins within the food system to retain water and bind fat. However, in corn germ protein formulations, carbohydrates must also be considered as functional contributors to these quality characteristics.

An important property of a protein intended as a meat additive is the ability to bind fat. A dialyzed isolate reportedly has the same emulsion-stabilizing capacity as soybean isolate (Nielsen et al. 1973b). Another important functional property of a protein additive is solubility. Neilson et al. (1973b) reported that a hexane extracted corn germ isolate reached its maximum solubility at pH 9 and its minimum at pH 5. Lin and Zayas (1987d) determined that the influence of pH on solubility was temperature dependent, with SC-CO_2- and hexane-extracted flours having different responses. These data were found to support the findings of Barbieri and Casiraghi (1983) that a higher degree of corn germ protein denaturation occurs during defatting with hexane.

Corn germ protein has been referred to as a protein source of high water binding capacity (Lucisano et al., 1984). Corn germ protein concentrate was found to have a water binding capacity similar to that of soy concentrate (Phillips and Sternberg, 1979). Tsen (1975) found bread dough absorption to increase with increasing levels of fortification with corn germ flour. The high level of carbohydrates in corn germ protein enable more water to be added (Bhattacharya and Hanna, 1985; Luallen, 1985). Carbohydrates increase the stability of emulsions by absorbing excess water. The swelling of carbohydrates was believed to play a significant role in increasing water retention in sausage processing (Lin and Zayas, 1987c). However, Mittal and Usborne (1985) reported that the carbohydrates in a meat system neither participate in the emulsifying process, nor improve the water holding capacity of the meat itself.

The growing industry that utilizes soy protein for its functional properties is interested in the functional potential of other major plant proteins. Soy protein has excellent functional properties, ie. solubility, water retention and binding, fat adsorption and emulsification.

These functional properties demonstrate the desirable uses of soy proteins in food applications (Kinsella, 1979). However, the use of soy is limited because of its flavor and flatuence problems (Kropf, 1985). Also, oilseed proteins must be heat treated to inactivate trypsin inhibitor before being used as a food. On the other hand, researchers have determined promising characteristics for corn germ which should make its use more favorable to the food industry than that of soy additives.

A defatted corn germ flour possessing high organoleptic and nutritional quality was obtained through a screening process of corn germ meal (Barbieri and Casiraghi, 1983). An acceptable flavor quality corn germ flour was also obtained by SC-CO_2 extraction. No significant differences were noted for the SC-CO_2 flours after accelerated and ambient temperature storages (Christianson et al., 1982). Corn germ protein has considerable potential for use as a supplement in a variety of foods and as a new protein source (Anonymous, 1975).

Expanded nutrient snacks were prepared by extrusion cooking of blends containing 85% corn germ meal and differing amounts of corn starch and milk protein (Peri et al., 1983). Acceptable bread was prepared with wheat flour fortified with 12% defatted corn germ flour, while levels of fortification over 24% produced loaves with lower volumes (Tsen, 1975). Cookies and muffins containing a commercial defatted corn germ flour up to 25% replacement, and beef patties containing up to 10% corn germ flour were not objectionable in color, odor or taste when evaluated by a taste panel (Blessin et al., 1972). In 1977, Tsen and Weber declared corn germ flour an economical, convenient, and nutritious ingredient for cookie manufacturing. They found it particularly suitable for deposit or wire-cut cookies with no detrimental quality effects occuring up to 48% replacement of wheat flour. Pasta containing up to 20% replacement with corn germ flour presented only minor changes in sensory and functional properties, but showed higher protein content and improved amino acid pattern (Lucisano et al., 1984).

In 1987, Lin and Zayas thoroughly researched the functional properties of solvent-extracted corn germ protein products when used in a sausage system. Their first paper (Lin and Zayas, 1987a) investigated the influence of corn germ protein, as a powder ingredient and as a stabilizer in pre-emsulified fat, on the microstructure of comminuted meat products. Corn germ protein increased the degree of fat globule stabilization by forming a protein film on the surface of fat droplets which prevented coalescence during heat treatment.

The second study of Lin and Zayas (1987b) determined the effect of corn germ protein on the textural properties, water holding capacity and fat binding capacity of a sausage batter, as well as the yield and quality characteristics of the finished product. It was reported that CGP had no effect on batter adhesiveness; however, the water holding capacity did increase with the addition of CGP. Addition of 4% CGP increased the yield of the comminuted meat product, while decreasing fat and weight losses. Instron shear force values decreased with the addition of corn protein, but color, hardness and moisture reportedly did not change.

Lin and Zayas further investigated the functional properties of CGP through their comparison of SC-CO_2 vs. hexane defatted products. Their third publication (Lin and Zayas, 1987c) deals with the fat and water binding characteristics of CGP, while their fourth article (Lin and Zayas, 1987d) discussed protein solubility and the resulting effects this property has on emulsifying stability and capacity of a sausage system. The overall pattern showed that in the model system, SC-CO_2 CGP had better functional properties than hexane-defatted CGP. SC-CO_2-defatted CGP had higher fat binding, water retention, protein solubility, emulsifying stability and emulsifying capacity. However, both SC-CO_2 CGP and hexane-defatted CGP were recommended as an additive to sausage batter because of their effects on improving the functional properties of the model system.

Use of Non-Meat Proteins

Non-meat proteins derived from a variety of plant and animal sources are used extensively as fillers, binders, and extenders in meat systems. Oilseed proteins are generally used as meat extenders. The increased use of soy protein products by the food industry has been expanding greatly because of their relatively low cost, high nutritional value, and ability to replace meat proteins, and as a result, increase total protein content.

Extenders and binders have been used for a wide array of meat products, but a large use has been in ground meat. Both the U.S. Department of Defense and the USDA school lunch program purchase patties and bulk product that are extended with hydrated soy protein. The use of up to 30% rehydrated textured vegetable product is allowed in the school lunch program, with the soy to water ratio frequently at 1 to 3 (Kropf, 1985).

The first major penetration for extender-type corn proteins will be the institutional market, including hospitals, schools and other institutions that must provide nutritious meals under food budget restraints. Certain restaurants are also prime markets for vegetable protein products since food served in restaurants is not subject to the same labeling requirements as food sold for home consumption. The trend toward more away-from-home eating is also likely to increase the potentional of this market for extenders.

Specifications for Ground Beef Products

Meat labeled as ground beef, chopped beef or hamburger must consist of chopped fresh and/or frozen beef with or without seasonings. Extenders (such as cereals), binders or water may not be added, and the product may contain no more that 25% trimmed beef cheek meat. Beef fat, as such, may be added to hamburger, but not to products labeled chopped or ground beef; neither may contain more than 30% fat. On the other hand, products labeled 'Beef Patties' should consist of chopped fresh and/or frozen beef with or without the addition of beef fat as such and/or seasonings. Binders or extenders, mechanically separated meat and/or partially defatted beef fatty tissue may be used without added water or with added water only in amounts such that the product characteristics are essentially that of a meat pattie (Office of the Federal Register, 1987).

Functionality of Meat Proteins

The great economic problem of weight losses during storage, cooking, or freezing and thawing of meat is related to the binding of water within the product. Thus, investigation of the water holding capacity (WHC) of meat products is of considerable economic interest (Hamm, 1975).

Water bound to the muscle proteins affects the eating quality of the meat, the yield, the meat color and the texture of the meat product. To obtain good yields during cooking the water holding capacity needs to be at the highest level possible to reduce cooking losses. Normally meat has its poorest WHC around the iso-electric point of the meat proteins (pH of 5.3-5.5). Generally, at pH values higher than 5.8, the water holding capacity increases significantly with increasing pH. By heating meats with higher pH values, the resulting cooked meats have a better water holding capacity (Hamm and Deatherage, 1960).

Keeton and Melton (1978) and Rhee et al. (1985), indicated that with increasing amounts of added soy protein, pH values of patties were higher which provided more favorable conditions for microbial growth. However, Harrison et al. (1983) showed that microbial growth in ground meat extended with textured soy protein can be reduced by adjustment of the system's pH.

Although there are dilution effects on overall protein content that result from extending meat with non-meat proteins, the protein flour is a good source of nutrients such as an increased content of free amino acids, as well as, increased carbohydrates and minerals (Lin, 1987).

Cooking Losses

Generally, researchers have found that as percentage ether extract in ground beef products increases, drip cooking losses increase and volatile cooking losses decrease; thus causing a variable effect on total cooking losses. Cole et al. (1960) studied cooking losses from broiled ground beef patties containing 15, 25, 35 or 45% lipid. They reported that as ether extract from the raw product increased, drip cooking losses increased more than volatile cooking losses decreased, resulting in increased total cooking losses. Kendall et al. (1974) found similar results.

The direction of change for percentage fat with cooking varies depending on the level of fat initially present in the raw product. Kendall et al. (1974) reported that in ground beef products with a lipid content of 20-30%, percentage ether extract decreased with broiling; however, in products with lipid contents below 12%, cooking increased percentage ether extract.

Heating with Microwaves

The popularity of microwave ovens has increased rapidly, especially in food service systems in hospitals, schools, and restaurants. Microwaves are high frequency energy waves, generated by a magnetron located in the oven.

The heat produced by microwaves occurs within the food. Water molecules in the food orient themselves to an alternating electric current, causing movement which constitutes work. This work is converted into heat energy and results in cooking of the food.

The primary advantage of microwave heating is decreased cooking time. Since the heat is produced within the food, there is no time lapse during which heat must pass from an external source to the interior of the food. This results in a drastic reduction in heating time.

Conventional heat treatment of meat products is a lengthy, labor-consuming process with yield and quality factors leaving much to be desired. Broiling of meat products is a popular means of cookery; however, it has beef found to be somewhat inconsistent due to the large number of variables which are present -- including temperature, distance away from heat source, and radiation intensity (Batcher and Deary, 1975). Processing meat products by microwave energy may provide better quality control (shrinkage, flavor) and greater retention of nutrients than conventional processes. Opportunities exist in the meat processing industry in which microwave energy can be applied. A Swedish manufacturer of microwave equipment has installed several microwave meat patty cooking systems in Europe. The system is completely automated from beginning to end with the ground meat formulation being formed into patties (Decareau, 1984). Continued expansion for the application of microwave energy within the food industry is expected as the costs of labor and fuel continue to escalate.

Microwave ovens are considered to be one of the most energy-efficient types of ovens. In 1982, Cremer found the energy used for heating beef patties in microwave ovens was considerably lower than for food heated in a convection oven. Rhee and Drew (1977) determined that surface and microwave cooking of beef patties cost the least to operate, followed by broiling, then baking. Methods of food preparation that are more energy efficient will always be welcomed news to the food industry.

A disadvantage of microwave heating is that surface browning does not occur. Reactions between amino acids and carbohydrates do not continue to completion to produce a flavorful browned exterior. However, browning units are available that help to eliminate this problem.

Although microwave heating is a rapid cookery method, it does have a tendency for increased cooking losses in meat (Korschgen et al., 1976). Reportedly, a large percentage of the loss due to drippings in microwave heating of meat is due to condensation of the evaporated moisture. It would seem that increased drip and evaporative losses would result in a drier, less palatable meat. However, Zayas and Naewbanij (1986) reported that increased losses in microwave meat were due to an increase in collagen (specifically hydroxyproline) solubility and increased fat loss, thereby resulting in a microwaved product with the same remaining moisture content as a conventionally cooked product but with decreased firmness. Fulton and Davis (1985) compared the cooking time, yield, and palatability of beef round and chuck roasts cooked in microwave and conventional ovens. They reported that microwave cooking greatly reduced cooking time for both cuts of meat, but there were no significant differences in yield of cooked lean or in panel ratings for juiciness, softness, and natural flavor.

Fat losses in microwave heated pork patties, roasts and chops were investigated by Apgar et al. (1959). All samples cooked electronically exhibited a slightly higher, but not significant, percentage of total fat and fat retention when compared with conventional oven cooking. Kylen et al. (1964) reported the fat losses for boneless beef rib and pork loin roasts were approximately the same. In beef loaves, the fat losses were higher for microwaved products.

Microwave heating may aid in the retention of total protein in foods. Penner and Bowers (1973) showed amounts of protein were not significantly affected by method of heating. Baldwin et al. (1976) found the free amino acid content tended to be greater in conventionally cooked meat when compared to that cooked by microwaves. Drippings from conventionally cooked meats contained more protein than those that were microwaved. Johnson et al. (1976), found no differences.

Protein digestibility was investigated in cod fillets by Kadaner et al. (1968). Microwave heating did not alter the susceptibility of fish proteins in vitro to proteolytic enzyme attack. Overall, the nutritional effects of microwaves on animal proteins appear to be minor.

Sensory Evaluation of Meat Products

Palatability factors usually considered in the evaluation of meat include appearance, color, aroma, flavor, juiciness and tenderness. Appearance and color may be evaluated on either raw or cooked meat; whereas, aroma, flavor, juiciness and tenderness usually are measured only on cooked meat. The ultimate test of palatability is human reaction which can be evaluated by consumers or by a trained sensory panel.

The flavor of cooked meat arises from fat-soluble precursors and other components present in the raw meat. Heating in air promotes reactions among the precursors to produce the flavor and aroma of the cooked meat. Generally, research has indicated that fat affects meat flavor by producing carbonyl compounds through the oxidation of fatty acids and/or by acting as reservoirs to retain flavor elements that might otherwise be volatilized (Paul, 1972).

Panel members who take part in the cooking of beef patties are influenced by observations of drip and spattering losses. Studies in which homemakers cooked and served samples to their families (Law et al., 1965; Mize, 1972) showed panel members preferred ground beef lower in fat than did studies in which panel members did not take part in the cooking process (Cole et al., 1960; Nielson et al., 1967). Furthermore, Law et al. (1965) noted that homemakers were more discriminating against increased fat content for visual characteristics associated with the cooking of ground beef (ie. color before cooking, shrinkage, and "general cooking qualities") than families were towards palatability characteristics (flavor, juiciness, and tenderness) associated with the eating quality of ground beef.

Ground beef is one of the most popular meat items on the retail market. It is one of the most widely used, as evidenced by the high percentage of household purchases. The market acceptance that ground beef has achieved is likely related to its cost and versatility. Ground beef is one of the most inexpensive beef products available to consumers. This tends to be true regardless of the level of beef production or the level of meat prices in general. In addition, ground beef is quite versatile as it is used in a number of dishes by virtually every segment of the population, ie. most income, social, racial and age groups (Mize, 1972). Baldwin et al. (1972) found no apparent relationship between age categories, number of children, education level or employment and the use of ground beef.

Objective for Study

Increased meat prices are causing many Americans to limit the amount of meat in their diets, thus making a dietary need for a low-cost, complete protein food for a large segment of the population. Plant proteins can be utilized as extenders of ground meat, thereby reducing the cost of the meat product. Long known for its high nutritional value, corn germ protein has the potential for use in the food industry as an extender of ground beef.

The success of non-meat proteins in ground beef will depend upon whether the finished product resembles the traditional beef patty. However, little information is available as to the actual functional and quality effects that result from extending ground beef with corn germ protein. Therefore, this study was undertaken to assess the effects of extending ground beef with corn germ protein when utilizing conventional and microwave heating methods.

MATERIALS AND METHODS

Sample Preparation

Meat trimmings were purchased from Flint Hill Foods of Alma, Kansas. A flow-diagram for preparation of experimental samples is illustrated in Figure 1. Fat (50/50) and lean (90/10) sources were ground separately through a 1" break plate (2.54 cm). A Pearson square calculation was used to determine the amounts of fat and lean portions needed to formulate the targeted fat content of 20%. A Hobart fat tester (Hobart Corporation, Troy, OH) was used to ensure that the ground product met the targeted fat level. The ground meat was then divided into three batches to correspond to the three replications of the study, and vacuum packaged. Ground meat was held in a walk-in cooler at $4^{o}C$ until treatments were prepared.

Treatments

Beef patties were extended with a slurry of corn germ protein at the levels of 0, 10, 20, and 30% of the raw weight of the total mix. This resulted in a CGP concentration of 0, 2.5, 5.0 and 7.5% of the total mix. The control samples were those prepared without added CGP. Formulations of patty treatments are illustrated in Table 2.

Figure 1. Flow-diagram for preparation of experimental samples.

Fat Source	Lean Source
50/50 Beef trim	90/10 Cow meat
One-inch grind	One-inch grind
Test fat content	Test fat content

Pearson square calculations = 20% fat

Hobart fat tester

Replication 1   Replication 2   Replication 3

Formulate CGP/meat treatments of

0% CGP Slurry	10% CGP Slurry	20% CGP Slurry	30% CGP Slurry

Grind each CGP/meat blend through 1/2-inch plate

Chill

Grind each blend for a second time through a 1/8-inch plate

Chill

Form patties weighing 175 g from each treatment

Freeze patties until solid and vacuum package

Freezer storage

Table 2. Formulations of corn germ extended beef patties.

Ingredients	Treatments			
	0%	10%	20%	30%
Ground Beef, g	2562	2492	2212	1932
Salt, g	28	28	28	28
Water, g	210	210	420	630
CGP[1], g	--	70	140	210
	2800	2800	2800	2800

[1]CGP = Corn germ protein.

Corn germ protein was supplied by the Lauhoff Grain Company (Danville, IL) and was produced by hexane extraction.

Corn germ slurries were prepared by hydrating the dry protein additive with distilled water in a ratio of 1:3. Slurries were prepared in glass beakers covered with plastic wrap and held at room temperature for 90 min to ensure complete hydration of the flour. Hydrated CGP was mixed with the meat and then ground through a 1/2 in (1.27 cm) plate. Grinding of the combined CGP and meat mixture was in effort to thoroughly incorporate the CGP throughout the product. The ground beef mixture was chilled in a freezer for 10 min to temper and lower the temperature of the mix before being ground for a second time. The chilled mix was passed through an 1/8 in (0.32 cm) plate and again chilled for 10 minutes.

The chilled mixture was then weighed into 175 g portions and formed into patties using a hand press (Tupperware, Orlando, FL) sprayed with a no-stick spray for easy release. The formed patties were placed between squares of waxed paper, layered on metal trays, and frozen solid. Frozen patties were vacuum packaged in groups of three and stored at -23^{o}C until heat treatment.

Heat Treatment

This study consisted of two heating methods: oven broiling and microwave cookery. Each cooking method was treated as a separate experiment. Before cooking, patties were thawed overnight in a refrigerator at 4^{o} C.

Broiling. A conventional electric oven (Waste King) with an overhead element was preheated to maximum temperature (550^{o}F) before broiling the patties. Patties were broiled on wire racks nestled in metal pans having the dimensions of 18cm x 28cm x 3cm (The West Bend Co., Westbend, WI). An oven rack was placed 12 cm from the heating element, and the oven door was held open 7.5 cm during cooking to allow for the use of an electronic temperature recording device (Doric Minitrend 205). Patties were broiled for 6 mins, turned, and broiled to the internal endpoint temperature of 77^{o} C, medium-well doneness. The temperature of the broiler was not thermostatically controlled.

Microwaving. A carousel microwave oven (Sharp Electronics Corp., Paramus, NJ, Model R-8200) was used as the heating source in this cookery method. In order to make a browned crust on the patty surfaces, a browning griddle (Corning Glass Works, Corning, NY, MW-11) was used as the manufacturer directed. Patties were cooked for 3 min at maximum power setting, turned over, and heated at one minute intervals until an internal endpoint temperature of 77^{o}C was obtained.

Quality Characteristics and Methods of Determination

Heating losses and yield

Weights of patties before and after cooking were obtained for purposes of calculating heating losses. Measurements of total cooking losses were separated as to drip losses and volatile losses. Yield calculations were made using the following formula:

$$\%\ \text{Yield} = \frac{\text{Raw Patty Weight} - \text{Cooked Patty Weight}}{\text{Raw Patty Weight}} \times 100 .$$

Moisture content

Moisture content of both raw and cooked samples was determined by drying overnight in an oven at 105°C (AOAC method 24.002). Duplicate measures for three patties of each treatment were obtained. Data were then used to calculate a retention factor using the following formula:

$$\%\ \text{Moisture Retention} = \frac{\%\ \text{Yield} \times \%\ \text{Cooked Moisture}}{\%\ \text{Raw Moisture}} .$$

Fat determinations

A Hobart fat analyzer was used for the formulation of ground beef with a fat content of 20% which was used as the meat ingredient in CGP-extended beef patty treatments.

Fat was determined in raw and cooked samples from three patties in each treatment group. Analysis was made using the Foss-Let fat analyzer (A/S N. Foss Electric, Denmark) according to the AOAC method 24.006. A 22.5 g sample of ground beef patty (raw and cooked) was reacted for 2.5 min along with 120 ml tetrachloroethylene and 50 g plaster of paris in the reaction chamber. The extracted filtrate was then analyzed for a direct reading of percent fat content. A fat retention factor was calculated as follows:

$$\% \text{ Fat Retention} = \frac{\% \text{ Yield} \times \% \text{ Cooked Fat}}{\% \text{ Raw Fat}}$$

Protein determination and amino acid analysis

Percent nitrogen was analyzed by the Buchi method (modified Kjeldahl) with the conversion factor of 6.25 being utilized to convert the data to percent protein. Samples of broiled beef patties were sent to an outside laboratory for analysis of amino acid content. Data were calculated to 100% recovery and expressed in g amino acid per 100 g protein.

Patty dimensions and calculation of shrink

Vernier calipers were used to measure the thickness of patties before and after cooking. Patties were placed on plexiglass squares with thickness measurements taken in each of the four quarters of the patty for a total of four measurements/patty. These measurements were averaged as an estimate of each patty's thickness (Campbell and Mandigo, 1978). The perimeter of both raw and cooked patties was traced on to paper with the area and diameter of the traced pattern measured twice and averaged. Data were reported as percent change in patty dimension (thickness, area, and diameter) since patties can increase or decrease in the various dimensions depending on formulation. Calculation of percent change for each dimension utilized the following equation:

$$\% \text{ Change} = \frac{\text{Raw Measure} - \text{Cooked Measure}}{\text{Raw Measure}} \times 100 .$$

Water holding capacity (WHC)

Water holding capacity of raw patties was determined using a modified Hamm press method. A 0.3 g sample was weighed on to filter paper (Whatman No. 1) which was placed between two plexiglass sheets and pressed with a Carver Laboratory Press for 5 min at 5,000 lbs of pressure. Areas were measured with a compensating polar planimeter and the WHC was calculated as follows:

$$\text{WHC} = 1 - \frac{\text{Total Area} - \text{Meat Film Area}}{\text{Meat Film Area}} .$$

Three samples per treatment were measured. The closer the value for WHC is to one the less expressed water, or a better water holding capacity.

pH determination

Duplicate readings were obtained for determining pH of raw and cooked samples using a Corning pH meter 140 (Corning Medical and Scientific, England). Samples were prepared by blending a 10 g sample of ground beef patties with 100 ml distilled water for 2 mins at high speed in a Waring Blender (Waring Model 91-203, New Hartford, CT).

Sensory evaluation

A six-member, professional panel was trained in two sessions to become familar with the product's characteristics of aroma, flavor and texture. Aromatic notes evaluated included meaty aroma, off-aroma, and off-aroma acceptability. Flavor notes included meaty flavor, off-flavor and off-flavor acceptability. Textural attributes evaluated were juiciness, mushiness, and grind. An evaluation of off-color was made as well.

Panelists were presented with wedges of cooked patties served in warmed custard cups covered with watch glasses. Under red light, panelists were asked to evaluate samples for aroma, flavor and texture in the order listed on the ballot. Red lighting was used in the sensory evaluation room to minimize panel perception of color differences caused by the differences in patty composition. Then panelists were presented with samples in natural daylight for an evaluation of off-color. All parameters were scored on a six-inch (15 cm) unstructured intensity line scale with anchors at each endpoint and a centerline. Results were converted into numerical values by measuring the distance of the line scores from the left end of the line scale. A copy of the actual ballot used is presented as Figure 2. Sessions were conducted separately for the sensory evaluations of the two methods of heat treatment, conventional and microwave. During these sessions, four samples were presented to panelists in a randomized order for each day of sensory data collection.

Texture analysis

Shear values and resistance to compression were measured on cooked patties at ambient temperature using an Instron Universal Testing Machine (Model 1122). The Instron was equipped with a 500 Kg compression load cell, and had a crosshead descent speed of 100 mm/min and a chart speed of 100 mm/min. Analysis by shear force and compression were performed on the same patty. Figure 3 illustrates the diagram of sampling for texture analysis. The upper crust

Figure 2. Ballot for sensory evaluation of cooked beef patties.

Sample #: ________   Name: ________________

Date: ________________

AROMA:

Meaty Aroma:

none ______________________|______________________ intense

Off-aroma:

none ______________________|______________________ intense

Off-aroma Acceptability:

dislike ______________________|______________________ like

FLAVOR:

Meaty Flavor:

none ______________________|______________________ intense

Off-flavor:

none ______________________|______________________ intense

Off-flavor Acceptability:

dislike ______________________|______________________ like

Juiciness:

none ______________________|______________________ intense

Tenderness:

none ______________________|______________________ intense

Mushiness:

none ______________________|______________________ intense

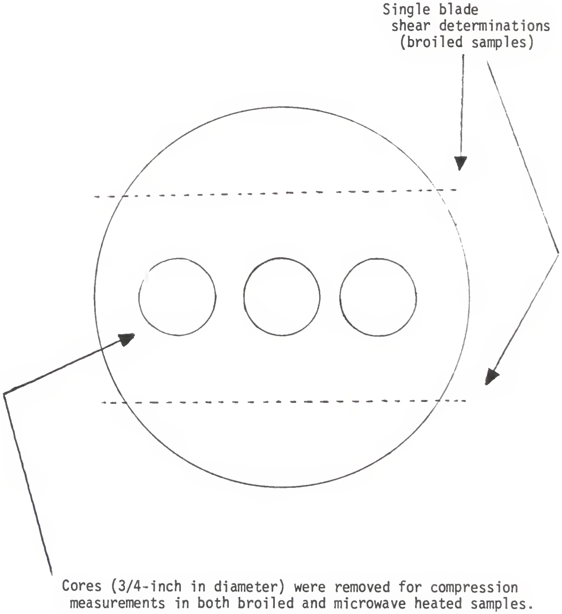
Grind:

fine ______________________|______________________ coarse

Off-color:

none ______________________|______________________ intense

Figure 3. Sampling diagram for instrumental analysis of beef patty textural characteristics.



of each patty was removed with use of a miterbox to make patties of uniform thickness (3/4 in or 1.89 cm).

For shear force evaluations, a single, straight-edged blade mounted on the Instron was utilized. The single blade shear device consisted of a rectangular blade having the dimensions of 3 in x 5-3/4 in (7.62 cm x 14.61 cm). There was a 2.5 cm clearance between the shearing edge of the blade and the corresponding surface edge of the hole in the base plate where shearing action occurs. A full scale setting of 2 was used for the shear determinations of the control patties, while a full scale setting of 1 was used for all other treatments. Hardness was measured by the height of the resulting curve and was expressed as Kg force.

Compression data were obtained using a plunger attachment to the Instron. Cores 1.89 cm (3/4 in) diameter were removed from each patty. One crust was left intact on the cores. The force necessary to compress the samples to 54% of original thickness was measured twice on each core. Hardness, measured by the height of the first compression force curve, was expressed as Kg force. Cohesiveness was measured as the ratio of the area under the second compression force curve (A_2) to the area under the first curve (A_1) as described by Bourne (1978).

Color measurement

Cooked patties which had been finely ground with a food processor were used for the Hunterlab color measurement (Hunterlab D54 Spectrophotometer, Hunter Associates Laboratory, Fairfax, VA). L, a, and b values using illuminant A and C light sources were obtained. A second reading was made for the same sample after it was turned 90 degrees and the two readings were averaged. L measures lightness and varies from 100 for pure white to 0 for black. The value of +a/-a measures redness when plus, gray when 0 and green when minus; while the value of +b/-b measures yellowness when plus, gray when 0 and blueness when minus. These data were then used to calculate the indices of hue and saturation (Little, 1975) as follows:

$$\text{Hue Angle: } H = \tan^{-1} b/a$$

$$\text{Saturation Index: } S = (a^2 + b^2)^{1/2} .$$

Statistical design

Cooking of beef patties, conventionally and microwaved, were conducted as separate experiments. A randomized block design was used for both experiments. Data were analyzed for differences due to level of CGP extension, using analysis of variance. For each source of variation for which the F-value was significant, least significant difference at the 5% level of probability was calculated. Correlations between selected measurements were determined.

RESULTS AND DISCUSSION

Heating losses

Heating losses were measured as weight changes between raw and cooked meat and were separated into drip and volatile losses. Volatile losses consist primarily of evaporated water which was released from the meat tissue as proteins became denatured and coagulated. This evaporated water also could include water-soluble materials such as salts and nonprotein nitrogenous compounds. Volatile losses may also include aromatic compounds, primary and secondary products of heat-decomposed fat and protein, as well as fat droplets that have spattered out of the pan. Drip cooking losses consist primarily of fat which has melted out of the meat tissue during heating, but also may include water and non-volatile water-soluble materials such as salts and sarcoplasmic proteins (Paul and Palmer, 1972).

Heating losses of broiled patties are shown in Table 3, while the losses resulting from microwave cookery are shown in Table 4. Losses caused by heating were affected by both percentage of corn germ protein added and method of heat treatment.

Table 3. Heating losses of broiled beef patties with added CGP.

Added CGP Slurry[d] (%)	Heating Losses (%)				
	Volatile	Drip	Total	Fat	Water
0	36.91[a]	6.97[a]	43.88[a]	-2.21[a]	6.39[a]
10	29.78[b]	6.56[a]	36.35[b]	-2.13[a]	6.64[a]
20	28.88[b]	5.45[a,b]	34.55[b]	-0.21[b]	6.79[a]
30	27.54[b]	4.53[b]	32.06[b]	+2.24[c]	9.57[b]

[a,b,c]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[d]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

Table 4. Heating losses of microwaved beef patties with added CGP.

Added CGP Slurry[d] (%)	Heating Losses (%)				
	Volatile	Drip	Total	Fat	Water
0	26.33[a]	10.11[a]	36.32[a]	1.60[a]	7.01[a]
10	25.87[a]	8.15[a,b]	34.02[a]	2.54[a]	5.50[a]
20	23.25[a]	6.96[b,c]	30.21[b]	1.46[a]	5.24[a]
30	23.26[a]	5.68[c]	28.94[b]	1.27[a]	6.64[a]

[a,b,c]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[d]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

Adding corn germ protein decreased total cooking losses in both broiled (conventional) and microwave heated beef patties. The overall trend was for a reduction in heating losses as the level of added CGP increased. Although this study's design did not allow for a stastical comparison of the heating methods, the method of cooking appeared to influence the amount of total losses since lower absolute values were obtained for beef patties heated by microwave energy at all treatment levels. This is contradictory to the findings of previous researchers who found increased cooking losses for microwave cooking of muscle tissue (Korschgen et al., 1976; Zayas and Naewbanij, 1986).

In both heat treatment methods, conventional and microwave, the average value for total cook loss was greater for the control patties than for beef-CGP products. Further discussion of results will illustrate that this decrease in cooking losses is produced by the ability of the corn germ protein additive to increase the retention of fat and water. Additional data also showed that the fat content of patties decreases with increasing levels of CGP. Therefore, the decrease in drip loss, especially for 20-30% added CGP, also supports the findings of Cole et al. (1960) and Kendall et al. (1974) relating losses to the initial amount of lipid present in the product. A correlation coefficient of 0.85 was found for the comparison of the fat content of raw patties and the amount of drip loss resulting with microwave heating.

Differences in the two components that make up total cooking losses also were noted. Volatile losses were reduced significantly in broiled patties at the 10% CGP treatment level, while drip losses remained constant up to the 30% treatment. On the other hand, data obtained for microwave heated samples showed no differences for volatile losses according to treatment levels (10, 20, and 30% added CGP), but values for drip losses were lowered significantly at the 10, 20, and 30% levels.

Percentage of fat and water loss in cooking were not significantly different for any of the CGP treatment levels in beef patties heated with microwave energy. However, data obtained for broiled patties indicated a significant decrease in the amount of fat lost at the 20 and 30% CGP levels; while, water losses displayed the trend to increase as the level of added CGP increased. Water losses were significantly different at the 30% CGP level.

Yield and proximate composition

Yield of products are of great economic concern to the food industry. Therefore, data were collected to evaluate the effects of corn germ protein on yield of cooked beef patties.

Corn germ protein was found to increase cooking yields in both conventionally and microwave heated beef patties (Tables 5 and 6). Mean values for percent yield were increased over the control patties at the 10% CGP treatment level for broiled beef patties and at the 20% CGP treatment level for microwave heated beef patties. Although not significantly different, the trend in both methods of heat treatment was for increasing percent yield as the level of CGP extension was increased. In broiled patties, yield was increased from 59.58% in the control to 70.37% in the 30% extension level; while the yield of microwave heated beef patties was increased from 63.68% in the control to 71.06% in the 30% CGP slurry (7.5% on a dry weight basis) treatment.

In a similar study, Blessin et al. (1973) also found that the percent yield of broiled meat products changed as the level of corn germ flour increased. They reported an increase in yield from 70% in the control patty to 77% at the 10% treatment level (dry weight basis).

In the series of experiments with microwave heating, percentage moisture was less in control patties than in beef-CGP blend patties. Yet, the opposite trend was noted in patties that were conventionally heated. Still the amount of rehydrated corn germ powder added did not affect the final moisture content of the broiled patties

Table 5. Proximate composition and yield of broiled beef patties with added CGP.

Added CGP Slurry[e] (%)	Protein (%)	Fat (%)	Water (%)	Yield (%)
0	28.12[a]	16.42[a]	56.47[a]	59.58[a]
10	25.97[b]	16.38[a]	54.86[a]	67.13[b]
20	23.01[c]	15.79[a]	55.85[a]	68.58[b]
30	20.74[d]	15.89[a]	55.14[a]	70.37[b]

[a,b,c,d]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[e]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

Table 6. Proximate composition and yield of microwave heated beef patties with added CGP.

Added CGP Slurry[e] (%)	Protein (%) Raw	Protein (%) Cooked	Fat (%)	Water (%)	Yield (%)
0	14.85[a]	24.11[a]	17.78[a]	55.70[a]	63.68[a]
10	14.88[a]	22.28[b]	16.10[b]	56.44[a,b]	65.98[a]
20	14.19[b]	19.89[c]	15.62[b]	56.93[b]	69.79[b]
30	13.54[c]	18.23[d]	13.73[c]	57.29[b]	71.06[b]

[a,b,c,d]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[e]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

significantly. However, the results for microwave heated beef patties showed an increased amount of water in cooked patties when CGP was added. Moisture content for microwave heated CGP-extended patties ranged from 56.44 to 57.29%, while broiled values ranged from 54.86 to 55.85%.

In microwave heated beef patties, percentage fat was significantly greater in the control than in the CGP-extended beef patties, and the beef patties with 10% CGP contained more lipid than those with 30% CGP (Tables 5 and 6). This is caused by the dilution effect of adding a defatted CGP product to ground meat during beef patty formulations. It was expected that the CGP-extended products would contain less fat and more moisture, since the corn germ product used contained 0.9% fat and was rehydrated with 3 times its weight of water.

Nutritional guidelines recommend a reduction in the caloric intake from fat. Results indicate that manufacturing of low-fat meat products (beef patties) is economically possible with the utilization of plant proteins such as corn germ protein. Addition of a low-cost, defatted cereal protein will not only lower production costs by increasing yields but could improve the nutritional quality of the product by lowering its fat content, and possibly its cholesterol content.

Experimental data showed that the protein content of cooked beef patties decreased significantly with the addition of CGP (Tables 5 and 6). When collecting data for the conventionally heated samples, a decrease in protein content of cooked beef patties was noted. Reduction in protein content was believed to be caused by the greater yield and the higher retention of fat and water in patties which were extended with corn germ protein rather than to any actual losses. Therefore, in the experiments with microwave heated beef patties, protein contents were determined in both raw and cooked patties in an effort to more fully explain the decreases in protein content.

As shown in Table 6, the result of CGP extension was a reduction in the overall protein content of the extended beef patties in both the raw and cooked state. At first this could sound surprising in light of the fact that CGP contains 23-26% protein and the meat it is replacing only contains 18-22% protein. However, this can be explained as a dilution effect on the quantity of protein present in the CGP slurries resulting when the protein additive is hydrated with an amount of water that is three times its weight. Therefore, the amount of protein present in the slurry was reduced significantly. Although protein content of beef patties is lowered by the addition of CGP, it is important to consider that CGP extension will result in beef patties containing increased levels of starch, fiber and minerals.

Data further shows that the method of cooking also affected protein content of cooked beef patties. Although not analyzed statistically, mean values for broiled beef patties were higher than the values obtained for beef patties heated by microwave energy with the same extension levels.

Amino acid analysis

Amino acid composition of protein from conventionally heated beef patties containing CGP is presented in Table 7. Generally, amino acid composition of the protein in beef patties was not affected greatly by the addition of corn germ protein. There were no significant differences noted among the treatment levels (10, 20, and 30% added CGP slurry) for the amount of each amino acid present except for phenylalanine. However, only the 30% CGP treatment level was significantly different in its phenylalanine content from that of the control patty. Therefore, the amino acid composition of experimental beef patties was affected only slightly by the addition of CGP.

Essential amino acids need to be considered for the discussion of nutritional quality of the proteins. In comparison with the requirements established by the FAO for human consumption (Table 1), it can be determined that CGP-extended beef patties meet or exceed the FAO's requirements

Table 7. Amino acid composition of broiled beef patties with corn germ protein added.

Amino Acid[c]	Amino acid composition of CGP-extended beef patties, g/100g			
	Control	10% CGP	20% CGP	30% CGP
Asp	9.37	9.66	9.65	9.46
Thr	4.31	4.32	4.43	4.14
Ser	4.41	4.50	4.49	4.48
Glu	14.95	15.82	15.45	15.34
Prol	5.30	6.06	5.62	6.60
Gly	7.86	8.22	6.86	9.10
Ala	7.34	7.37	7.04	7.61
Cys	0.82	0.56	0.86	0.69
Val	3.84	3.48	3.84	3.54
Met	2.27	1.98	2.25	1.86
Isoleu	3.17	2.93	3.16	2.81
Leu	7.40	7.36	7.64	7.07
Tyr	3.69	3.36	3.75	3.17
Phe	4.29[a]	3.93[a,b]	4.23[a,b]	3.82[b]
His	4.77	4.52	4.63	4.44
Lys	7.57	7.50	7.45	6.93
NH_4	1.23	1.22	1.26	1.16
Arg	7.41	7.22	7.40	7.78

[a,b]Means in rows with the same or no superscripts are not different ($P < 0.05$).

[c]Tryptophan was not determined.

for threonine, methionine, leucine, tyrosine, phenylalanine, and lysine; while remaining low in cysteine, isoleucine and valine. However, the same limitations also were found in the control patties which did not contain CGP. Supplementation of cysteine, isoleucine and valine is a possibility for bringing the amino acid composition of broiled beef patties extended with CGP within the FAO requirements.

Retention of water and fat

A desirable nutritional characteristic of CGP is its low content of fat. This positive quality would be partially negated if beef patties extended with CGP retain a greater percentage of fat in cooking than all-beef patties.

The methods of Anderson and Lind (1975) were employed to determine differences in the retention of water and fat in the extended beef patties. Data for fat and water contents and their retention following heat treatment are presented in Table 8 for broiled beef patties and Table 9 for microwave heated beef patties. In general, fat retention increased as the level of CGP increased. Different levels of fat retention were obtained for conventional and microwave heating methods. Values for fat retention were highest in broiled beef patties.

Table 8. Content and retention of fat and water in raw and conventionally cooked beef patties with added CGP.

Added CGP Slurry[d] (%)	Fat (%)		Water (%)		Yield (%)	Retention (%)	
	Raw	Cooked	Raw	Cooked		Fat	Water
0	18.63[a]	16.42[a]	62.86[a]	56.47[a]	59.58[a]	52.74[a]	53.47[a]
10	18.51[a]	16.38[a]	61.49[b]	54.86[a]	67.13[b]	59.52[a,b]	59.95[b]
20	16.00[b]	15.79[a]	62.64[a]	55.85[a]	68.58[b]	67.88[b]	61.62[b]
30	13.64[c]	15.89[a]	64.71[c]	55.14[a]	70.37[b]	82.11[c]	60.05[b]

[a,b,c]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[d]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

Table 9. Content and retention of fat and water in raw and microwave heated beef patties with added CGP.

Added CGP Slurry[d] (%)	Fat (%)		Water (%)		Yield	Retention (%)	
	Raw	Cooked	Raw	Cooked	(%)	Fat	Water
0	19.32[a]	17.78[a]	62.71[a,b]	55.70[a]	63.68[a]	57.54[a]	55.47[a]
10	18.64[a,b]	16.10[b]	61.94[a]	56.44[a,b]	65.98[a]	58.64[a,b]	60.56[b]
20	17.08[b]	15.62[b]	62.17[a,b]	56.93[b]	69.79[b]	63.93[a,b]	63.97[c]
30	14.38[c]	13.73[c]	63.92[b]	57.29[b]	71.06[b]	68.90[b]	64.40[c]

[a,b,c]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[d]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

CGP extension significantly decreased fat content in raw beef patties. This is caused by a dilution effect of replacing meat fat with a defatted cereal product. This dilution effect for fat content also was noted in the beef patties cooked with microwave energy. However, beef patties heated by the conventional method of heat treatment showed no significant differences for fat content in the cooked patties, thereby illustrating the increased fat retention in broiled beef patties. Still, beef patties containing added CGP had the lowest values for final fat content of broiled beef patties. Final fat content of microwave heated patties was lowered significantly with 10% CGP extension.

Addition of CGP improved the retention of water in beef patties. The retention of water was greatest in the microwave heated samples. Both cooking methods resulted in significantly higher values for retention of water in beef patties extended with corn germ protein than for the control beef patties.

The addition of corn germ protein slurries increased the moisture content of raw beef patties. Finished beef patties containing CGP slurry and prepared by microwave cookery, displayed an increase in moisture over the control samples (Table 9). However, cooking by conventional methods brought an equilibrium across treatment levels showing no significant differences in the moisture content of cooked beef patties (Table 8). Therefore, water retention played a significant role in reducing drip losses in microwave heated products.

Anderson and Lind (1975) found that the percent retention of moisture was greater for the cooked beef patties containing textured soy protein, while the retention of fat was greater for the cooked all-beef patties and that the retention of fat and moisture was directly related to the percent of textured vegetable protein present in the patties. Our results showed that corn germ protein had a higher fat retention than water retention, especially at the level of 30% added CGP in broiled patties.

Changes in physical measurements of patties

Knowledge of the degree of shrinkage that will result with cooking is important in maintaining the quality standards of beef patties prepared in food-service establishments. Therefore, data were collected for calculation of the amount of change in the patty dimensions of thickness, area, and diameter.

Physical measurements of the broiled beef patties did not differ significantly; however, a trend was for a decrease in the percent change of patty area and diameter, while patty thickness increased with increasing levels of incorporated CGP (Table 10). Other researchers have

Table 10. Changes in physical characteristics of beef patties following conventional heat treatment.

Added CGP Slurry[b] (%)	Increase in Thickness (%)	Decrease in Area (%)	Decrease in Diameter (%)
0	26.36[a]	58.08[a]	34.63[a]
10	33.03[a]	55.25[a]	32.20[a]
20	35.08[a]	53.22[a]	28.36[a]
30	44.20[a]	56.04[a]	31.91[a]

[a]Means in the same column with the same superscript letters are not different ($P < 0.05$)

[b]CGP slurry = corn germ slurry; CGP hydrated with distilled water in ratio 1:3

Table 11. Changes in physical characteristics of beef patties following heat treatment with microwave energy.

Added CGP Slurry[c] (%)	Increase in Thickness (%)	Decrease in Area (%)	Decrease in Diameter (%)
0	26.97[a]	48.62[a]	28.44[a]
10	31.11[a]	45.86[a,b]	25.58[a,b]
20	27.20[a]	44.17[a,b]	25.47[a,b]
30	34.42[a]	40.70[b]	22.73[b]

[a,b]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[c]CGP slurry = corn germ slurry; CGP hydrated with distilled water in ratio 1:3.

reported that soy added to meat decreased shrinkage (Judge et al., 1974; Bowers and Engler, 1975). Data for the microwave heated beef patties proved not to be significantly different for the amount of change in patty thickness, but were different at the 10% treatment for decreasing patty change in area and diameter (Table 11). Changes in physical measurements were higher for all treatment levels in the broiled beef patties than for the patties which were heated by microwave energy. This difference in physical measurements was most likely caused by the extremely high temperature and longer cooking times encountered in the conventional heating method.

Effects on pH, water holding capacity, and heating time

Hamm and Deatherage (1960) found that heating beef muscle increased the pH of the meat about 0.4 pH units. Data for the pH values of broiled beef patties are presented in Table 12. The level of change in pH between raw and cooked beef patties containing CGP decreased as the level of CGP extension was increased. The pH of the raw beef patties increased with the addition of CGP, since the pH of the CGP slurries ranged from 5.62 for 10% CGP slurry to 5.87 for 30% CGP slurry.

Water holding capacity (WHC) is known to be affected by changes in pH (Swift and Berman, 1959). Results showed

Table 12. Effect of heating and added CGP on pH, WHC, and yield of broiled beef patties.

Added CGP Slurry[d] (%)	pH Raw	pH Cooked	WHC[e] (Raw)	Yield (%)	Heating Time (mins)
0	5.80[a]	5.96[a]	.05[a]	59.58[a]	13.44[a]
10	5.89[a]	6.04[b]	.48[b]	67.13[b]	13.56[a]
20	6.03[b]	6.13[c]	.56[b]	68.58[b]	12.89[a]
30	6.11[b]	6.14[c]	.63[b]	70.37[b]	12.00[a]

[a,b,c]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[d]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

[e]WHC = water holding capacity.

addition of CGP slurry significantly increased WHC of CGP-extended beef patties over that found in control beef patties. Average WHC value for the control beef patties were 0.05, while values for CGP-extended beef patties ranged from 0.48 with 10% added CGP to 0.63 with 30% added CGP. There were no significant differences found among any of the values for extended patties.

Previous discussion of results explained that water retention and yield of beef patties was increased when CGP was included in the patty formulation. Table 12 displays the trend for the yield of cooked patties to increase as the WHC of raw patties increased. A correlation factor of 0.68 was found for the relationship between increased WHC and increased yield of broiled beef patties, while a factor of 0.85 was found for the correlation of water retention and yield of conventionally cooked beef patties.

The heating time required to reach the internal endpoint of $77^{\circ}C$ is also shown in Table 12. Although values were not significantly different, the trend was for decreased heating time as the level of added CGP in beef patties increased.

Sensory evaluation of meat

Human senses play an important role in perceiving subtle differences in food flavors and textures. Sensory methods are used to measure differences in characteristics of food such as taste, aroma, juiciness, texture, or tenderness. Sensory attributes of quality can be measured best by trained, discriminating people responding under controlled conditions. Data in Tables 13 - 16 were obtained from a trained, professional panel as they evaluated the sensory characteristics of beef patties.

In general, the absolute values for measurements of the sensory characteristics of meaty aroma were rated higher in beef patties heated by microwave energy, while a higher level of off-aroma was noted in the broiled samples (Tables 13 and 14). When comparing absolute values, panelists found the off-aroma of CGP-extended beef patties to be slightly more acceptable in broiled patties, especially at the 30% treatment level.

With the exception of juiciness, all other sensory characteristics were similar for both heat treatments (Tables 15 and 16). Attributes of meaty flavor, off-flavor acceptability, and the perceived grind (all treatments utilized the same grinding technique in formulation) decreased with increasing levels of added CGP; while the attributes of off-flavor, tenderness, mushiness, and off-color increased. The perception of off-flavor increased and the evaluation for meaty flavor decreased as the amount of

Table 13. Aroma characteristics of broiled beef patties with added CGP.

Added CGP Slurry[d] (%)	Meaty Aroma[e]	Off-Aroma[e]	Off-Aroma Acceptability[f]
0	4.40[a]	0.98[a]	4.78[a]
10	2.08[b]	3.55[b]	3.90[b]
20	1.62[b]	4.11[b,c]	3.38[b]
30	0.96[b]	4.87[c]	3.47[b]

[a,b,c]Means in the same column with the same superscript letters are not different ($P < 0.05$)

[d]CGP slurry = corn germ protein slurry; GCP hydrated with distilled water in ratio of 1:3.

[e]Based on six-inch sensory line-scale anchored on opposing ends--"none" (0) and "intense" (6)-- with midpoint marked. Measured to 1/16 of an inch.

[f]Based on six-inch sensory line-scale anchored on opposing ends--"dislike"(0) and "like"(6)--with midpoint marked. Measured to 1/16 of an inch.

Table 14. Aroma characteristics of microwaved beef patties with added CGP.

Added CGP Slurry[d] (%)	Meaty Aroma[e]	Off-Aroma[e]	Off-Aroma Acceptability[f]
0	4.49[a]	0.97[a]	4.73[a]
10	2.86[b]	2.91[b]	3.70[b]
20	1.77[c]	3.94[c]	3.31[b,c]
30	0.94[c]	4.66[c]	2.86[c]

[a,b,c]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[d]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

[e]Based on six-inch sensory line-scale anchored on opposing ends--"none" (0) and "intense" (6)-- with midpoint marked. Measured to 1/16 of an inch.

[f]Based on six-inch sensory line-scale anchored on opposing ends--"dislike" (0) and "like" (6)-- with midpoint marked. Measure to 1/16 of an inch.

Table 15 . Sensory properties of broiled beef patties with CGP added.

Added CGP Slurry[e] (%)	Meaty Flavor[f]	Off-Flavor[f]	Off-Flavor Acceptability[g]	Juiciness[f]	Tenderness[f]	Mushiness[f]	Grind[h]	Off-Color[f]
0	4.92[a]	0.64[a]	4.86[a]	2.31[a]	3.12[a]	0.85[a]	4.58[a]	0.65[a]
10	3.06[b]	2.84[b]	4.12[b]	3.30[a]	3.58[a,b]	1.62[a,b]	3.86[a]	0.83[a]
20	1.85[c]	3.83[c]	3.45[c]	3.50[a]	4.06[b]	2.57[b,c]	2.92[b]	1.25[a,b]
30	0.91[d]	5.02[d]	3.13[c]	3.75[b]	3.92[b]	3.18[c]	2.10[b]	1.65[b]

[a,b,c,d]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[e]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

[f]Based on six-inch sensory line-scale anchored on opposing ends--"none" (0) and "intense" (6)--with midpoint marked. Measured to 1/16 of an inch.

[g]Based on six-inch sensory line-scale anchored on opposing ends--"dislike" (0) and "like" (6)--with midpoint marked. Measured to 1/16 of an inch.

[h]Based on six-inch sensory line-scale anchored on opposing ends--"fine" (0) and "coarse" (6)--with midpoint marked. Measured to 1/16 of an inch.

Table 16. Sensory properties of microwaved beef patties with CGP added.

Added CGP Slurry[e] (%)	Meaty Flavor[f]	Off-Flavor[f]	Off-Flavor Acceptability[g]	Juiciness[f]	Tenderness[f]	Mushiness[f]	Grind[h]	Off-Color[f]
0	4.76^{a}	0.73^{a}	4.79^{a}	3.41^{a}	2.83^{a}	1.02^{a}	3.76^{a}	0.64^{a}
10	2.86^{b}	2.86^{b}	3.73^{b}	2.91^{a}	2.92^{a}	2.27^{b}	$2.95^{a,b}$	1.42^{b}
20	1.51^{c}	4.22^{c}	3.07^{c}	2.83^{a}	$3.68^{a,b}$	2.86^{c}	$2.36^{a,b}$	1.14^{b}
30	0.85^{d}	5.08^{d}	2.48^{d}	3.54^{a}	4.14^{b}	3.82^{d}	1.54^{b}	1.10^{b}

[a,b,c,d]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[e]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

[f]Based on six-inch sensory line-scale anchored on opposing ends--"none" (0) and "intense" (6)--with midpoint marked. Measured to 1/16 of an inch.

[g]Based on six-inch sensory line-scale anchored on opposing ends--"dislike" (0) and "like" (6)--with midpoint marked. Measured to 1/16 of an inch.

[h]Based on six-inch sensory line-scale anchored on opposing ends--"fine" (0) and "coarse" (6)--with midpoint marked. Measured to 1/16 of an inch.

added CGP was increased. This suggested that the corn germ additive affected the flavor of beef patties.

Juiciness did not differ significantly for microwave heated patties, but were different at the 30% level of extension in the broiled samples. Even though CGP-beef blends contained more moisture than control beef patties, adding CGP did not affect juiciness until the 30% level and then only in the broiled samples. Retention values explained earlier suggest that this difference in the degree of juiciness perceived by panelists at the 30% level of extension is attributed to an increased retention of fat rather than water. Addition of CGP had an increasing effect on patty tenderness.

Contrary to these findings, Blessin et al. (1972) reported that corn germ flour could be added to beef patties on a dry weight basis up to the level of 10% without significant flavor changes occurring in the products. Results of their taste panel reportedly showed no objectionable color, odor or taste in any of the beef patties. On the other hand, our results prove that panelists can detect an off-flavor at the 10% level of added CGP slurry (only 2.5% CGP on a dry weight basis), with acceptability of the off-flavor decreasing with increasing levels of extension.

An important conclusion is that the results for panel evaluation of off-flavor acceptability of broiled beef patties never crossed the midpoint of the line-scale into the "dislike" region. Therefore, no objectionable flavor was found in any of the broiled beef patties. However, data suggested that any extension level of CGP greater than 7.5% on a dry weight basis (30% when rehydrated 1:3 with water) would surely result in an evaluation in the "dislike" region of the scale for off-flavor acceptability. Microwave heated beef patties containing 30% CGP slurry did fall within the "dislike" region of the sensory scale with a mean value of 2.48 for off-flavor acceptability.

A study by Blessin et al. (1972) consisted of adding defatted corn germ flour to ground beef with 20% fat as 1, 3, 5, and 10% of the total uncooked weight. The only reported differences among the treatments was that beef patties containing 10% corn germ flour were firmer and browned faster than the control or the other extended patties. The faster rate of browning was explained by the high level of sugars present in the corn germ flour.

Evaluation of patty textural characteristics

Instrumental measurements for hardness of cooked beef patties slightly increased as the amount of beef in the mixture increased (Tables 17 and 18). A sensory panel also provided data that suggested beef patties containing all beef were less tender than the corn/beef blend patties.

Table 17. Textural properties of broiled beef patties with CGP added.

Added CGP Slurry[c] (%)	Shear Force (Kg)	Compression	
		Hardness (Kg)	Cohesiveness (Peak II: Peak I)
0	5.52[a]	2.52[a]	.62[a]
10	5.68[a]	2.61[a]	.55[a,b]
20	3.97[b]	2.19[a]	.49[b]
30	3.72[b]	1.53[b]	.52[b]

[a,b]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[c]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

Table 18. Textural properties of microwave heated beef patties with CGP added.

Added CGP Slurry[c] (%)	Compression	
	Hardness (Kg)	Cohesiveness (Peak II: Peak I)
0	2.42[a]	.76[a]
10	2.19[a]	.71[a,b]
20	2.12[a]	.63[b]
30	1.65[a]	.60[b]

[a,b]Means in the same column with the same superscript are not different ($P < 0.05$).

[c]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

Cross et al. (1975) reported that the factors responsible for toughness in ground beef are related to the myofibrillar and stromal proteins. Addition of CGP would have a diluting effect on these proteins and thus provide a possible explanation for the increased tenderness in CGP-extended beef patties.

In the broiled heating treatment, beef patty hardness was evaluated as Kg force by both the shear and compression methods. Results of both evaluations, shear and compression, resulted in a correlation of 0.82. Only data for compression measurements were collected on patties which were heated by microwave energy.

As a measure of the binding ability of corn germ protein, cohesiveness was determined on cooked samples by a compression test using the Instron Universal Testing Machine. In both experiments, the cohesiveness of cooked patties containing the added CGP slurry was lower than for control beef patties. Mean values for cohesiveness were slightly higher in patties that were heated by microwave energy than for beef patties heated conventionally. Overall, results indicate that the binding ability, or cohesiveness, of cooked patties was reduced with the addition of corn germ protein as an extender. Development of methods which optimize the extraction of protein from meat could presumably improve the binding capacity of CGP-extended beef. However, development of such techniques was beyond the realm of this study.

Color determination

The objective of the color evaluation in the study was to detect tendencies for the corn germ protein additive to change the apparent color of the cooked beef patties. Two light sources were utilized in making the evaluation of color. Illuminate A results are presented for cooked beef patties in Tables 19 and 20, while Illuminate C data are presented in Tables 21 and 22.

Broiled beef patties resulted in significant color changes with the addition of CGP. Extended beef patties were lighter and less red in color than the control, therefore, resulting in a significantly higher hue angle. However, no significant differences were noted in the amount of yellowness among these patties with either light source. This suggests that the change in color was not an effect of the corn germ protein (a white-yellow compound) imparting its color, but rather to a dilution effect of the additive on the amount of meat pigments (red) present in the patty.

On the other hand, data for patties which were heated by microwave energy did not reveal any significant difference in the amount of color or its intensity within the treatments evaluated under the light source of

Table 19. Tristimulus color values of broiled beef patties with CGP added.

Added CGP Slurry[d] (%)	Illuminate A				
	L	a	b	Hue Angle	Saturation Index
0	43.53[a]	5.93[a]	3.73[a]	31.97[a]	7.00[a]
10	45.24[a,b]	5.77[a,b]	3.73[a]	32.81[a]	6.87[a]
20	46.13[b]	5.24[a,b]	3.65[a]	34.84[b]	6.37[a]
30	46.19[b]	4.94[b]	3.85[a]	38.00[c]	6.27[a]

[a,b,c]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[d]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

Table 20. Tristimulus color values of microwaved beef patties with CGP added.

Added CGP Slurry[d] (%)	Illuminate A				
	L	a	b	Hue Angle	Saturation Index
0	46.34[a]	7.18[a]	4.25[a]	30.74[a]	8.34[a]
10	44.39[a]	6.10[a]	4.02[a]	33.44[a,b]	7.30[a]
20	45.78[a]	5.82[a]	4.03[a]	34.63[a,c]	7.08[a]
30	45.64[a]	5.73[a]	4.38[a]	37.48[c]	7.21[a]

[a,b,c]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[d]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio 1:3.

Table 21. Tristimulus color values of broiled beef patties with CGP added.

Added CGP Slurry[d] (%)	Illuminate C				
	L	a	b	Hue Angle	Saturation Index
0	42.71[a]	2.58[a]	6.51[a]	67.93[a]	7.01[a]
10	44.43[a,b]	2.57[a]	6.45[a]	68.02[a]	6.95[a]
20	45.39[b]	2.25[b]	6.32[a]	70.32[a,b]	6.71[a]
30	45.43[b]	1.97[c]	6.67[a]	73.46[b]	6.93[a]

[a,b,c]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[d]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

Table 22. Tristimulus color values of microwaved beef patties with CGP added.

Added CGP Slurry[c] (%)	Illuminate C				
	L	a	b	Hue Angle	Saturation Index
0	45.34[a]	3.01[a]	7.52[a]	68.38[a]	8.11[a]
10	43.54[a]	2.38[a,b]	7.18[a]	71.63[a,b]	7.57[a]
20	44.90[a]	2.24[a,b]	7.17[a]	72.43[a,b]	7.52[a]
30	44.78[a]	1.99[b]	7.81[a]	75.67[b]	8.07[a]

[a,b]Means in the same column with the same superscript letters are not different ($P < 0.05$).

[c]CGP slurry = corn germ protein slurry; CGP hydrated with distilled water in ratio of 1:3.

Illuminate A. Data for Illuminate C showed a significant decrease in red color as the level of CGP increased. Again, this supports the theory that addition of lightly colored plant proteins dilutes the amount of red pigmentation in the meat.

Data for sensory evaluation showed that panelists were capable of detecting an off-color in the patties extended with corn germ protein. However, this off-color was only slight in intensity, with ratings remaining at the lower end of the sensory line-scale. Panelist evaluation displayed agreement with instrumental data by giving higher values for off-color to the patties cooked conventionally.

CONCLUSIONS

Based on the conditions of this study, the following conclusions can be made:

1. Experimental data showed that incorporation of rehydrated corn germ protein increased the yield of cooked beef patties by decreasing cooking losses. The corn germ additive was found to improve the retention of both fat and water in cooked patties, while also increasing the water holding capacity of the raw CGP/beef formulations.

2. Protein contents of both raw and cooked beef patties decreased with increasing levels of CGP extension. This was reported as a dilution effect resulting from the replacement of meat with a slurry of hydrated corn germ protein. However, amino acid composition of the experimental beef patties was affected only for the amount of phenylalanine present when CGP was added.

3. Beef patties extended with CGP slurry contained an off-aroma, off-flavor and off-color which increased in intensity with increasing levels of extension. However, no objectionable flavor was found in any of the broiled beef patties evaluated in this study. Addition of CGP increased patty tenderness but had little effect on the juiciness characteristic. Although all treatments were prepared in the same manner, panelists perceived the grind (particle

size) of beef patties containing CGP to be finer than typical of ground beef.

4. Instrumental values showed agreement with panel evaluations for off-color and tenderness. Hunter lab color values for extended beef patties were lighter and less red in color than the control. This was attributed to a dilution effect of the protein additive on the amount of red meat pigments present in the finished beef patties. Data from an Instron Universal Testing Machine showed that the hardness of cooked patties increased as the amount of beef in the patty formulation increased. Cohesiveness of cooked beef patties was reduced with the addition of corn germ protein as an extender.

5. Addition of corn germ protein to beef patties reduced the shrinkage in patty measurements during heat treatment. Although absolute values were not significantly different, a trend for increased thickness was noted in beef patties extended with CGP. The amount of change in patty diameter and area tended to decrease in treatments containing CGP, especially in patties heated with microwave energy.

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APPLICATION OF CORN GERM PROTEIN
IN BEEF PATTIES

by

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ABSTRACT

Beef patties containing 20% fat were extended at the levels of 10, 20, and 30% of the uncooked weight with a slurry of defatted corn germ protein (CGP) hydrated in the ratio of 1:3 with distilled water. Patties were heated to an internal endpoint of 77°C by two methods of heat treatment, conventional (broiled) and microwave. Influence of CGP on chemical composition (fat, water, protein, amino acid), physical properties (color, thickness, area, diameter), heating characteristics (yield, water and fat retention, textural properties), and sensory characteristics of beef patties were studied.

Results of this study indicate that addition of corn germ protein effectively increases the yield of cooked product by decreasing both drip and volatile losses in cooking. Although values were not always statistically different, beef patties containing the plant protein tended to increase in patty thickness, diameter and area over that found in the control patties.

Proximate analysis of cooked beef patties showed protein and fat contents decreasing with increasing levels of extension, while water content increased only in products heated by microwave energy. Amino acid composition of the protein in broiled beef patties was not altered greatly by addition of CGP. Consequently, incorporation of CGP at

levels of 10, 20 and 30% had no negative effects on the amino acid composition of the finished products. Retention of fat and water increased when CGP was added to beef patty formulations.

Sensory panel evaluations for the quality characteristics of extended beef patties demonstrated that patty tenderness increased as the level of added CGP slurry increased. However, extended patties were found to have an off-flavor, off-aroma and off-color, all of which increased in intensity with increased levels of the corn germ protein. Panelists perceived the texture of CGP-extended beef patties to be of a finer grind than what was considered typical for ground meat, and rated these patties higher in mushiness than the control. CGP-extended beef patties were less hard (more tender) and less cohesive than all-beef patties according to instrumental data. Extended patties were lighter and less red in color than control samples.