QUALITY CHARACTERISTICS OF BEEF PATTIES CONTAINING CORN GERM PROTEIN

by

Deborah Kaye Hix

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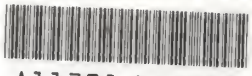
Joseph Loyas

Major Professor



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This master's thesis is dedicated to the author's husband Jesse, and daughters Shanna, and Sarah. Without your constant love, support, and willingness to make those necessary sacrifices, this goal could not have been accomplished.

INTRODUCTION

As the consumer becomes better informed about diet and health, desire increases for foods offering high quality, superior nutrient balance, lower saturated fat and cholesterol content, and fewer calories, all at an economical price (Altschul 1989). Since earliest times, man has sought to satiate hunger with proteins of animal and plant origins (Fennema 1985). The primary sources of dietary protein in the American diet are meat and dairy products. In an effort to provide proteins which meet consumer needs and desires, processors and manufacturers of meat products are finding it necessary to rely upon proteins of plant origin to extend and partially replace animal proteins.

Although cereal grains are an inexpensive source of protein and calories and are consumed in most countries to varying degrees, their use as a high-protein food additive is limited. The problem of malnutrition and protein deficiency in growing populations of Third World countries, coupled with the desire for larger quantities of protein by affluent countries, creates an important market for cereal grains in providing for the expanding consumption of protein.

Corn, a major cereal grain, is the basic ingredient of the human diet in several countries. Data from compositional studies and nutritional analyses indicate that a protein source of good nutritional value, well-suited for

use as a food additive, can be obtained by employing defatted corn germ protein flour (CGPF) (Barbieri and Casiraghi 1983). Although its use as a food ingredient has been proposed, CGPF seems destined to be used exclusively as animal feed. This situation is apparently due to the fact that little has been done to promote use of CGPF as an element in food formulations (Blessin 1973).

The changing attitudes of consumers, including their greater acceptance of soy extenders, coupled with the expected rise in the price of beef, may result in increased demand for extenders of animal origin proteins. CGPF has the potential to replace other plant protein extenders in formulations of meat products.

REVIEW OF LITERATURE

PROTEINS

Bodily Functions of Proteins

Proteins have been associated with all forms of life since Mulder identified them in 1838 (Munro and Crim 1980). Proteins associated with living matter function as organic catalysts (enzymes), as structural components of the cell, as messengers (peptide hormones), and as antibodies (Munro and Crim 1988). Proteins can supply energy if carbohydrates are in short supply, ensure nutritional well-being during times of growth and development, and be utilized for tissue building and restoration during disease (Jones 1974; Munro and Crim 1980).

Nutritional Significance of Proteins

The usual dietary intake of protein is approximately 1 g/kg body weight per day (Spencer and Kramer 1988). The primary sources of protein for Americans are meat and dairy products (Spencer and Kramer 1988). The primary function of protein in the diet is to provide amino acids (Munro and Crim 1980). After ingestion, protein is enzymatically hydrolyzed in the alimentary tract, passes into the blood as free amino acids, and combines with amino acids from the tissues (Munro and Crim 1988). Protein polymers are constructed from amino acid monomers which are released during the digestion process. Nine amino acids are essential (indispensable) dietary constituents because

their carbon skeletons cannot be synthesized by man; others are nonessential (dispensable) because they can be manufactured from simple carbon and nitrogen precursors supplied by dietary proteins (Munro and Crim 1988). The amino acid composition of a protein is an important factor in determining its nutritive quality. Essential amino acids for humans include histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine; cystine and tyrosine are sometimes included because they can, in part, replace methionine and phenylalanine (Jones 1974; Munro and Crim 1988). These 11 amino acids are all found in most proteins present in body cells. The nine nonessential amino acids include alanine, arginine, aspartic acid, asparagine, glutamic acid, glutamine, glycine, proline, and serine (Munro and Crim 1988). Proteins are so intimately associated with life processes, that regulation of protein metabolism is obligatory in the maintenance of bodily functions (Munro and Crim 1988).

FUNCTIONS OF ESSENTIAL AMINO ACIDS

Cystine

Cystine breaks down in the body to two molecules of cysteine. It is the most common sulphur-containing amino acid and is associated with skeletal and connective tissue (Jones 1974). Together with tyrosine, cystine supplementation is reported to return cirrhotic patients to positive nitrogen balance (Blendis and Jenkins 1988).

Lysine

Lysine is usually absent in vegetarian diets depending solely on cereals (Jones 1974; Goodhart 1980). Loss of lysine in foods has been attributed to mild heat treatment during food processing. Severe heat treatment produces lysinoalanine, a toxic product which decreases availability of lysine for absorption (Munro and Crim 1988).

Methionine

Methionine is similar to cystine in that it carries sulphur as its "R" group. Like lysine, it is frequently lacking in diets (Jones 1974). Loss of methionine in protein originally containing it is due to oxidative conditions such as the use of SO_2 during food processing (Munro and Crim 1988). Methionine dosage has been reported to overcome the effects of methotrexate interference during choline synthesis (Appel and Briggs 1980).

Phenylalanine

Phenylalanine is essential because the human body finds it impossible to synthesize the phenyl group, although it can synthesize alanine (Jones 1974). Inherited disorders of phenylalanine metabolism in humans are referred to as Phenylketonuria (PKU), and is characterized by developmental delay, microcephaly, abnormal electroencephalogram, eczema, musty odor, and hyperactivity, and can produce irreversible mental retardation if not treated

before three weeks of age (Elsas and Acosta 1988).

Threonine

Threonine is known to be an essential constituent of blood proteins (Jones 1974). While some amino acids are toxic in large amounts, excessive quantities of threonine have been attributed only to a moderate reduction in growth rate in humans (Munro and Crim 1980).

Tryptophan

Tryptophan affects growth rate in animals (Jones 1974). It may be assumed that 1% of a protein is tryptophan (Horwitt 1980). Diets supplying 235 mg of tryptophan plus 5.2 mg nicotinamide have been reported to cause pellagra, a chronic disease characterized by dermatitis, dementia, delirium tremors, and diarrhea (Horwitt 1980). During the Great Depression (1930-1940), pellagra was epidemic throughout the Southern United States where people subsisted on diets of corn and corn products.

Tyrosine

Tyrosine is the least soluble of the amino acids (Munro and Crim 1988). It is involved with the manufacture of the hormones adrenaline and thyroxine (Jones 1974). Adrenaline is a compound which increases blood pressure and sugar content of blood. Together with cystine, tyrosine supplementation is reported to return cirrhotic patients to positive nitrogen balance (Blendis and Jenkins 1988).

Isoleucine

Isoleucine is one of the three essential amino acids having a branched aliphatic side chain, reported to participate in special regulatory functions (Hoffer 1988).

Leucine

Leucine is one of the three essential amino acids having a branched aliphatic side chain, believed to affect rates of protein synthesis or breakdown in various isolated tissue preparations (Hoffer 1988).

Valine

Valine is one of the three essential amino acids having a branched aliphatic side chain, reported to have special regulatory functions (Hoffer 1988).

PROTEIN FUNCTIONALITY

Proteins contribute significantly to the function properties and quality of food (Fox and Condon 1981). The term "protein functionality" has been defined as those physical and chemical properties which affect the behavior of proteins in food systems during processing, storage, preparation, and utilization (Fox and Condon 1981; Knorr 1983). The functional and physical properties of proteins in protein-containing foods are largely responsible for determining their acceptability as additives in prepared foods (Johnson 1970). Several researchers have identified the most important functional properties in food applica-

tions as being sensory properties, hydrophilic attributes, hydrophilic-hydrophobic qualities, intermolecular interctions, and textural characteristics (Barbieri and Casiraghi 1983; Fennema 1985). Although laboratory tests can provide information regarding the physical and chemical nature of a protein-containing additive, the logical procedure to examine how an ingredient will function in a food system is to incorporate that ingredient into a food formulation to produce the finished product (Johnson 1970).

DIETARY IMPORTANCE OF MACRO- AND MICROELEMENTS

Webster's New World Dictionary (Guralnik 1974) defines a mineral as:"

1. an inorganic substance occurring naturally in the earth and having a consistent and distinctive set of physical properties and a composition that can be expressed by a chemical formula: sometimes applied to substances in the earth of organic origin, such as coal
2. any substance that is neither vegetable nor animal
3. any of certain elements, as iron, phosphorus, etc., essential to the physiology of animals and plants."

The following listing includes 5 macro- or bulk essential elements (Ca, Mg, Na, K, P) and 10 micro- or trace elements (Fe, Cu, Mn, Zn, I, Se, Mo, Cr, Co, F)

(Clydesdale 1988). Not all of the trace elements have been proven to be essential for human life, but they have been proven to be essential for some systems, or for normal health and longevity in man (Kutsky 1981). Mineral element deficiencies can severely impair health (Kutsky 1981).

Detection Of Macro- and Microelements In Foods

David (1958) investigated the use of atomic absorption spectroscopy to analyze plant material for zinc, magnesium, copper, and iron. He concluded that the primary advantages to employing atomic absorption spectrophotometry were element versatility without appreciable spectral interferences and only minor chemical interferences. Further advantages of atomic absorption include; elimination of numerous chemical separations and ease of sample preparation, with resultant time-saving benefits (David 1958). Investigation into the precision and accuracy of the technique have shown atomic absorption to be superior to standard methods in the quantitation of magnesium and copper (Garcia *et al.* 1972). Increasing use of atomic absorption spectrophotometry has shown human depletion of various trace elements to occur more commonly than was previously assumed (Shils 1988).

Macro- and Microelements In the Diet

Research using animal and human models has produced results which suggest that certain vitamins and trace elements may modify, protect against, or alleviate specific

forms of cancer (Levander 1988). Mechanisms through which a vitamin or microelement might protect against tumorigenesis include one or more of the following: inactivation of carcinogens; inhibition of early stages of carcinogenic activity by affecting the activity of various enzymes or the expression of genetic information; enhancement of host-defense mechanisms; and/or promotion of changes in tissue morphology or chemical composition which are not conducive to tumor growth or metastasis (Nielsen 1983). The macro- and microelements responsible for the mechanisms discussed above include selenium, iron, zinc, copper, manganese, arsenic, and iodine (Nielsen 1983).

Phosphorus

Phosphorus is found in all plant and animal cells, and is essential for life, normal growth, development, and life span of all organisms including humans (Kutsky 1981). Phosphorus is absorbed as a free ion, its primary synergist is Ca, while its chief antagonists are sulfate and bicarbonate (Kutsky 1981). All phosphorus in the body exists as phosphate (PO_4) (Alvioli 1988).

Many phosphorus compounds are present in the body, and are involved in specific metabolic pathways (Alvioli 1988). Of the 11 to 14 g of phosphorus per kg fat-free tissue in the normal adult, 85% is deposited in the skeleton, the remainder is distributed in the cells and between tissue and membranous components of skeletal muscle, skin, and

nervous tissue (Alvioli 1988). Four major metabolic functions involving phosphorus include:

1. Energy transport as a constituent of high-energy phosphate bonds created via carbohydrate metabolism (ATP, ADP, etc)
2. As a principal component in living membranes, as phospholipids
3. Participation in genetic functions, as DNA and RNA, and as phosphate polymers
4. Buffering, Ca transport, and regulation of osmotic pressure for intracellular fluid (Kutsky 1981; Alvioli 1988).

Because phosphorus is highly conserved during homeostasis, need for replenishment arises in only special physiological circumstances (Kutsky 1981). Although there is no evidence to suggest insufficient quantities of phosphorus in the average American diet, temporary deficiencies may be caused by growth spurts, lactation, or pregnancy (Kutsky 1981).

Clinical manifestations of phosphorus deficiency include rickets, osteomalacia, osteitis fibrosa cystica, and familial hypophosphatemia (Kutsky 1981).

Calcium

Calcium is the most abundant cation and the fifth most common inorganic element found in the human body, consti-

tuting 20.7 to 24.8 g per kg of fat-free body tissue in the average adult human (Alvioli 1988). Approximately 99% of body calcium is in the skeleton, the remainder is extracellular. This form has four major metabolic functions:

1. Membrane effects including permeability regulation, calcium pump action, muscular contraction, nerve impulse conduction, intercellular cement
2. Body fluid regulation including buffering, viscosity control, PO_4 transfer, and control of clotting mechanisms
3. Control of cell division (mitosis)
4. Adjustment of hormonal secretion (Kutsky 1981).

The lifelong intake of an adequate supply of calcium appears to have an important role in maintaining normal skeletal structure, and minimizing the extent of bone loss with aging, particularly in women (Spencer and Kramer 1988). In addition to serving as the principal component of skeletal tissue, calcium plays a vital role in numerous essential physiological and biochemical processes including blood coagulation, neuromuscular excitability, and transmission of nerve impulses (Alvioli 1988). The synergistic agents for calcium metabolism also function as its principal antagonists: magnesium, sodium, and potassium (Kutsky 1981). Calcium appears to function with

phosphorus, magnesium, and fluoride in maintaining the normal structure of the skeleton, which is necessary in the prevention of such bone disorders as osteoporosis (Spencer and Kramer 1988).

The recommended dietary intake of calcium in the U. S. is 800 mg/day (Spencer and Kramer 1988). Because calcium salts are generally insoluble, the calcium present in food may not be digested. Calcium absorption is aided by the presence of proteins and vitamin D, while fats and phytic acid act to reduce absorption (Kutsky 1981). There may be factors which interfere with calcium utilization such as fiber, phytates, and oxalates. Clinical deficiencies of calcium are manifested as rickets, osteoporosis, osteomalacia, tetany, hypoparathyroidism, and hypocalcemia (Kutsky 1981).

Selenium

Selenium first received biological interest in the 1930's when it was recognized to cause alkali disease in livestock (Levander 1988). In 1957, Schwartz discovered that traces of selenium prevented liver necrosis in vitamin E-deficient rats (Levander 1988; Mason 1988). Although the first reports of its potential significance in human nutrition appeared in 1979 (Levander 1988), its function is not yet completely understood (Mason 1988).

Selenium was identified as a nutritionally important mineral when it was discovered that selenium supplemen-

tation could reverse symptoms of Keshan's disease (Levander 1988; Mason 1988). Keshan's disease is an endemic cardiomyopathy affecting children and young women in the Keshan region of China, an area where soil levels of selenium are extremely low and the food consumed by residents is grown locally (Mason 1988). Selenium has been implicated in vitamin E function, and is a component in glutathione peroxidase. The latter appears to indicate a requirement for selenium in the human diet (Kutsky 1981).

Selenium is the most studied of the trace elements with respect to its influence on tumorigenesis. Nielsen (1983) has reported appreciable epidemiological and experimental evidence suggesting that selenium may be an effective naturally occurring chemopreventive or chemotherapeutic agent for some types of cancer. Neoplasms inversely associated with the relationship between cancer mortality and selenium include those of the tongue, esophagus, stomach, intestine, liver, pancreas, larynx, lung, bladder, kidney, and breast (Nielsen 1983). Another type of associative study linking low selenium status to decreased incidence of cancer compares the blood selenium levels of normal and cancerous individuals. A positive diagnosis of cancer was actually an indication of subnormal levels of plasma selenium (Nielsen 1983).

In the inorganic state, selenium has limited application due to its toxicity (Kutsky 1981). A range of selenium intake of 50-200 ug per day is suggested to be the

adequate and safe level for adults (Recommended Dietary Allowances, 1980), the level of dietary selenium needed to cause toxicity in animals in 5 ug/g (Levander 1988).

Possible diseases related to selenium deficiency include kwashiorkor, neonatal jaundice, alcoholic hepatic failure, acanthocytosis, and Glanzmann's thrombasthenia (Kutsky 1981). Cereal products are reported to be a major contributor of dietary selenium (Clydesdale 1988).

Magnesium

Magnesium is the fourth most plentiful cation in the body, second only to potassium in its intracellular concentration (Schwartz 1988; Shils 1988). The fact that magnesium is an essential nutrient was established in the early 1930's by inducing a magnesium deficiency syndrome in rats (Schwartz 1988; Shils 1988). Since that time, clinical manifestations of magnesium deficiency have been documented in alcoholics, in patients on magnesium-free intravenous solutions, and in persons prescribed various drugs which induce renal losses of magnesium (Shils 1988).

Approximately 60% of the 28 to 40 g of magnesium contained in the adult human body is in the skeleton. The structure showing the highest tissue magnesium concentration (Schwartz 1988). The remaining 40%, distributed in the muscles and soft tissues, has three main metabolic functions (Schwartz 1988):

1. Membrane functions including permeability,

muscular contraction, nerve impulse conduction, and antagonism of calcium

2. Intracellular fluid regulation, including viscosity, buffering, PO_4 transport, activation of enzyme systems, chelating, and antagonism of calcium
3. Regulation of protein synthesis (Kutsky 1981).

Magnesium is absorbed as the free ion. Its primary synergist and antagonist is potassium and calcium, respectively (Kutsky 1981). The RDA for magnesium is 40 to 70 mg per day for infants, increasing to 250 mg per day for children under 10 years of age, and 300 to 400 mg per day for adolescents, adult males, and nonpregnant, nonlactating females (Shils 1988).

As the essential metal in chlorophyll, magnesium has a role in life processes (Schwartz 1988). Absorbed magnesium is retained either for tissue and bone growth, or for turnover replacement. The remainder is excreted in the urine (Shils 1988). Additional roles of magnesium in plants and animals include: all reactions depending upon synthesis or hydrolysis of ATP (adenosine triphosphate), stabilization of macromolecules such as DNA and ribosomes, activation or regulation of more than 300 enzyme reactions, primarily those involved in phosphate transfer, (Schwartz 1988; Shils 1988).

Because magnesium is abundantly distributed in food, there is no evidence of a magnesium deficiency in the aver-

age American's diet. However, magnesium depletion (hypomagnesemia) is a common occurrence in hospitals with both acutely and chronically ill patients (Shils 1988).

Numerous reports since 1969 have described decreased magnesium levels in the myocardium of patients dying with ischemic heart disease (Shils 1988). Magnesium salts have been used for 50 years to treat atrial, junctional, and ventricular tachyarrhythmias (occurring in patients with myocardial ischemia), alcoholism, digitalis toxicity, diuretic therapy, and other conditions (Shils 1988).

Magnesium depletion is a severe and far-reaching disorder which may include, in addition to disturbances of central nervous and neuromuscular function, derangement in calcium metabolism, bone development and structure, and calcification of renal and other soft tissues (Schwartz 1988). One of the most consistent consequences of magnesium depletion is alteration in calcium utilization (Schwartz 1988).

Zinc

Zinc has been recognized as an fundamental element since 1509 (Solomons 1988). Zinc ranks among the top 25 abundant mineral elements in the earth's outer layer, and is found in all microorganisms, plants, and animals (Kutsky 1981; Smith 1988). The broad distribution and participation of zinc in essentially all physiological and biochemical roles ranks this microelement as the very cornerstone

of biology (Smith 1988). In humans, zinc is located in all visceral organs such as the brain, muscle, bones, teeth, skin, eyes, gonads, blood, saliva, pancreatic secretions, biliary secretions, and cerebrospinal fluid (Smith 1988).

In humans, zinc is essential for normal growth, development and life span, even though life may proceed for a time without it (Kutsky 1981). The four distinct functions of zinc in mammalian metabolism have been reported (Solomons 1988) to be:

(1) as a component of zinc-containing metalloenzymes

(2) as activator and constituent of vital enzymes, such as the nucleic acid polymerases which affect protein synthesis (Kutsky 1981; Smith 1988)

(3) in the stabilization of membrane structure

(4) in various functions within the cell as a free ion.

Zinc has been shown to participate in lipid and protein metabolism, cellular differentiation during embryogenesis, normal growth-stimulation, reproduction, and regulation of hormonal interactions under normal conditions and during infectious episodes (Smith 1988).

There is some evidence that the normal American's diet does not include sufficient amounts of zinc for replacement of losses (Kutsky 1981). Signs of zinc deficiency in the Persian and Egyptian dwarfs included growth retardation, hypogonadism, and delayed sexual maturation (Solomons

1988). The numerous manifestations of zinc deficiency in man (dermatitis, sexual infantilism, immune deficiencies, behavioral disturbances, night blindness, impaired taste, and alopecia). firmly establish zinc as essential in the process of keratogenesis and wound healing (Kutsky 1981; Smith 1988; Solomons 1988).

Iron

Iron is one of the most abundant metals in the universe and in the earth's crust (Fairbanks and Beutler 1988; Thompson 1988). It ranks second in abundance among metals only to aluminum (Thompson 1988). Iron has been a familiar metal since the time of early Mediterranean civilizations where it was used for a variety of tools and weapons as well as for medicinal purposes such as the treatment of chlorosis, a disorder now regarded as having been caused by iron deficiency (Fairbanks and Beutler 1988). Scientific evidence of the value of iron in this disorder was first published in 1932, ending the dispute over this controversial topic (Fairbanks and Beutler 1988).

Iron has three primary roles: oxygen transport, cellular respiration, and deactivation of deadly cellular peroxides (Kutsky 1981). Iron is essential to vertebrate life forms due to its role in the heme molecule of hemoglobin (Fairbanks and Beutler 1988). Hemoglobin is located in circulating red blood cells, where it transports oxygen from the lungs to respiring tissues (Thompson 1988). The

majority of iron in blood is associated with hemoglobin. In myoglobin, iron and oxygen associate to store oxygen delivered to the tissues by hemoglobin (Thompson 1988).

The dietary requirement for iron is based upon the amount of iron lost from the body of a healthy individual (Thompson 1988). The requirement varies according to age and sex. For the adult male, 10 mg is the RDA based upon the estimated loss of 1 mg per day (Thompson 1988). Synergistic agents of iron metabolism include porphyrin, copper, selenium, molybdenum, vitamin B_{12}, and folic acid; antagonistic elements include zinc and cobalt (Kutsky 1981).

Iron deficiency is manifested as anemia, during which insufficient iron is available to sustain normal hemoglobin production (Fairbanks and Beutler 1988; Thompson 1988). Severe clinical manifestations of anemia are characterized by hypochromic, microcytic anemia, reduced synthesis of other heme complexes, fatigue, epithelial modifications, and polycythemia (Kutsky 1981; Fairbanks and Beutler 1988).

Iron deficiency anemia is reportedly the most prevalent nutritional deficiency worldwide, causing few deaths, but contributing severely to the frailty, ill health, and substandard work performance of as many as one billion individuals (Fairbanks and Beutler 1988; Thompson 1988). Other functional implications of iron deficiency include decreased immunocompetence, increased infection, less efficient thermoregulation, and diminished mental devel-

opment (Thompson 1988).

Copper

Essential to many body functions, copper has an antagonistic relationship with zinc. Copper absorption has been shown to increase during periods of zinc deficiency, while the effect of copper on zinc absorption in humans is negligible (Smith 1988). In fact, elevated doses of zinc have been prescribed for the treatment of Wilson's disease (copper accumulation disease), by limiting amounts of dietary copper available for absorption (Smith 1988).

Almost all soft water supplies contain an excessive quantity of copper, attributed largely to dissolution of copper piping (Kutsky 1981). Because copper is also plentiful in food, there is a very good likelihood of dietary excess in the American diet, which would antagonize iron and zinc by replacement (Kutsky 1981). Deficiencies in man have primarily been found to occur in infancy as hypochromic anemia, hypocupremia, neutropenia, and Menke's syndrome (defective absorption) (Kutsky 1981).

Molybdenum

Molybdenum was detected in biological matter in 1900, however studies regarding its biological properties began to receive attention after 1930 (Nielsen 1988). Evidence for the essentiality of molybdenum was first recognized in 1953 when xanthine oxidase (necessary for production of

uric acid) was identified as a molybdenum containing metalloenzyme (Kutsky 1981; Nielsen 1988). Three major investigations have reported the richest food sources of molybdenum to be milk and milk products, dried legumes, organ meats, cereals, and baked goods (Nielsen 1988).

Molybdenum functions as an enzyme cofactor, catalyzing oxygen transfer from water to a variety of compounds (Nielsen 1988). Minimum levels of dietary molybdenum required for optimal human health and performance are unknown at present, therefore requirements can only be estimated (Nielsen 1988). Signs of molybdenum deficiency in animals has been reported (Nielsen 1988) to include depressed feed consumption and growth, impaired reproduction characterized by elevated mortality in both mothers and offspring, elevated copper concentrations in liver and brain, mandibular distortion, defects in bone development, skeletal lesions. A patient receiving total parenteral nutrition (TPN) therapy acquired a syndrome specified as acquired molybdenum deficiency which was characterized by hypermethioninemia, hypouricemia, hyperoxypurinemia, hypouricosuria, low urinary sulfate excretion, and mental disturbances that progressed to coma (Nielsen 1988).

Manganese

Manganese was reported to be essential to mammals in 1931, when it was shown to be required for growth and reproduction in laboratory animals (Levander 1988). Human

manganese poisoning was first described in 1837 as a condition resembling paralysis agitans, and was later observed after World War II when increased mining resulted in increased incidence of chronic manganese poisoning among miners (Levander 1988). Manganese is reported to be a potential carcinogen (Kutsky 1981).

In mammals, the highest concentrations of manganese can be found in the bones, liver, pituitary gland, and in two metalloenzymes located in the mitochondria, the cellular organelle with the highest level of manganese (Levander 1988). Manganese levels in human plasma are very low, ranging form 0.4 to 1.0 ng/ml. Manganese levels in body tissues remain nearly constant throughout the life-cycle (Levander 1988).

Several indications of manganese deficiency in experimental animals include skeletal defects involving the long bones, skull abnormalities, enlarged joints, and slipping of the gastrocnemius tendon from its condyles (Levander 1988).

Evidence for the necessity of manganese in humans is limited to one report in which the subject who was fed a chemically defined diet as part of an investigation of vitamin K requirements, developed mild dermatitis, reddening of his black hair and beard, delayed growth of hair, nails, and beard, occasional nausea and vomiting, decreased serum phospholipids and triglycerides, and moderate weight loss (Levander 1988). Manganese deficiency has not been

reported in free-living humans even though dietary sources are limited to tea, nuts, grains, bran, wheat germ, corn, and parsley (Kutsky 1981; Levander 1988). Low blood manganese levels have been reported in children with convulsive disorders and in adults with epilepsy (Levander 1988).

CONTRIBUTION OF MEAT TO THE AMERICAN DIET

Meat is defined to be the flesh of animals used for food (Bennion 1980). Meat is commonly the major item around which a menu is planned, and is likely to be the most expensive portion of the meal. As an excellent source of high-quality protein, vitamins, iron, and zinc, meat plays a significant role in a well-balanced diet. USDA data obtained between 1965 and 1985 indicated that animal products provided approximately 36% of the caloric content of the food supply while contributing more than one-third of the iron, vitamin A, thiamin, and magnesium content; one-half of the niacin, riboflavin, and vitamin B^6 content; more than 70% of the zinc content; and nearly 100% of the vitamin B^{12} content (Altschul 1989). Beef comprises nearly half of all the meat eaten in the United States, with an average consumption of 109 pounds per person recorded in 1973 (Bennion 1980).

The gross composition of retail meat cuts varies greatly, depending upon the amount of adipose tissue which accompanies the muscle tissue.

Because fat contributes substantially to the flavor,

juiciness, tenderness, and overall palatability of food, production of low-fat meat products is difficult (Altschul 1989). Savell and Cross (1988) reported that the maximum amount of fat necessary in cuts of meat to ensure nutritional merit is 7.3% on an uncooked basis. While the meat industry has incorporated a number of changes to increase the availability of lean meat, opportunity for production of low-calorie, low-fat meat products also exists in processing after slaughter (Altschul 1989).

On the basis of extensive clinical and epidemiological data, specific recommendations have been made by the American Heart Association (1986) and by the National Institute of Health (1985) to reduce dietary fat intake to 30% or less of total caloric intake. In 1988, the Surgeon General issued a report, "Nutrition and Health," which summarized available scientific evidence for the role of diet in health promotion and disease prevention and comprehensively documented the grounds for recommended dietary changes (HHS 1988). The primary conclusion of this report was that overconsumption of certain dietary components is now a major concern for Americans, who disproportionately consume foods high in fat. This suggests a specific concern for dietary fat (Altschul 1989). The Surgeon General also reported obesity to be a risk factor for several chronic diseases and recommended increased availability of foods and food products low in calories,

total fat, saturated fat, cholesterol, sodium, and sugar but high in a variety of natural forms of fiber as well as certain vitamins and minerals.

SIGNIFICANCE OF CEREAL GRAINS

Protein Content

An adequate protein reserve is of critical importance in the world food dilemma. Protein content of edible plants varies considerably. Although some cereal grains may contain appreciable quantities of protein (Fennema 1985), most cereal diets do not have the concentration of utilizable protein relative to calories required for optimum growth and development unless they are supplemented by a source of more concentrated protein (Bodwell 1977). Proteins of plant origin are the basic foundation upon which the world's food supply has been and will continue to be built (Clausi 1971). These proteins are an important nutritional source for several reasons: (1) proteins of plant origin are consumed by most countries in varying degrees, (2) proteins of plant origin represent a major source of protein and calories for both developed and developing countries, (3) they are generally available, and (4) proteins of plant origin are inexpensive (Clausi 1971). It has been estimated that 91% of the cereal, legume, and vegetable protein produced in the United States, which is suitable for human consumption, is fed to livestock (DuPont 1987). Cereals will remain the primary source of food and

protein in the world and, therefore, an important key to the solution of the world food problem (Quentin 1969).

Cereal Grains As Substitutes For Animal Proteins

The production and utilization of cereal grains for human consumption has burgeoned in the past 25 years (DuPont and Osman 1987). Proteins of plant origin are often incorporated with meat as an extender, for the desirable attributes which they impart to the meat product, as well as for their low-cost and availability.

CORN

Origin and History

Corn is a widely utilized plant, known by several names: maize, corn, and Indian corn (Benson and Pearce 1987). The term *corn* is also employed in other countries to designate different crops: in England, wheat; in Scotland and Ireland, oats; and in parts of Africa, grain sorghum (Benson and Pearce 1987). In the United States, the preferred the term is *corn*, while the internationally accepted term for corn is *maize.*

Zea mays (L). is the botanical name given to corn in the 18th century. The important role played by corn in the diet of numerous populations is reputedly the meaning of its botanical name. *Zea* is Greek for cereal, being derived form a verb meaning "to live" and *mays* is of Indian origin and meant "that which sustains us" (Weatherwax 1923).

The earliest archaeological evidence of corn was dis-

covered in Mexico's Tehuacan Valley, and dates back between 2000-5000 B.C. (Wellhausen *et al.* 1952; Benson and Pearce 1987). Apparently, corn originated in Mexico, spread northward to Canada, and southward to Argentina (Benson and Pearce 1987). After European discovery of the Americas, corn was quickly carried to Europe, Africa, Asia, Spain, France, Germany, and Austria (Benson and Pearce 1987). Today corn is produced on every continent except Antartica (Benson and Pearce 1987). In Latin America, Africa, and Asia, several hundred million people depend on corn for their daily food. For many, corn is the main source of dietary protein (Bostid 1988).

Production and Utilization of Corn In the U. S.

Benson and Pearce (1987) have reported corn to be "...the only important cereal crop indigenous to the Americas." Corn is the dominant grain crop in the U.S., reportedly the most important crop in terms of acreage planted, production (more than double that of any other crop), and value (Ford 1978; Benson and Pearce 1987), with annual production statistics exceeding 143 million tons. The largest single production area is the U.S. (Iowa, Illinois, Nebraska, Minnesota, Indiana, Ohio, Wisconsin, Michigan, Missouri, South Dakota, Kentucky, and Kansas, in order of production) which produces 40% of the world's total corn supply.

Utilization of the United States corn crop is esti-

mated at approximately 75% for animal feed, 5% for industry, 2-3% for food and the remaining 20% for export (Johnson 1978).

Kernel Composition

The mature kernel has four distinct parts: tip cap, pericarp, endosperm, and germ. The major constituent of corn is starch, of which 98% is found in the endosperm (Watson 1987). The endosperm also contains 73% of the total protein (approximately 9-10% of the kernel's composition), the majority in the form of insoluble storage proteins (Johnson *et al.* 1978; Watson 1987).

The germ contains 83% of the total kernel lipids (mostly triacylglycerides) which, upon extraction, give "the well-known oil of commerce" (Watson 1987). The majority of the mineral elements (73%) are also contained in the germ (Watson 1987). As its most abundant element, phosphorus is present largely as the potassium-magnesium salt of phytic acid (Watson 1987). The tip cap and pericarp together contain the largest percentage of kernel fiber (51.1%) (Watson 1987).

CORN GERM PROTEIN FLOUR

CGPF Production Techniques

Corn germ obtained by the wet milling process is inapplicable for human food use following the steeping process due to loss of organoleptic and nutritional quality

(Barbieri and Casiraghi 1983). The protein-rich products resulting from corn wet milling include gluten feed, gluten meal, condensed fermented corn extractives, and germ meal (Cluskey et al. 1978). Endosperm products contain minor quantities of lysine and tryptophan deficient protein (Cluskey et al. 1978).

Corn germ acquired from the dry milling process can be used for human consumption after oil extraction because it has not been degraded (Barbieri and Casiraghi 1983). The endosperm and germ account for 65-70% and 10-12% of the total food products resulting from the dry milling of corn, respectively (Wall *et al.* 1971; Cluskey et al. 1978).

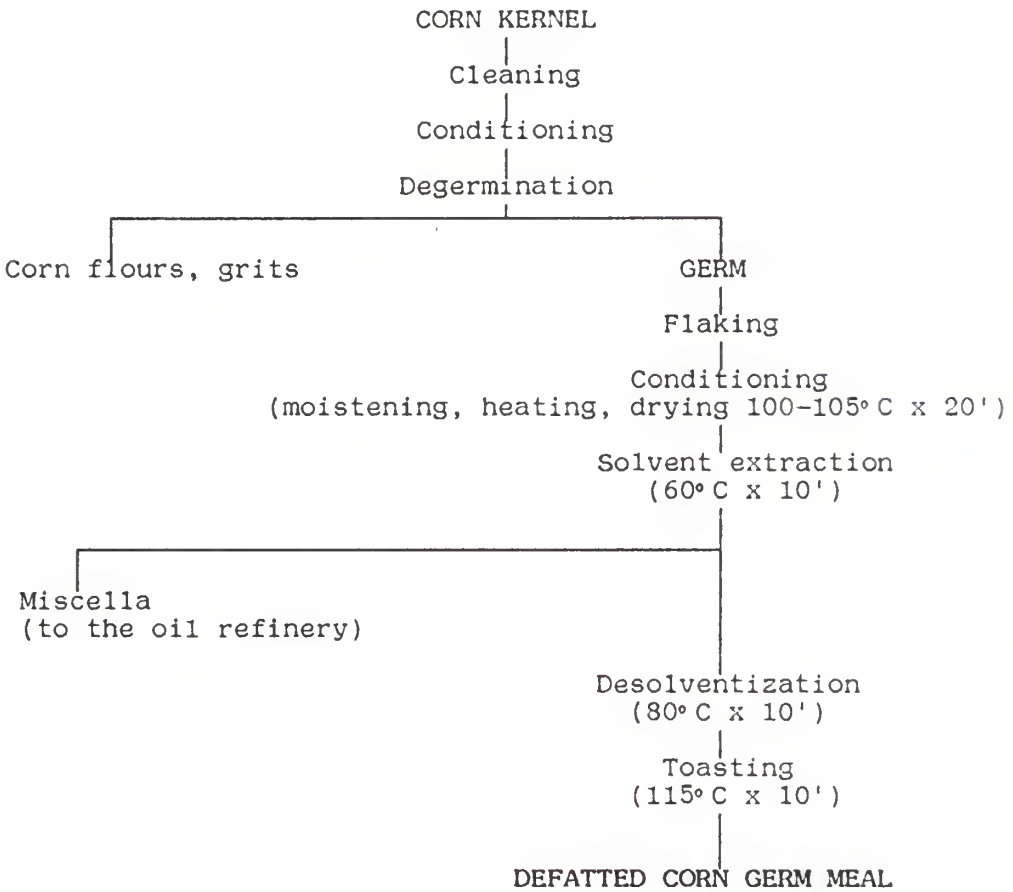
Barbieri and Casiraghi (1983) evaluated the heat effects on protein in the intermediate and final products of a commercial oil extraction installation. They found that the conditioning step sharply reduced protein solubility, while protein digestibility remained constant throughout the process. Figure 1 outlines the corn germ oil extraction process.

Availability of CGPF

Of all the corn produced in the world, very little is actually degerminated (Barbieri and Casiraghi 1983). The reasons for this are purely economical; high cost of degermination, greater value of whole kernels for animal feed, and low commercial value of defatted meal (Barbieri

FIGURE 1.

CORN GERM EXTRACTION PROCESS



Adapted from Barbieri and Casiraghi (1983).

and Casiraghi 1983). The dry milling process reportedly processes some 120 million bushels of corn each year, of which the germ comprises 12 million bushels (Tsen 1975; Ford 1978). Increased acceptance of defatted CGPF as a food ingredient could change the profitability of the degermination process.

Functional and Sensory Properties of CGPF

The functional properties of CGPF have been investigated (Lucisano *et al.* 1984). Some properties of CGPF that indicate its potential for use in many food applications include a bland taste in contrast to the "beany" taste of soya proteins. This allows for larger amounts of CGPF to be incorporated into the product (Ford 1978). CGPF has a strong water-binding ability enabling it to stabilize oil-in water emulsions (Zayas and Lin 1989). CGPF also has a light tan color (Anon. 1975).

Four solubility classes of corn proteins exist: albumins (water soluble), globulins (saline solution soluble), prolamines (70% ethanol soluble), and glutelins (soluble in 0.1*M* NaOH). The protein fraction of CGPF is composed primarily of globulins and albumins (Inglett and Blessin 1979; Zayas and Lin 1989). The solubility of CGPF at neutral and acid pH has been reported to be similar to the solubility of soy protein isolates (Cluskey et al. 1978). The water absorption capacity of CGPF is similar to that of soy concentrate.

Food blends containing CGPF have been tested for consumer acceptability and palatability by several different researchers (Anon. 1975; Blessin *et al.* 1973, 1979). CGPF can be added to beef patties up to the 10% level and used in cookies and muffins as a replacement for wheat flour up to the 25% level without any significant flavor changes in the products (Blessin *et al.* 1972). In all of these tests, the food blends were reported to be acceptable, although some products (cookies) were darker after baking and had a faint but perceptible corn odor (Anon 1975).

NUTRITIONAL VALUE OF CGPF

Proximate Composition

While successful performance of any plant protein as a food ingredient is dependent upon the functional characteristics and sensory qualities which it imparts to the final product, its contribution to nutritional value is also a significant consideration. Defatted CGPF has not been used widely for human consumption even though it contains protein of good nutritional quality, similar to that of legumes, with an amino acid pattern resembling that of hen's egg (Blessin *et al.* 1972, 1973; Ford 1978).

Corn germ flour is reported to contain 17-25% protein (which exceeds FAO/WHO provisional requirements), 20-24.7% starch, 13.8% sugars, 11.7% pentosans, 10.3% ash, 4-10% fiber and 0.5-2% fat (Blessin *et al.* 1972; Garcia *et al.*

1972; Peri and Barbieri 1980).

As the extraction residue of the corn oil industry, CGPF is an inexpensive nutritional source as shown by the current trend for incorporating CGPF in animal feeds. One reason livestock receive the most nutritious part of the kernel is that nonruminants are unable to digest the high fiber content found in the milled fraction (Ford 1978).

Barbieri and Casiraghi (1983) have described the primary obstacle to direct use of CGPF in food formulations to be the presence of fibrous fragments of kernel integument which are perceived as a sandy sensation in the mouth. These researchers were able to eliminate the fiber fragments, improve organoleptic quality, and increase protein concentration.

Corn is one of the most efficient suppliers of food energy (Cluskey et al 1978). CGPF is reported to have a protein efficiency ratio (PER) of 2.19, comparable to those determined for soybeans and whole milk powder. It possess a biological value (BV) close to 70 (Gardner *et al.* 1971; Ford 1978; Satterlee *et al.* 1979). As early as 1944, Mitchell and Beadles suggested that CGPF should be a valuable protein source. The protein of CGPF was 85% as digestible as that in beef round steak (Tsen 1975). The nutritional quality of the corn germ proteins are reportedly similar to that of soya protein. CGPF has also been reported to be of practically equal value in maintaining nitrogen balance in the adult dog (Tsen 1975).

Fidanza reported the enzymatic ultrafiltrate digestibility (EUD) of corn germ protein to be 67, a value which is comparable or superior to values obtained from proteins of other plant sources (Fidanza, 1978). In addition, defatted corn germ meal does not contain significant antinutritional factors (Barbieri and Casiraghi 1983).

By subjecting the defatted CGPF to a milling-screening process to remove fibrous fragments, Barbieri and Casiraghi (1983) were able to obtain CGPF with 20% protein, 60% starch, 3.3% fiber, 8.4% minerals, and 1.7% fat. This implies that with proper processing and the technology available today, CGPF can yield a product which is adequate for human consumption.

Amino Acid Pattern of CGPF

As shown in Table 1, defatted CGPF has a higher content of cystine than either sodium caseinate or soybean protein. Defatted CGPF also contains more methionine, threonine, and valine than does soybean protein. Defatted CGPF compares favorably with hen's egg protein (Blessin *et al.* 1973), contains more total essential amino acids per 100 g protein than soybean protein, and compares favorably with the FAO/WHO provisional amino acid pattern for human consumption. CGPF is slightly low in tryptophan, isoleucine, and methionine, but exceeds the FAO/WHO reference pattern for leucine, lysine, phenylalanine, tyrosine, threonine, and tryptophan. Taken together, this ranks CGPF

TABLE 1.

ESSENTIAL AMINO ACID PATTERNS OF DEFATTED CGPF[a]

Amino Acid	g Amino Acid Per 100 g Protein				
	CGPF	Hen's Egg[b]	Sodium Caseinate[c]	Soybean Protein[d]	FAO/WHO Reference Pattern[e]
Isoleucine	3.4	6.6	5.5	4.2	4.2
Leucine	7.2	8.8	9.7	7.4	4.8
Lysine	5.9	6.4	8.3	6.4	4.2
Phenylalanine	4.1	5.8	5.3	4.5	2.8
Tyrosine	3.1	4.2	5.9	3.4	2.8
Cystine	1.4	2.4	0.36	0.9	2.09
Methionine	2.1	3.1	2.8	1.2	2.2
Threonine	4.1	5.1	4.8	3.6	2.8
Tryptophan	1.2	1.6	1.6	1.7	1.4
Valine	5.6	7.3	6.9	4.3	4.2
Total essential Amino acids	38.3	51.3	51.16	37.6	34.29

[a]CGPF = corn germ protein flour

[b]Blessin et al 1973.

[c]Anon 1975

[d]Del Valle 1981.

[e]FAO/WHO 1965.

among the best sources of plant protein (Anon. 1975; Ford 1978). Tests performed in Peoria, IL at the National Regional Research Laboratory (NRRL) have shown corn germ to contain slightly higher percentages of most essential amino acids than wheat germ, although total protein content of corn germ is 25% compared to about 36% protein in wheat germ (Ford 1978).

Trace Mineral Content of CGPF

The ashed content of defatted CGPF is reported to be approximately 10.3% (Blessin *et al.* 1972; Tsen 1975). Major mineral elements in CGPF ash include; phosphorus, potassium, zinc, and magnesium (Blessin *et al.* 1972; Anonymous 1975; Tsen 1975). While calcium, iron and sodium levels are relatively low, sodium and iron content of defatted CGPF is greater than that of enriched wheat flour (Blessin *et al.* 1972; Tsen 1975). Table 2 presents macro- and microelement content of defatted germ meal (Barbieri and Casiraghi 1983).

Potential Applications For CGPF

Peri *et al.* (1983) found that defatted CGPF could be used to produce an expanded nutrient snack possessing a mild flavor and crisp texture by extrusion cooking. The addition of milk proteins (23% of total protein content) to the snack was found to improve both organoleptic and nutritional qualities.

TABLE 2.

MACRO- AND MICRO MINERAL COMPOSITION OF DEFATTED CGPF[a]

Mineral Element	Content in CGPF	U.S. RDA[b]
Sodium	5.4 mg/100 g	900-3300 mg
Potassium	945.0 mg/100 g	1525-5625 mg
Calcium	18.5 mg/100 g	800-1200 mg
Magnesium	425.0 mg/100 g	300-400 mg
Iron	16.2 mg/100 g	10-18 mg
Manganese	2.1 mg/100 g	2.5-5.0 mg
Zinc	11.4 mg/100 g	15 mg
Copper	0.8 mg/100 g	2.0-3.0 mg
Cobalt	0.2 mg/kg	---------
Nickel	0.5 mg/kg	---------
Lead	1.0 mg/kg	---------
Chromium	0.5 mg/kg	0.05-0.2 mg
Cadmium	0.1 mg/kg	---------

[a] CGPF = Corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b] RDA = Recommended Dietary Allowances, 1980. Values reflect the RDA for children 11+ to adult, excluding pregnant and lactating females.

Table adapted from Barbieri and Casiraghi 1983.

More research has been conducted with soy flour as a high-quality protein additive in baked products than with CGPF. Wheat flour, fortified with full-fat soy flour, can increase protein content, balance essential amino acid content, and increase the caloric value of baked products. Such fortification has been shown to affect both rheological properties and baking quality of wheat flour adversely (Tsen and Hoover, 1973).

Blessin *et al.* (1973) combined defatted CGPF with wheat flour in formulations for cookies, muffins, and beef patties. The cookie's ash content doubled, fat content remained constant, and fiber and protein levels increased minimally. Similar results were obtained for the muffins, but to a lesser extent.

Tsen (1975) incorporated CGPF in dough for bread-making and found that:

(1). CGPF, like soy flour, weakened dough structure.

(2). CGPF, like soy flour, increased water and fat absorption levels.

(3) CGPF, like soy flour, reduced dough mixing time.

A U.S. patent was issued (*#4.849.244*) to J. Zayas for the incorporation of CGPF to comminuted meat systems. Addition of 2% and 4% CGPF was found to reduce fat content, increase water and fat binding capacity, and to prevent coalescence of fat globules during heat treatment of sausages (Lin and Zayas 1987_a).

CGPF is applicable as an additive to fudge, pancakes, waffles, chocolate chip cookies, and as an instant supplement; sprinkled over cereals in the same manner as wheat germ (Ford 1978). CSM, a corn-soya-milk supplement developed for preschool children, containing a mixture of heat-processed corn meal, soybean meal, nonfat dry milk, vitamins and minerals, has been shipped to developing countries under the Food for Peace Program since 1966 (Gardner *et al.* 1971).

OBJECTIVE FOR STUDY

This following study was conducted to evaluate quality characteristics of ground beef patties extended with hydrated defatted CGPF at 10, 20, and 30% of uncooked beef weight. The effect of CGPF on proximate composition, cooking losses, color, texture, water holding capacity, amino acid composition, and content of macro- and trace elements in broiled and raw beef patties was studied.

MATERIALS AND METHODS

Sample Preparation

Defatted CGPF, was provided by Lauhoff Grain Company, Danville, IL. CGPF was added to distilled water in a ratio of 1:3. Hydration was allowed to continue at room temperature during beef trim preparation.

Fresh beef trim was purchased from the Meat Lab (Department of Animal Science and Industry, KSU) and used to produce beef patties by the scheme illustrated in Figure

2. Formulation of experimental treatments is illustrated in Table 3.

Heat Treatment

For this study, all-beef patties and CGPF extended patties were broiled in a conventional electric oven (Waste King). Prior to broiling, frozen patties were allowed to thaw overnight at 4° C. Thawed patties were placed on wire racks inside metal broiling pans having the dimensions 18cm x 28cm x 3cm (the West Bend Co., Westbend, WI). Oven rack placement was 12cm from the overhead heating element, and the oven door was open 7.5cm during broiling to allow for insertion of an electronic temperature recording device (Doric Minitrend 205). Two treatment groups, consisting of two patties each, were broiled in separate pans in the same oven. After 4 minutes, patties were turned, temperature probes were inserted, and patties were broiled to an internal temperature of 77° C (medium-well).

Cooking Losses

Losses during cooking were calculated as the change in weight between raw and broiled, cooled, beef patties. Eight replications per treatment were measured. These losses were categorized and calculated as volatile, drip, and total cooking losses as follows:

1. Loss due to evaporation:

$$\frac{\text{Raw wt of pan + patty} - \text{Cooked wt. pan + patty + drip}}{\text{Raw wt. of patty}} \times 100$$

FIGURE 2.

BEEF PATTY PREPARATION

*CGPF = Corn Germ Protein Flour

TABLE 3.

TREATMENT FORMULATION

Ingredients	TREATMENT			
	Control[c]	10% CGPF Slurry	20% CGPF Slurry[a]	30% CGPF Slurry[a]
Ground beef, g	870.0	825.0	765.0	690.0
Salt[b], g	8.7	8.4	7.8	6.9
Water, g	26.1	62.1	115.2	155.7
CGPF[d], g	0.0	20.7	38.4	51.9
Total, g	904.8	916.2	926.4	904.5

[a] CGPF slurry = corn germ protein flour hydrated with distilled water in ratio 1:3.

[b] Salt added as 1% of ground beef weight.

[c] 3% water added to control in compliance with federal "Added Water" regulations.

2. Loss due to drip:

$$\frac{\text{Cooked wt. pan + drip - Raw wt. pan + rack}}{\text{Uncooked weight of patty}} \times 100$$

3. Total cooking losses:

$$\frac{\text{Raw patty weight - cooked patty weight}}{\text{Weight of raw patty}} \times 100$$

Protein Content

Percent nitrogen in broiled and raw beef patties was determined using the Buchi Semi-macro Kjeldahl technique. Replications consisted of 8 broiled and 2 raw patties per treatment. Samples weighing 0.5 g were digested in concentrated H_2SO_4 with catalyst ($CuSO_4$, K_2SO_4) by heating until the solution became clear. Distillation was performed using a Buchi 321 Distillation Unit (Buchi Corporation, Denmark). Total nitrogen was determined by titration with 0.1N HCL. Percent protein was calculated using the following formulas:

$$\%\text{Nitrogen} = \frac{0.1N \times (\text{mL HCl} - \text{mL Blank}) \times 14.007}{\text{Sample Weight (mg)} \times 100}$$

$$\%\text{Protein} = \%\ \text{Nitrogen} \times 6.25$$

Fat Content

Percent fat in broiled and raw beef patties was determined using the Fosslet method (Model 15500, A/S N. Foss Electric Corporation, Hillerod, Denmark).

A 22.5 g homogenized sample was weighed into the

Fosslet cup with 40 g plaster of Paris and 120 mL tetrachloroethylene. The covered cup was installed in the Fosslet orbital shaker and shook 2.5 minutes. The resulting solution was filtered through the Fosslet pressure filtration device, lined with Rundfilter 70 mm paper, to produce a clear filtrate free of moisture droplets. The extraction was pressed through the Fosslet measuring chamber from which fat content was read directly. Eight replications were performed for broiled patties, 2 were made for raw patties in each treatment.

Moisture Content

Moisture in broiled and raw beef patties was determined by drying a 10 g sample to constant weight at 105° C (AOAC method 24.002). Duplicate measurements were completed for both broiled and raw patties, with 8 replications being performed on broiled samples. Percent moisture was calculated using the following formula:

$$\frac{\text{Patty weight prior to drying} - \text{Patty weight after drying}}{\text{Weight of patty prior to drying}} \times 100$$

Ash Content

Ash content was determined by placing a 2.0 g dried sample into 550° C muffle furnace overnight (Type 2000 Thermolyne Furnace). Ashed samples were cooled in a desiccator before weighing. Duplicate measurements were obtained for broiled and raw patties, with 8 replications being performed on broiled samples. Percent ash was cal-

culated using the following formula:

$$\%Ash = \frac{\text{final weight}}{\text{sample weight}} \times 100$$

Macro- and Microelement Determination

Macro- and microelement content was analyzed in the KSU Analytical Lab using direct current plasma spectrophotometry. Zn, P, Mn, Mg, Mo, Ca, and Se were analyzed from a 0.3 g beef patty sample while Cu and Fe were analyzed from a 2.0 g sample. Three replications per treatment were made using broiled beef patties. One measurement was performed using raw beef patties.

Amino Acid Composition

Amino acid content was quantitatively determined by the KSU Department of Grain Science and Industry, using a D-300 Dionex Kit Amino Acid Analyzer (Sunnyvale, CA). Samples were hydrolyzed 31 hours with p-toluenesulfonic acid. Triplicate measurements were acquired for broiled beef patties, one measurement was performed on a raw patty from each treatment group. Amino acid analysis data were calculated automatically using a computer technique described by Cavins and Friedman (1968).

Color Measurement

Color differences between treatments were determined using a HunterLab D54 Spectrophotometer (Hunter Associates Lab, Inc., Fairfax, VA). Illuminant A and C light sources,

horizon light and Northern daylight, respectively, were used for measurements. Values for L (lightness on a scale of 100 for pure white to 0 for black), a+ (redness), and b+ (yellow) were recorded using three broiled and one raw sample per treatment. Following the initial reading, each sample was rotated 90° and read again. The average of these two readings was used to calculate least square means.

Textural Analysis

Shear force evaluations were made using the Warner Bratzler attachment to the Instron Universal Testing Machine (Model 1122). Seven circular cores (diameter 1.81 cm) were taken from each patty, six patties were analyzed per treatment. Each sample was inserted into a triangular opening in the blade between two rectangular bars. The Instron was equipped with a 500 kg tension-compression load cell. Crosshead descent and recording chart speeds were 50 mm/min, full scale deflection was 2 kg. The force necessary to shear each circular core was calculated from the peak height recorded.

Water Holding Capacity

Water holding capacity (WHC) was determined on raw beef patties using a modified Hamm press method. Triplicate measurements were procured by weighing 300 mg samples onto filter paper (Whatman No. 1) positioned

between Plexiglass sheets, and pressed with a Carver Laboratory Press 5 min using 5,000 pounds of pressure. The ratio of the area of pressed muscle to the area of expressed liquid (measured with a compensating polar planimeter) was designated as the expressible liquid index (ELI). Values for WHC were obtained by subtracting the ELI from 1.0, arbitrarily chosen as the maximum ELI. Because the ELI is inversely related to the amount of liquid expressed from the sample, the larger the WHC value, the more liquid expressed.

Analysis of shrink

Analysis of shrink was calculated by tracing each patty area three times before and after heat treatment. Eight replications of two patties per treatment were averaged to calculate percent shrink.

$$\% \text{ Shrink} = \frac{\text{Area of raw patty} - \text{area of broiled patty}}{\text{Area of raw patty}} \times 100$$

Statistical Analysis and Design

An incomplete block design with two treatments per block (time) was used. To determine if significant differences existed among treatments due to level of CGPF extension, the SAS procedure GLM was used to analyze data from broiled patties. For each source of variation where the F-value was found to be significant, the least significant difference at the 5% level of probability was determined.

RESULTS AND CONCLUSIONS

Cooking Losses

Heating of muscle tissue causes extensive biochemical and physical changes (Fennema 1985). As muscle tissue is cooked, it first becomes firmer as contractile proteins are denatured (Fennema 1985). Shrinkage occurs during the heating of meat, causing weight and volume losses. Fat is melted, adipose tissues are ruptured, and there is a significant redistribution of fat. These processes continue as the internal temperature of the meat is increased (Fennema 1985). Factors affecting the desirability of these changes include age of the animal prior to slaughter, postmortem changes and contraction state, fat content, moisture binding capacity, characteristic behavior of protein components during heating, rate of temperature increase, method of cooking, and time-temperature conditions imposed (Laakkonen 1970). In this study, cooking losses were evaluated as the change in weight between raw and broiled beef patties, and were divided into drip and volatile (evaporative) losses. Drip losses consist primarily of lipids lost from the meat tissue as it is heated, but may also contain water and nonvolatile water-soluble materials such as salts and sarcoplasmic proteins (Paul 1972).

Volatile losses are primarily composed of evaporated water which was squeezed from the tissues as myofibril proteins become denatured and coagulate during the cooking process, but may also contain water-soluble substances such

as salts, sarcoplasmic proteins, and nonprotein compounds. Most of the water evaporates during oven broiling. Severe heating of meat triggers further changes in proteins and free amino acids producing volatile breakdown products such as hydrogen sulfide, mercaptans, sulfides, and disulfides, as well as aldehydes, ketones, volatile amines and others (Fennema 1985). That fat which is spattered out of the roasting pan is likewise considered to be part of the volatile losses. Lipid components may decompose to form volatile products such as aldehydes, ketones, alcohols, acids, or hydrocarbons (Fennema 1985). Many of these volatile compounds contribute to the tantalizing flavor and aroma of cooked meat (Fennema 1985).

Cooking losses of broiled patties are shown in Table 4. The general trend was for a reduction in cooking losses as the level of CGPF increased. Volatile cooking losses were greater for control patties, which was expected since the control had 3% added water in compliance with "added water" regulations, but did not contain additional proteins to bind this added water. During preliminary research, the control was formulated without 3% added water. Even without the added water, control patties exhibited significantly greater volatile, drip, and total cooking losses ($P<0.05$). Whereas the decrease in volatile losses was not statistically significant for the 10% CGPF treatment, the 20% and 30% CGPF treatments did reflect significantly

TABLE 4.

COOKING LOSSES OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[d,e]

Treatment	COOKING LOSSES		
	Volatile (%)	Drip (%)	Total (%)
Control	27.89[a]	8.55[a]	36.25[a]
CGPF, 10%	25.47[a,b]	7.31[b]	32.72[a,b]
CGPF, 20%	23.71[b]	6.61[b]	30.40[b]
CGPF, 30%	24.61[b]	5.41[c]	30.09[b]

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

[d]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[e]Experimental data averaged using least square means.

lower values when compared to the control. Brown (1988) reported similar findings, but found a statistically significant difference to exist also between the control and 10% CGPF treatments. This discrepancy between data can be resolved by contemplating differences in patty formulation. Brown (1988) did not incorporate 3% added water to the control treatment, consequently there was significantly less water available for evaporation during heating.

Drip losses for all treatments containing CGPF were significantly lower than for the control. This disclosure supports the hypothesis that corn germ protein flour has strong fat and water binding capacity. The 30% CGPF treatment also exhibited a statistically significant reduction in drip losses when compared to the 10% and 20% CGPF treatments ($P<0.05$). The same trend for reduced drip losses with extension by CGPF was reported by Brown (1988). Zayas and Lin (1989) established fat and water binding capacity of CGPF in a model system in comparison with soy protein (Zayas and Lin 1989). Total cooking losses were observed to decrease as CGPF content increased. Statistical difference ($P<0.05$) between control and CGPF samples was documented at the levels of 20% and 30% CGPF. Brown (1988) reported significant differences between control and 10% CGPF treatments, which were due to the absence of added water in control patties.

CGPF has hydrophilic and hydrophobic properties which

promote moisture and fat retention. These properties enable CGPF extended beef patties to have decreased cooking losses (volatile and drip) regardless of whether the beef patties are cooked by microwave or by conventional oven (Brown 1988).

Water Holding Capacity

Water retention and hydration are the first critical steps in imparting desired functional properties to proteins. In CGPF formulations, carbohydrates also may have an active role in these steps (Lin and Zayas 1987_c). Binding of water in meat products is connected with structural properties of the muscle, since bound water increases solid-like properties of the food system, and determines such quality characteristics as juiciness, texture, appearance, and yield of the final product (Zayas 1985). Water holding capacity values for all-beef patties and CGPF extended patties were not shown to be significantly different as shown in Table 5, however WHC did increase with addition of CGPF. This finding supports the idea that proteins of plant origin need to be heated before they will hold moisture (Lin and Zayas 1987_a). Other researchers have reported similar results after extending food products with CGPF (Lucisano *et al.* 1984; Lin and Zayas 1987_a; Brown 1988).

Percent Shrink

Production of meat products with limited potential for

TABLE 5.

WATER HOLDING CAPACITY, PERCENT SHRINK, WEIGHT LOSS, AND SHEAR FORCE OF BEEF PATTIES CONTAINING CGPF SLURRIES[d,e]

Treatment	WHC[f] (Raw Patties)	Shrink (%)	Weight Loss (%)	Shear Force (kg)
Control[g]	0.516[a]	31.17[a]	36.00[a]	1.10[a]
CGPF, 10%	0.556[a]	27.32[b]	32.13[b]	0.86[b]
CGPF, 20%	0.569[a]	27.03[b]	30.18[b]	0.84[b]
CGPF, 30%	0.665[a]	22.54[c]	31.14[b]	0.68[c]

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

[d]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[e]Experimental data were averaged using least square means.

[f]WHC = water holding capacity.

[g]Control in this analysis had 3% added distilled water.

shrink is of economic value since consumers purchase these foods on a price per pound basis, and shrinkage reduces final product yield. Analysis of variance for percent shrink (Table 5) revealed significant differences between all-beef control patties and CGPF extended beef patties. This incident was found to be related to the higher cooking losses associated with the control treatment. Percent shrink was found to have an inverse relationship to content of CGPF: shrink decreased as CGPF content increased. An increase in moisture evaporation has a positive correlation to an increase in percent shrink, which is demonstrated by increased volatile loss in all-beef patties.

Weight Loss During Heating

WHC strongly influences the yield of the finished product (Zayas 1985). Water accounts for the major portion of the weight loss during meat cooking, especially with low-fat cuts. Therefore, the weight loss reflects the stability and water holding capacity of the meat proteins.

Hamm (1960) agreed that weight loss upon cooking is a usable measure of the water holding capacity of meat, but may be somewhat imprecise. The samples were weighed before and after heating; weight loss is reported in Table 5 (Laakkonen *et al.* 1970).

Experimental samples containing CGPF had significantly lower weight loss than all-meat control samples ($P<0.05$).

However, there was no significant difference between 10, 20, and 30% CGPF extended samples ($P<0.05$). All-beef patties had significantly greater weight loss than did CGPF extended patties. This agrees with data from cooking losses and supports data reported from other researchers incorporating CGPF in comminuted meats (Lin and Zayas 1987[b])

Results from water holding capacity, shrink, and weight loss imply cooked yield of beef patties extended with CGPF would exceed those of all-beef patties. Other researchers have reported the same trend in ground beef patties extended with defatted soybean flour, ground beef patties extended with defatted CGPF, and comminuted meat products extended with defatted CGPF (Blessin *et al.* 1973; Anderson and Lind 1975; Lin and Zayas 1987[b]; Brown 1988).

Textural Analysis

Texture is an important attribute affecting consumer reaction to food (Szczesniak 1966). In order to predict consumer acceptance of a new food product, the food technologist needs to quantify texture objectively (Szczesniak 1966).

As shown in Table 5, incorporation of CGPF decreased the force required to shear extended patties, indicative of a more tender product. Beef patties extended with the 30% CGPF slurry received significantly lower shear force values than did the all-meat control patties and experimental

patties containing 10 and 20% CGPF slurries.

Results from other studies incorporating defatted CGPF in meat systems reported the same trend (Lin and Zayas 1987b ; Brown 1988). Blessin *et al.* (1972) found that beef patties extended with 10% CGPF were firmer than the control or the other treatment groups. This is due to the CGPF being added in powder form instead of as a slurry.

PROXIMATE COMPOSITION

Protein content

CGPF incorporated beef patties had a protein content ranging from 13.66% in the 30% raw treatment to 23.58% in the 10% broiled treatment (appendix Table 14). Experimental data showed protein content of both raw and broiled beef patties decreased slightly with the addition of CGPF (Tables 6 and 7). This decrease was more significant in broiled beef patties than in raw beef patties ($P<0.05$).

This data may sound perplexing, considering CGPF contains 23-26% protein while the ground beef which it is replacing contains only 18-20% protein. The reduction in protein content is believed to be due to a dilution effect rather than to any actual protein losses. Dilution may have been caused by several factors: hydrating CGPF with three times its weight in water during slurry formation, combining two proteins of different origin: plant with animal, and other components present in CGPF such as minerals, oil, sugars, fiber, starch, and carbohydrate

TABLE 6.

PROXIMATE COMPOSITION OF RAW BEEF PATTIES CONTAINING CGPF SLURRIES[a b]

Treatment	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Control	17.13	17.99	62.23	1.72
CGPF, 10%	16.68	16.55	62.37	1.79
CGPF, 20%	15.90	15.41	63.92	1.55
CGPF, 30%	14.14	14.57	64.04	1.79

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b]Experimental data were averaged using arithmetic mean.

TABLE 7.

PROXIMATE COMPOSITION OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[e f]

Treatment	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Control	25.20[a]	18.62[a]	52.64[a]	2.22[a b]
CGPF, 10%	22.90[b]	16.70[b]	54.37[b]	2.27[a]
CGPF, 20%	20.92[c]	16.36[b]	54.99[b]	2.07[b]
CGPF, 30%	20.13[c]	15.91[b]	55.03[b]	2.12[a b]

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

[e]CGPF slurries = Corn germ protein flour hydrated with distilled water in ratio of 1:3.

[f]Experimental data were averaged using least square means.

(Blessin *et al.* 1973)

Other researchers have reported the same trend for slight protein decrease in CGPF extended patties (Blessin *et al.* 1972, 1973; Brown 1988). Blessin *et al.* (1973) reported addition of as much as 5% CGPF maintained acceptable levels of protein. Bressani *et al.* (1976) reported comparable results from a study where soybean protein (textured vegetable protein) was combined with beef. These researchers found increasing amounts of soybean protein progressively decreased the protein quality of beef protein when fed to rats. The reason given for this constant decrease was that the limiting amino acid in both soybeans and beef is methionine. Zayas and Lin (1988) reported no significant difference in protein content between control and CGPF extended frankfurters at 3.5% extension level. It is important for nutrition-oriented persons to bear in mind that although total protein content of beef patties extended with CGPF was shown to be significantly less than the protein content of control patties ($P<0.05$), CGPF extended patties will contain lower levels of fat, and higher levels of starch, fiber, essential amino acids, and trace minerals.

Fat content

A desirable nutritional characteristic of CGPF is its low fat content. This would be negated if beef patties extended with CGPF were to retain a greater percentage of

fat in cooking than all-beef patties.

Examination of experimental data in Tables 6 and 7 reveal significant differences ($P<0.05$) in fat content of all-meat patties and those extended with CGPF. As CGPF content increased, a more substantial decrease occurred in fat content. This decrease in fat content is due to the dilution effect achieved by replacing animal tissue with a defatted plant protein. Similar results using CGPF extended beef patties have been reported (Blessin *et al.* 1972, 1973; Brown 1988). Anderson and Lind (1975) found the same trend for decreased fat content in beef pattties extended with expanded defatted soybean flour.

Dietary fat and cholesterol have been identified as risk factors in premature coronary heart disease (Sweeney and Weirauch 1976; Hoelscher *et al.* 1987). Since cholesterol is stored in adipose tissues, it follows that a decrease in fat content would also decrease cholesterol content. In an effort to reduce the risk of heart disease, the American Heart Association has recommended reducing dietary fat intake to no more than 30% of caloric intake.

Experimental results imply that extending meat products with defatted CGPF can significantly reduce dietary fat and cholesterol intake, thereby improving nutritional quality of the product. Further research on the effect of extending animal proteins with defatted CGPF and cholesterol content is necessary.

Moisture content

Moisture contents of broiled products ranged from 52.64% in control patties to 55.03% in extended patties containing 30% CGPF, with significant differences shown to exist between control and extended patties (Tables 6 and 7).

The same trend for increased moisture in beef patties extended with expanded defatted soybean flour has been reported (Anderson and Lind 1975). It has been reported that fried or broiled patties of ground beef extended with expanded defatted soybean flour (textured vegetable protein; TP) seemed juicier than all-beef patties prepared in a similar manner (Anderson and Lind 1975). As mentioned earlier, corn germ flour is known to have excellent water-binding proteins which are responsible for this increased moisture content in ground beef patties.

Contrary to the results of this study, Zayas and Lin (1988) found that moisture content of frankfurters extended with CGPF at a 3.5% level (added in slurry and powder form) decreased more than that of all-meat control frankfurters. Blessin *et al.* (1973) reported no discernible trend related to levels of CGPF incorporation at the levels of 1, 3, 5, and 10% CGPF (added in powder form).

Ash content

The total mineral content of plant tissues, known to be nonuniform, is sometimes expressed as ash content; resi-

due remaining after incineration (Fennema 1985). Experimental results for ash content are shown in Tables 6 and 7.

Experimental results showed no difference in ash content between all-meat control and experimental samples. Ash content for 10% CGPF containing samples was slightly higher than for 20% CGPF extended samples. Other researchers have reported increased ash content of beef patties when CGPF was added as a powder (Blessin *et al.* 1973).

Macro- And Microelement Content

Methods of nutrient assay using absorption spectrophotometry have been utilized for a long period of time. The chemical reactions involved during absorption spectrophotometry of mineral elements impart a larger amount of sensitivity and specificity than can be acquired by direct spectrophotometric examination of a food product, and the overall assay precision has been well-documented (Gregory 1989).

Data from macro- and microelement determination and U.S. RDA shown in Tables 8 and 9, demonstrate the high nutritional quality of beef patties extended with defatted CGPF. Phosphorus and magnesium are major mineral elements found in CGPF, which helps to explain the trend for these elements to increase with increasing quantities of CGPF extension in meat products. Significant increases were evident in content of most mineral elements ($P<0.05$), however most notable were magnesium (340%), iron (131%), phos-

TABLE 8.

MACRO- AND MICRO ELEMENT CONTENT OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIESef COMPARED TO U.S. RECOMMENDED DIETARY ALLOWANCES (RDA)

Element (ppm)	TREATMENT							U.S. RDA (mg)
	Control	10% CGPF	Increase (%)	20% CGPF	Increase (%)	30% CGPF	Increase (%)	
Mg	230.83a	430.83b	187	585.83c	254	785.83d	340	300-400
Ca	91.92a	94.67a	103%	108.17ab	118%	121.92b	133	800-1200
Zn	56.67a	54.67a	----	57.67a	102%	61.67a	109	15
Fe	25.67a	27.17ab	106%	29.17b	114%	33.67c	131	10-18
Cu	1.43a	1.48a	103%	1.95a	136%	2.35b	164%	2.0-3.0
P (%)	0.19a	0.22b	116%	0.24b	126%	0.28c	147%	800-1200
Mo	< 0.09a	< 0.09a	----	< 0.09a	----	< 0.09a	----	0.15-0.5
Mn	0.13a	1.11b	854%	2.09c	1,608%	3.24d	2,492%	2.5-5.0
Se	0.15a	0.18a	120%	0.17ab	113%	0.19b	127%	0.05-0.2

a,b,c,dMeans is the same column with the same superscript letter are not significantly different ($P < 0.05$).

eCGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

fExperimental data were obtained using least square means.

gRecommended dietary allowances (1980) for safe and adequate daily dietary intakes (children 11+ years and nonpregnant, nonlactating adults).

TABLE 9.

MACRO- AND MICRO ELEMENT CONTENT OF RAW BEEF PATTIES CONTAINING CGPF SLURRIES[a]

Element (ppm)	Treatment			
	Control	10% CGPF	20% CGPF	30% CGPF
Mg	182.00	320.00	440.00	550.00
Ca	65.00	68.00	70.00	72.00
Zn	38.00	36.00	40.00	39.00
Fe	17.00	19.00	25.00	22.00
Cu	1.50	1.10	1.40	1.70
P(%)	0.14	0.16	0.18	0.21
Mo	< 0.09	< 0.09	< 0.09	< 0.09
Mn	0.10	0.77	1.50	2.10
Se	0.10	0.16	0.13	0.14

[a] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

phorus (147%), and manganese (2492%). Copper (164%), selenium (127%), and calcium (133%) were shown to increase significantly ($P<0.05$) at the 30% level of CGPF incorporation. An explanation detailing the importance of these mineral elements in the human diet is presented in the "Literature Review" section of this manuscript.

Blessin *et al.* (1973) reported addition of 10% defatted CGPF to beef patties to produce a twofold increase in phosphorus and potassium and a sevenfold increase in magnesium when compared to the control. Mineral content of CGPF slurry extended patties was not found to increase as dramatically as when CGPF was added in powder form. The distilled water added during slurry formulation apparently had a dilution effect on macro- and micro element concentrations.

Amino Acid Analysis

The nutritive quality of dietary protein is receiving increasing attention from consumers, governmental agencies, and the food industry (Phillips and Sternberg 1979). The amino acid composition of a protein is an important factor in ascertaining its nutritive quality.

Whole kernel proteins are documented to be an incomplete protein source due to their low lysine content. Ford (1978) reported lysine content in the kernel to be 2.5%. Corn germ protein possesses a quite different amino acid content, especially in regard to lysine content.

Judging by the essential amino acid profiles in Table 10 and the FAO/WHO provisional pattern, the superior nutritional value of CGPF extended beef patties is manifested by their elevated lysine content (6.33-7.92 g per 100 g protein). The lysine content in the defatted CGPF fraction is superior to the lysine content in any other fraction (Inglett 1970).

On the basis of grams of amino acid per 100 g of protein, CGPF extended patties exceeded the provisional amino acid pattern for human consumption for six of the essential amino acids. Although experimental samples containing CGPF were slightly deficient in valine, isoleucine, and cystine when compared to the FAO/WHO (1965) reference, CGPF samples compared favorably with hen's egg proteins, an ideal protein source recognized to contain optimum amino acid content (Blessin *et al.* 1973).

The addition of CGPF did not have a significant effect ($P<0.05$) on the amino acid content of experimental beef patties at all three extension levels. Content of some amino acids increased significantly ($P<0.05$) with CGPF extension (leucine, asparagine, serine, alanine, and ammonia). No significant decreases in amino acid content were observed. Zayas and Lin (1989) reported similar results from CGPF incorporation in frankfurters.

Color measurement

Color and appearance of foods are usually the first

TABLE 10.

AMINO ACID COMPOSITION OF BROILED BEEF PATTIES CONTAINING CGPF[d f]

Amino Acid	g amino acids per 100 g protein					
	TREATMENT				Hen's Egg Protein[g]	FAO/WHO Reference Pattern[h]
	Control	10% CGPF	20% CGPF	30% CGPF		
Lys	8.01[a]	7.62[a]	6.33[a]	7.92[a]	6.4	4.2
Thr	4.65[a b]	4.70[a b]	4.87[a]	4.57[b]	5.1	2.8
Val	3.55[a]	3.68[a]	3.81[a]	3.65[a]	7.3	4.2
Met	2.68[a]	2.27[a]	2.30[a]	2.75[a]	3.1	2.2
Isoleu	3.29[a]	3.29[a]	3.28[a]	3.21[a]	6.6	4.2
Tyr	4.01[a]	3.90[a]	3.58[a]	4.14[a]	4.2	2.8
Phe	4.57[a b]	4.61[a b]	4.01[a]	4.97[b]	5.8	2.8
Leu	7.51[a]	7.84[a]	8.47[b]	7.55[a]	8.8	4.8
Cys	0.95[a]	0.77[a]	0.47[a]	1.02[a]	2.4	2.0

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

[d] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[e] Reported in g amino acid per 100 g protein.

[f] Experimental data were averaged using least square means.

[g] Blessin et al. 1973

[h] FAO/WHO 1965

[i] Tryptophan was not determined.

TABLE 11.

AMINO ACID COMPOSITION OF RAW BEEF PATTIES CONTAINING CGPF SLURRIES[a]

Amino Acid	g amino acids per 100 g protein					
	TREATMENT				Hen's Egg Protein[g]	FAO/WHO Reference Pattern[h]
	Control	10% CGPF	20% CGPF	30% CGPF		
Lys	8.18	6.00	5.56	8.14	6.4	4.2
Thr	4.59	4.61	4.63	4.36	5.1	2.8
Val	3.78	3.66	3.59	3.73	7.3	4.2
Met	2.76	2.64	2.27	2.34	3.1	2.2
Isoleu	3.26	3.30	3.09	2.99	6.6	4.2
Tyr	4.07	3.90	3.31	3.74	4.2	2.8
Phe	4.99	4.56	3.77	4.92	5.8	2.8
Leu	7.62	7.93	7.84	7.42	8.8	4.8
Cys	0.83	0.59	0.49	0.72	2.4	2.0

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b]Reported in g amino acid per 100g protein.

impressions to register in the consumer's mind, influencing quality evaluation, product acceptability, and choice (Little 1975; Phillips and Sternberg 1979; Contreras and Harrison 1981; Harbers *et al.* 1981). Color measurements for experimental beef patties are shown in Tables 12-16.

Raw patties. Under illuminant A and C light sources, HunterLab L and a values revealed that CGPF extended patties did not differ significantly ($P<0.05$) from control all-meat patties, although extended patties were slightly lighter and more red than all-beef patties (Tables 12 and 13). Analysis of variance showed extended patties to be significantly more yellow than control patties under illuminant A and C light sources ($P<0.05$). Although 10% and 20% treatments were not significantly different from each other, they were significantly less yellow than the 30% treatment ($P<0.05$).

Broiled patties. Under illuminant A and C light sources, HunterLab L values showed no significant difference ($P<0.05$) between control and CGPF patties extended at the levels of 20% and 30%, although extended patties were somewhat lighter in color (Tables 13 and 14). Extended patties containing 10% CGPF slurry were significantly darker in color than all-beef, 20%, and 30% CGPF extended patties under illuminant A and C light sources (Tables 13 and 14).

Under illuminant A lighting, CGPF extended patties at

the 10% extension level were significantly ($P<0.05$) more red than all-beef patties, while all-beef patties were more red than both 20% and 30% CGPF extended beef patties (Table 14). Under illuminant C light, only the 10% CGPF extended patties differed significantly ($P<0.05$) from the control treatment (Table 15).

Under illuminant A light, no significant difference ($P<0.05$) was shown to exist between the 4 treatment groups in yellow color, although CGPF extended patties were slightly more yellow under both light sources (Tables 14 and 15).

These results indicate very little difference in red color between all-meat control and CGPF extended patties at this level of extension. There were nonsignificant differences in intensity of yellow color which suggests that the change in color was not an effect of CGPF (a yellowish-white substance) incorporation, but rather it was related to a dilution effect of the additive on the amount of meat pigments (red). Similar trends were observed by Brown (1988) in CGPF extended beef patties and in CGPF extended macaroni by Lucisano *et al.* (1984). Harbers *et al.* (1981). observed higher L and b values for patties with higher fat levels. This observation may also be applicable to this study, since control patties were shown to contain a higher fat content. The slight yellow color of the CGPF extended patties should not be a deterrent to using this new ingredient in meat systems.

TABLE 12.

TRISTIMULUS COLOR VALUES OF RAW BEEF PATTIES CONTAINING CGPF SLURRIES[d e] UNDER ILLUMINANT A LIGHT SOURCE

Treatment	ILLUMINANT A LIGHT SOURCE L	a	b
Control	39.06[a]	7.47[a]	3.74[a]
CGPF, 10%	39.81[a]	11.62[a]	4.55[b]
CGPF, 20%	42.47[a]	9.57[a]	4.65[b]
CGPF, 30%	40.13[a]	13.28[a]	5.37[c]

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

[d] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[e] Experimental data were averaged using least square means.

TABLE 13.

TRISTIMULUS COLOR VALUES OF RAW BEEF PATTIES CONTAINING CGPF SLURRIES[d] UNDER ILLUMINANT C LIGHT SOURCE

Treatment	ILLUMINANT C LIGHT SOURCE L	a	b
Control	38.07[a]	3.89[a]	6.43[a]
CGPF, 10%	38.47[a]	6.22[a]	7.77[b]
CGPF, 20%	41.28[a]	4.71[a]	8.05[b]
CGPF, 30	38.57[a]	7.23[a]	9.07[c]

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

[d]CGPF = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[e]Experimental data were averaged using least square means.

TABLE 14.

TRISTIMULUS COLOR VALUES OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[d e] UNDER ILLUMINANT A LIGHT SOURCE

	ILLUMINANT A LIGHT SOURCE		
Treatment	L	a	b
Control	44.60[a]	6.62[a]	4.42[a]
CGPF, 10%	46.51[b]	7.55[b]	4.41[a]
CGPF, 20%	44.31[a]	6.36[c]	4.47[a]
CGPF, 30%	44.49[a]	6.38[c]	4.68[a]

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

[d] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[e] Experimental data were averaged using least square means.

TABLE 15.

TRISTIMULUS COLOR VALUES OR BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[d,e] UNDER ILLUMINANT C LIGHT SOURCE

	ILLUMINANT C LIGHT SOURCE		
Treatment	L	a	b
Control	43.71[a]	2.61[a]	7.87[a]
CGPF, 10%	45.43[b]	3.16[b]	7.91[a]
CGPF, 20%	43.44[a]	2.45[a]	7.94[a]
CGPF, 30%	43.71[a]	2.46[a]	8.26[a]

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

[d]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[e]Experimental data were obtained using least square means.

SUMMARY

Incorporation of defatted corn germ protein flour (CGPF) in the formulations of beef patties was studied. Defatted CGPF with its exceptional protein content, amino acid pattern, mineral content, and economical low-cost has potential to be utilized by the meat industry as an extender, filler, and replacer of meat proteins in the production of ground beef patties.

Incorporation of CGPF in beef patties increased water holding capacity as noted by a reduction in percent weight loss and shrink, decreased cooking losses, resulting in greater percent yield.

CGPF extended beef patties were more moist, had improved textural properties as analyzed instrumentally, resulting in a more tender product.

CGPF incorporation in beef patties improved content of nutritionally important macro- and microelements.

CGPF extension decreased fat content of beef patties.

Incorporation of CGPF did not affect essential amino acid content of broiled beef patties indicating the potential value of CGPF as a high-quality protein for human consumption.

Incorporation of CGPF did not significantly change yellow color and did affect red color of broiled beef patties.

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APPENDIX

TABLE 16.

EXPERIMENTAL DESIGN SHOWING OVEN-BROILING COMBINATIONS

Replication 1

Day 1	Control & 10% CGPF
Day 2	20% CGPF & 30% CGPF
Day 3	Control & 20% CGPF
Day 4	10% CGPF & 30% CGPF
Day 5	Control & 30% CGPF
Day 6	10% CGPF & 20% CGPF

Replication 2

Day 7	Control & 10% CGPF
Day 8	20% CGPF & 30%
Day 9	Control 20% & CGPF
Day 10	10% CGPF 30% CGPF
Day 11	Control & 30% CGPF
Day 12	10% CGPF & 20% CGPF

Replication 3

Day 13	Control & 10% CGPF
Day 14	20% CGPF & 30%
Day 15	Control & 20% CGPF
Day 16	10% CGPF & 30% CGPF
Day 17	Control & 30% CGPF
Day 18	10% CGPF & 20% CGPF

TABLE 17.

COOKING LOSSES OF BEEF PATTIES CONTAINING CGPF SLURRIES[a b]

Treatment	Cooking Losses		
	Volatile (%)	Drip (%)	Total (%)
Control	27.66	8.52	35.91
CGPF, 10%	24.92	7.17	32.13
CGPF, 20%	23.32	6.69	30.23
CGPF, 30%	25.79	5.52	31.18

[a] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b] Experimental data were averaged using arithmetic mean.

TABLE 18.

RAW DATA FOR COOKING LOSSES OF BEEF PATTIES CONTAINING CGPF SLURRIES[a]

Treatment		Cooking Losses		
		Volatile (%)	Drip (%)	Total (%)
Control				
	1.	25.00	8.55	33.22
	2.	25.49	9.09	34.74
	3.	34.75	10.16	44.59
	4.	25.97	7.14	33.12
	5.	27.06	7.92	34.65
	6.	27.06	7.92	34.65
	7.	27.83	9.06	36.25
	8.	28.15	8.28	36.09
CGPF, 10%				
	1.	19.28	7.84	26.80
	2.	27.72	7.59	34.98
	3.	23.93	6.56	32.13
	4.	25.73	6.84	32.25
	5.	27.60	6.82	34.42
	6.	24.10	6.84	30.94
	7.	23.20	6.54	29.74
	8.	27.76	8.36	35.79
CGPF, 20%				
	1.	21.43	7.14	28.25
	2.	23.86	5.56	29.55
	3.	20.72	6.25	29.28
	4.	22.74	6.02	28.43
	5.	26.96	7.17	34.13
	6.	21.86	6.11	28.30
	7.	25.71	6.98	32.70
	8.	23.26	8.31	31.23
CGPF, 30%				
	1.	20.59	4.90	25.16
	2.	28.38	4.95	33.00
	3.	25.41	6.27	32.01
	4.	30.55	6.75	36.98
	5.	26.54	4.85	31.07
	6.	24.27	5.18	29.13
	7.	23.38	5.52	29.22
	8.	27.18	5.70	32.89

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

TABLE 19.

RAW DATA FOR PROXIMATE COMPOSITION OF RAW BEEF PATTIES CONTAINING CGPF SLURRIES[a]

Treatment		Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Control					
	1.	17.14	18.34	62.22	1.85
	2.	17.12	17.64	62.23	1.58
CGPF, 10%					
	1.	16.94	16.70	62.23	1.68
	2.	16.41	16.40	62.51	1.91
CGPF, 20%					
	1.	15.42	15.57	64.37	1.39
	2.	16.37	15.24	63.47	1.72
CGPF, 30%					
	1.	13.66	14.70	63.98	1.92
	2.	14.62	14.44	64.10	1.67

[a]CGPF slurries = Corn germ protein flour hydrated with distilled water in ratio of 1:3.

TABLE 20.

PROXIMATE COMPOSITION OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[a b]

Treatment	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Control	25.27	18.52	52.44	2.26
CGPF, 10%	22.67	17.07	54.44	2.25
CGPF, 20%	20.88	16.28	55.36	2.04
CGPF, 30%	20.23	15.60	54.92	2.14

[a] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b] Experimental data were averaged using arithmetic mean.

TABLE 21.

RAW DATA FOR PROXIMATE COMPOSITION OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[a]

Treatment		Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Control					
	1.	25.05	18.27	54.73	1.89
	2.	24.53	17.90	53.75	----
	3.	24.83	18.10	49.67	1.87
	4.	24.08	18.24	52.94	2.28
	5.	25.31	18.47	52.14	2.47
	6.	26.61	18.07	52.59	2.25
	7.	25.07	23.30	51.49	2.63
	8.	26.72	16.80	52.18	2.45
CGPF, 10%					
	1.	19.86	17.10	57.08	1.56
	2.	22.85	17.07	54.10	----
	3.	22.83	17.10	53.82	1.73
	4.	23.23	17.34	52.81	2.52
	5.	22.70	17.00	52.84	2.53
	6.	23.58	16.84	54.56	2.46
	7.	23.36	17.07	54.67	2.58
	8.	22.94	17.00	55.64	2.34
CGPF, 20%					
	1.	19.54	15.00	59.08	1.56
	2.	21.31	15.77	55.18	----
	3.	21.69	16.64	55.52	1.49
	4.	21.38	16.74	55.56	2.17
	5.	22.89	16.07	54.07	2.34
	6.	20.39	17.00	55.32	2.00
	7.	20.35	17.04	53.69	2.47
	8.	20.27	15.97	54.46	2.22
CGPF, 30%					
	1.	22.05	15.80	56.69	1.56
	2.	20.52	14.74	54.47	----
	3.	20.37	16.27	54.77	1.88
	4.	20.71	15.84	54.06	2.04
	5.	19.73	15.50	54.61	2.32
	6.	19.69	15.47	55.11	2.24
	7.	18.01	15.47	55.79	2.56
	8.	20.76	15.67	53.85	2.38

[a]CGPF slurries = Corn germ protein flour hydrated with distilled water in ratio of 1:3.

TABLE 22.

TRACE ELEMENT DETERMINATION IN BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[a b]

Element (ppm)	Treatment			
	Control	CGPF,10%	CGPF,20%	CGPF,30%
Mg	250.00	427.00	583.00	773.00
Ca	97.00	97.00	106.00	117.00
Zn	60.00	55.00	56.00	60.00
Fe	27.00	27.00	29.00	33.00
Cu	1.50	1.60	1.90	2.20
P (%)	0.20	0.22	0.24	0.27
Mo	< 0.09	< 0.09	< 0.09	< 0.09
Mn	0.21	1.10	2.10	3.20
Se	0.15	0.17	0.17	0.19

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b]Experimental data were obtained using arithmetic mean.

TABLE 23.

RAW DATA FOR TRACE ELEMENT DETERMINATION IN BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[a]

Element (ppm)	Treatment			
	Control	CGPF,10%	CGPF,20%	CGPF,30%
Mg				
1.	260	450	570	760
2.	240	390	600	750
3.	250	440	580	810
Ca				
1.	99	110	98	110
2.	93	82	110	120
3.	99	99	110	120
Zn				
1.	65	58	54	57
2.	55	49	59	55
3.	60	57	56	67
Fe				
1.	28	28	28	33
2.	26	24	31	30
3.	27	28	29	35
Cu				
1.	1.8	1.7	1.9	2.0
2.	1.5	1.5	1.9	2.4
3.	1.1	1.6	1.9	2.3
P (%)				
1.	0.21	0.23	0.23	0.27
2.	0.19	0.20	0.25	0.27
3.	0.19	0.22	0.23	0.28
Mo				
1.	< 0.09	< 0.09	< 0.09	< 0.09
2.	< 0.09	< 0.09	< 0.09	< 0.09
3.	< 0.09	< 0.09	< 0.09	< 0.09
Mn				
1	0.22	1.20	2.00	3.10
2	0.21	1.00	2.10	3.10
3	0.20	1.10	2.10	3.40
Se				
1	0.16	0.18	0.17	0.20
2	0.14	0.16	0.18	0.18
3	0.16	0.18	0.17	0.19

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

TABLE 24.
RAW DATA FOR WATER HOLDING CAPACITY, PERCENT SHRINK, AND SHEAR FORCE OF BEEF PATTIES CONTAINING CGPF SLURRIES[a b]

Treatment	WHC[c] (Raw Patties)	Shrink (%)	Shear Force (kg)
Control	1. 0.510	25.04	1.02
	2. 0.567	30.81	1.05
	3. 0.427	35.97	1.04
	4. -----	30.36	1.10
	5. -----	29.00	1.20
	6. -----	29.47	1.08
	7. -----	32.29	----
	8. -----	35.16	----
CGPF, 10%			
	1. 0.490	24.95	0.86
	2. 0.581	28.65	0.89
	3. 0.604	26.26	0.90
	4. -----	28.76	0.87
	5. -----	29.54	0.89
	6. -----	24.90	0.86
	7. -----	25.18	----
	8. -----	25.10	----
CGPF, 20%			
	1. 0.600	27.43	0.84
	2. 0.607	24.79	0.87
	3. 0.564	25.76	0.92
	4. -----	31.34	0.77
	5. -----	27.42	0.78
	6. -----	21.38	0.98
	7. -----	26.07	----
	8. -----	26.37	----
CGPF, 30%			
	1. 0.630	24.53	0.73
	2. 0.683	24.83	0.70
	3. 0.649	24.32	0.63
	4. -----	20.35	0.64
	5. -----	28.45	0.67
	6. -----	19.58	0.61
	7. -----	23.02	----
	8. -----	29.66	----

[a] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b] WHC = water holding capacity.

[c] Reported values reflect the average of 3 measurements.
[d] Reported values reflect the average of 7 measurements.

[e] Control in this analysis had 3% added distilled water.

TABLE 25.

WATER HOLDING CAPACITY, PERCENT SHRINK, AND SHEAR FORCE OF BEEF PATTIES CONTAINING CGPF SLURRIES[a b]

Treatment	WHC[c] (Raw Patties)	Shrink (%)	Shear Force (kg)
Control[d]	0.501	31.01	1.08
CGPF, 10%	0.568	26.67	0.88
CGPF, 20%	0.590	26.32	0.86
CGPF, 30%	0.654	24.34	0.66

[a] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b] Experimental data were averaged using arithmetic mean.

[c] WHC = water holding capacity.

[d] Control in this analysis had 3% added distilled water.

TABLE 26.

RAW DATA FOR TRISTIMULUS COLOR VALUES OF RAW BEEF PATTIES CONTAINING CGPF SLURRIES[a] UNDER ILLUMINANT A LIGHT SOURCE

Treatment	ILLUMINANT A LIGHT SOURCE L	a	b
Control	40.02	7.26	3.73
Rotate 90°	38.09	7.67	3.75
CGPF, 10%	40.42	11.37	4.54
Rotate 90°	39.20	11.86	4.56
CGPF, 20%	40.17	12.69	4.68
Rotate 90°	40.13	12.82	4.83
CGPF, 30%	40.54	13.39	5.36
Rotate 90°	39.71	13.17	5.38

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

TABLE 27.

TRISTIMULUS COLOR VALUES OF RAW BEEF PATTIES CONTAINING CGPF SLURRIES[a b] UNDER ILLUMINANT A LIGHT SOURCE

Treatment	ILLUMINANT A LIGHT SOURCE L	a	b
Control	39.06	7.47	3.74
CGPF, 10%	39.81	11.62	4.55
CGPF, 20%	40.15	12.76	4.76
CGPF, 30%	40.13	13.28	5.37

[a] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b] Experimental data were obtained using arithmetic mean.

TABLE 28.

RAW DATA FOR TRISTIMULUS COLOR VALUES OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[a] UNDER ILLUMINANT A LIGHT SOURCE

Treatment	ILLUMINANT A LIGHT SOURCE L	a	b
Control			
1.	44.08	6.67	4.37
Rotate 90°	44.08	6.53	4.20
2.	43.37	6.78	4.40
Rotate 90°	44.66	6.78	4.49
3.	46.41	6.71	4.73
Rotate 90°	46.03	6.30	4.55
CGPF, 10%			
1.	46.09	7.32	4.52
Rotate 90°	45.09	7.58	4.43
2.	45.88	7.68	4.34
Rotate 90°	44.49	7.48	4.11
3.	46.94	7.54	4.38
Rotate 90°	46.03	7.53	4.18
CGPF, 20%			
1.	45.37	6.40	4.51
Rotate 90°	44.87	6.39	4.60
2.	45.48	6.64	4.59
Rotate 90°	43.17	6.32	4.26
3.	43.06	6.19	4.18
Rotate 90°	44.77	6.45	4.61
CGPF, 30%			
1.	45.30	6.41	4.70
Rotate 90°	45.69	6.30	4.81
2.	45.62	6.48	4.87
Rotate 90°	41.09	6.24	4.39
3.	45.79	6.38	4.74
Rotate 90°	45.67	6.40	4.82

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

TABLE 29.

TRISTIMULUS COLOR VALUES OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[a b] UNDER ILLUMINANT A LIGHT SOURCE

Treatment	ILLUMINANT A LIGHT SOURCE L	a	b
Control	44.77	6.63	4.46
CGPF, 10%	45.82	7.52	4.33
CGPF, 20%	44.45	6.40	4.46
CGPF, 30%	44.86	6.37	4.72

[a] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b] Experimental data were obtained using arithmetic mean.

TABLE 30.
RAW DATA FOR TRISTIMULUS COLOR VALUES OF RAW BEEF PATTIES CONTAINING CGPF SLURRIES[a] UNDER ILLUMINANT C LIGHT SOURCE

Treatment	ILLUMINANT C LIGHT SOURCE L	a	b
Control	39.05	3.73	6.43
Rotate 90°	37.08	4.05	6.43
CGPF, 10%	39.10	6.00	7.79
Rotate 90°	37.83	6.44	7.74
CGPF, 20%	38.73	6.98	7.89
Rotate 90°	38.66	7.06	8.14
CGPF, 30%	38.98	7.27	9.07
Rotate 90°	38.16	7.19	9.07

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

TABLE 31.

TRISTIMULUS COLOR VALUES OF RAW BEEF PATTIES CONTAINING CGPF SLURRIES[a] UNDER ILLUMINANT C LIGHT SOURCE

Treatment	ILLUMINANT C LIGHT SOURCE L	a	b
Control	38.07	3.89	6.43
CGPF, 10%	38.47	6.22	7.77
CGPF, 20%	38.70	7.02	8.02
CGPF, 30%	38.57	7.23	9.07

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b]Experimental data were averaged using arithmetic mean.

TABLE 32.

RAW DATA FOR TRISTIMULUS COLOR VALUES OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[a] UNDER ILLUMINANT C LIGHT SOURCE

Treatment	ILLUMINANT C LIGHT SOURCE L	a	b
Control			
1.	43.15	2.66	7.78
Rotate 90°	43.18	2.63	7.49
2.	42.42	2.89	7.72
Rotate 90°	43.71	2.72	7.97
3.	45.45	2.43	8.52
Rotate 90°	45.12	2.15	8.25
CGPF, 10%			
1.	45.10	3.02	8.06
Rotate 90°	44.49	3.24	7.90
2.	44.88	3.33	7.75
Rotate 90°	43.52	3.40	7.24
3.	45.95	3.16	7.87
Rotate 90°	45.06	3.25	7.49
CGPF, 20%			
1.	44.46	2.32	8.10
Rotate 90°	43.94	2.34	8.24
2.	44.53	2.59	8.16
Rotate 90°	42.26	2.67	7.45
3.	42.18	2.53	7.37
Rotate 90°	43.84	2.44	8.21
CGPF, 30%			
1.	44.36	2.39	8.35
Rotate 90°	44.75	2.23	8.57
2.	44.65	2.44	8.60
Rotate 90°	40.16	2.76	7.53
3.	44.85	2.23	8.52
Rotate 90°	44.73	2.20	8.66

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

TABLE 33.

TRISTIMULUS COLOR VALUES OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[a,b] UNDER ILLUMINANT C LIGHT SOURCE

Treatment	ILLUMINANT C LIGHT SOURCE L	a	b
Control	43.84	2.58	7.96
CGPF, 10%	44.84	3.24	7.72
CGPF, 20%	43.54	2.48	7.92
CGPF, 30%	44.08	2.38	8.37

[a] CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b] Experimental data were averaged using arithmetic mean.

TABLE 34.

RAW DATA FOR AMINO ACID COMPOSITION OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES[a], WITH REFERENCE TO THE FAO PATTERN FOR HIGH-QUALITY PROTEINS

Amino Acid	Treatment[b]				FAO Reference Protein
	Control	CGPF, 10%	CGPF, 20%	CGPF, 30%	
Lys	8.33	8.54	5.63	7.79	4.2
	8.28	8.74	5.80	8.27	
	8.42	5.60	5.69	8.53	
Thr	4.63	4.58	4.70	4.29	2.8
	4.57	4.72	4.82	4.62	
	4.68	5.01	5.06	4.67	
Val	3.76	3.65	3.91	3.59	4.2
	3.42	3.64	3.80	3.64	
	3.44	3.86	3.72	3.65	
Met	2.82	2.21	2.41	2.97	2.2
	2.38	2.07	2.49	2.75	
	2.52	2.73	2.38	2.29	
Isoleu	3.62	3.24	3.29	3.14	4.2
	3.07	3.28	3.33	3.13	
	3.09	3.62	3.26	3.13	
Tyr	4.48	3.94	3.60	4.41	2.8
	3.55	3.91	3.69	4.03	
	3.77	4.19	3.55	3.76	
Phe	4.97	4.87	4.07	5.89	2.8
	4.25	4.63	4.04	4.84	
	4.43	4.48	3.90	4.63	
Leu	7.56	7.85	8.24	7.01	4.8
	7.50	7.96	8.40	7.87	
	7.72	7.90	8.27	7.88	
Cys	1.38	0.74	0.59	1.17	2.0
	0.65	0.55	0.57	0.71	
	0.69	1.23	0.55	0.82	

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b]Reported in g amino acid per 100g protein.

TABLE 35.

AMINO ACID COMPOSITION OF BROILED BEEF PATTIES CONTAINING CGPF SLURRIES, WITH REFERENCE TO THE FAO PATTERN FOR HIGH-QUALITY PROTEINS

Amino Acid	Treatment[bc]				FAO Reference Protein
	Control	CGPF, 10%	CGPF, 20%	CGPF, 30%	
Lys	8.18	7.63	5.71	8.20	4.2
Thr	4.63	4.77	4.86	4.53	2.8
Val	3.54	3.72	3.81	3.63	4.2
Met	2.57	2.34	2.43	2.67	2.2
Isoleu	3.26	3.38	3.29	3.14	4.2
Tyr	3.93	4.01	3.61	4.07	2.8
Phe	4.55	4.66	4.00	4.95	2.8
Leu	7.59	7.90	8.30	7.59	4.8
Cys	0.95	0.77	0.47	1.02	2.0

[a]CGPF slurries = corn germ protein flour hydrated with distilled water in ratio of 1:3.

[b]Reported in g amino acid per 100g protein.

[c]Experimental data were averaged using arithmetic mean.

QUALITY CHARACTERISTICS OF BEEF PATTIES CONTAINING CORN GERM PROTEIN

by

Deborah Kaye Hix

B.S., Northeast Missouri State University, 1983

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Hydrated defatted corn germ protein flour (CGPF) was incorporated in ground beef patties at 10, 20, and 30% of uncooked beef weight. Patties were conventionally heated to an internal endpoint of 77oC. Results of this study indicated incorporation of hydrated CGPF increased yield by decreasing drip, volatile, and total cooking losses. CGPF increased water holding capacity and decreased shrinkage during heating. Proximate analysis showed moisture content increased with incorporation of CGPF, resulting in a more tender product. Textural analysis showed less force required to shear CGPF extended patties. Quantitative analysis of amino acids revealed no significant difference with increased CGPF extension in beef patty formulations ($p<0.05$). Protein and fat contents were shown to decrease with increased CGPF extension. Absorption spectrophotometry by direct current plasma showed increased content of macro- and microelements elements (Mn, Mg, Cu, P, Fe, Ca, Se) in CGPF extended patties. Incorporation of CGPF did not change the yellow color but did affect the red color of broiled beef patties. Improved nutritional value of beef patties containing CGPF was related to: 1. increase in specified macro- and microelements; 2. decreased fat content; and 3. extended patties exceeded the FAO/WHO provisional amino acid pattern for human consumption.