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Chemical, physical and sensory characteristics of ground

and comminuted pork with various fat levels and

corn milling secondary products

by

Cheryll Ann Reitmeier

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Department: Food and Nutrition
Major: Food Science

Approved: Members of the Committee:

In Charge of Major Work

For the Major Department

For the Graduate College

Iowa State University
Ames, Iowa

1988

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INTRODUCTION

Fat and Cholesterol in Meat Products

Consumer awareness of recommendations to obtain 30% of total calories from fat and to consume less than 300 mg dietary cholesterol each day (American Heart Association, 1985) has increased the demand for low-fat, low-cholesterol meat products. Ground meat and frankfurters have been listed as "foods to avoid" by the American Heart Association (1985), and pork generally has been perceived as a high-fat and high-cholesterol food. The American Heart Association (1985) also recommended that consumers purchase ground beef with no more than 15% fat.

Ground pork typically contains 15 to 30% fat, but is often confused with seasoned pork sausage which may contain up to 50% fat (Rust, 1987). Raw pork sausage with 40.3% fat contained 68 mg of cholesterol per 100 g; when cooked, the sausage contained 31.2% fat and 83 mg of cholesterol per 100 g (USDA, 1980). The average cholesterol content of five raw lean pork muscles was 65 mg per 100 g (Tu et al., 1967).

Frankfurters may contain no more than 30% fat by U.S. government regulation (Rust, 1987). Beef and pork frankfurters with 29.2% fat were found to contain 50 mg cholesterol per 100 g (USDA, 1980). Research has been conducted on the fat and cholesterol contents of ground beef (Kregel et al., 1986; Rhee and Smith, 1983), but few studies have examined the fat and cholesterol contents of ground pork, particularly low-fat ground pork.

Low-fat meats are desirable for health reasons but may be tough, less flavorful and less palatable than meats with higher fat contents

(Rakosky, 1974). Fat in meats contributes to flavor and juiciness. Generally, as the fat level decreases in ground beef, tenderness and juiciness sensory scores decrease (Kregel et al., 1986; Berry and Leddy, 1984; Cross et al., 1980).

Meat Emulsions

Meat emulsions, such as frankfurters, are made by comminuting meat, water, and salt to a fine homogenate. An important function of the contractile muscle proteins is to bind water and fat. Water influences palatability by contributing to tenderness and juiciness of finished sausages. Water and fat are the chief determinants of both these quality attributes. As the moisture and fat contents of sausages increase, tenderness and juiciness also increase (Rust, 1987).

Binders and Extenders in Meat Emulsions

Emulsion stability, determined by meat proteins as well as by added proteins, is crucial to the acceptability of processed meats. Binders and extenders, usually high protein meals, are allowed at levels of 3.5% in meat emulsions (Lauck, 1975). There is no restriction on the amount of extender in nonspecific loaves and meat patties other than the amount "sufficient for purpose" (Olson, 1981).

Soy protein, whey, sodium caseinate, wheat gluten and various vegetable and cereal protein products have been added to a variety of meat products to increase water- and fat-binding capacities, to improve emulsion stability, cooking yields and slicing charac-

teristics, to reduce formulation costs and to provide product stability (Kinsella, 1976; Mittal and Usborne, 1985). A binder should replace some of the functions of the meat in an all-meat frankfurter, the most critical of which is to stabilize the fat during smoking and cooking (Lauck, 1975).

Soy in meat emulsions

Soy protein preparations are widely used in frankfurters, bologna, sausages and salami for their emulsifying ability and binding properties. Soy proteins have an affinity for meat juices which helps reduce cooking losses and makes the product more juicy and flavorful (Rakosky, 1974). Soy protein in ground beef improves tenderness, increases moisture retention, prevents fat migration during cooking and decreases cook shrink (Kotula and Berry, 1986). On the basis of protein, soy products are among the most economical binders in meat (Rakosky, 1974).

Soy flour (50% protein) binds meat juices and fat, but has a poor mouthfeel and flavor (Rakosky, 1974). When 4% soy concentrate (70% protein) was added to a minced pork product, fat and moisture loss was reduced 34% for the sterilized product (Kotula and Berry, 1986). Soy concentrate has been added to ground meat patties at a level of 20% with no adjustments for flavor (Rakosky, 1974). Soy protein isolate (90% protein) forms an extremely stable emulsion and is allowed at a 2% level in frankfurters, bologna and similar products, but it is more effective in nonspecific loaves where there is no restriction on the amount of water added.

Plant proteins in meat emulsions

Cereal flours, and oilseed flours other than soy, such as sunflower (Lin et al., 1975; Wills and Kabirullah, 1981), cottonseed (Smith et al., 1973; Terrell et al., 1979), sesame (DePadua, 1983), mustard, peanut and wheat have been utilized as binders in meat emulsions (Mittal and Usborne, 1985). Corn meal has been added to chili con carne to aid in fat retention during cooking (Rakosky, 1970).

Cereal protein concentrates and isolates have been prepared for use in meats. Sunflower (Lin et al., 1975), navy bean (Patel et al., 1980), rapeseed, pea and chickpea protein concentrates have been added to meats in experimental trials (Mittal and Usborne, 1985).

Lin et al. (1975) reported that sunflower concentrate (70% protein) provided better fat emulsion stability than soy flour and soy concentrate. Sausages prepared with sunflower flour produced a more stable emulsion when compared with sausages prepared with wheat gluten or soy protein isolate (Wills and Kabirullah, 1981).

Cottonseed concentrate (65% protein), soy flour (48% protein) and cottonseed protein isolate (90% protein) did not improve frankfurter texture when 30% of the meat was replaced with oilseed protein (Terrell et al., 1979). However, Instron force values of frankfurters were increased by the addition of textured soy flour, textured cottonseed flour, soy concentrate and soy isolate. Textured defatted sesame flour (50% protein) could replace up to 30% of the meat in meat loaves without affecting the acceptability of the product (DePadua, 1983).

Protein concentrates have been made from whole corn (Wu and Sexson, 1976) and from corn gluten (Phillips and Sternberg, 1979;

Neumann and Wall, 1984). The emulsifying activity of the corn protein concentrate (65% protein) was better than that of a soy protein isolate. The corn gluten concentrate (67-72% protein, less than 0.6% fat, 18-27% carbohydrate, 5% fiber, 3% ash and 5-7% moisture) had a water absorption ability similar to that of soy concentrate (Phillips and Sternberg, 1979).

A corn germ protein isolate was prepared by an alkaline extraction procedure (Nielsen et al., 1973). The isolate was 74% protein, 4.3% ash and 0.08% fiber. The isolate was mild in flavor, light tan in color, soluble at neutral and low pH with an ability to stabilize an oil-in water emulsion (Nielsen et al., 1973) and was suggested for use as a meat binder (Blessin et al., 1973).

Carbohydrates in meat emulsions

Substances other than protein can contribute to juiciness in ground and comminuted meats by binding water or fat and preventing drip loss during cooking. Wolf (1970) attributed the water-binding ability of soy flour not only to the presence of the proteins but also to the polysaccharides present. Starches or flours added to comminuted meats to bind water have been found to neither participate in the emulsifying process nor improve the water holding capacity of the meat itself (Mittal and Usborne, 1985). Rather, carbohydrates stabilize emulsions by absorbing or binding excess water enabling more water to be added than the meat emulsion could hold. Starch granules hold the moisture loosely, resulting in softer gels. Frankfurters with 3% potato starch were more tender than frankfurters made with wheat

flour (Bushway et al., 1982). Starch fractions extracted from legume

flour and refined starches had similar water hydration capacities

of 1.0 g/g of product (Sosulski and Sosulski, 1986).

Fiber also can bind large amounts of water. Refined legume fiber

had a water hydration capacity of over 20 g/g of product (Sosulski

and Sosulski, 1986). Reichert (1981) attributed the high water hydra-

tion capacity of field pea to the pectic substances in the cell wall

material.

Corn Milling

Corn milling industries in the United States process one billion

bushels of corn each year (Leath and Hill, 1987). Approximately 10%

of the U.S. corn production is used for human foods such as cornmeal,

flour, grits, starches, tortillas, snacks and breakfast cereal

(Rooney and Serna-Saldivar, 1987). Thirty percent of the corn

processed each year represents by-products that contain 15 to 25%

protein and 5 to 20% crude fiber. Corn milling products, such as

corn gluten meal, are sold inexpensively as feedstuffs and have not

been used in human foods. Potential human food uses for corn-milling

secondary products could have a tremendous impact on the corn processing

industry. Corn milling secondary products, with high protein and fiber

contents, have potential for use as binders and extenders in meats.

Dry-milling

Each year in the United States, approximately 111 million

bushels of corn are dry-milled into grits, meal and flour (Alexander,

1987). Processing steps include dry cleaning, wet cleaning and

tempering of corn to about 20% moisture content. Abrasion is used

to separate bran and germ from an intact endosperm. Subsequent

use of aspirators, sieves and gravity tables completes the separation of

corn parts. The endosperm is milled to various sizes for production

of grits, meal or flour.

Bran is removed from the germ by aspiration and can be used as

a fiber ingredient in human foods. The oil is removed from dry-milled

corn germ by expelling or hexane extraction. Defatted germ meal,

one of the primary by-products of dry-milling (43 million bu/yr),

is often combined with bran, fines from milled endosperm and broken

corn kernels for sale as "hominy feed." Over two billion pounds of

animal feed was produced as a dry-milling by-product in 1973 (Alexander,

1987).

Fractions of hominy feed have been investigated for use in human

foods. Dry-milled corn bran has high water absorption properties

and a high fiber content. Corn bran is 70% hemicellulose, 23% cellu-

lose and 0.1% lignin on a dry weight basis (Watson, 1987).

Dry-milled germ

Dry-milled corn germ meal has been found to contain 25.3%

protein, 24.7% starch, 13.8% sugars, 0.5% ash, 0.5% fat, 11.7%

pentosans and 4.2% crude fiber (Inglett and Blessin, 1979). Germ

meal has been added to baked products, such as muffins, breads and

pasta and to beef patties, as a source of high-quality protein

and a good source cf dietary fiber (Blessin et al., 1972, 1973; Tsen

et al., 1974; Lucisano et al., 1984).

Blessin et al. (1972) reported that dry-milled corn germ flour could be added as a nutrient supplement to beef patties at a level of 10%. Corn germ was roll-cooked for use in a corn, soy and milk (CSM) formulation as a nutritious food supplement (Gardner et al., 1971). The water-binding capacity of germ proteins exceeded the absorption ability of whey protein concentrate and soy (Promine D) (Hermannson, 1977).

Corn germ (19.4% protein) was added as an ingredient (4%) in sausage batter (Lin and Zayas, 1987). By binding water and fat, the corn germ increased stability of the batter and the yield of the finished product.

Wet-milling

The major product of the corn wet-milling industry is starch. Modified starch, corn oil, nutritive sweeteners and feed by-products also are produced.

The first step of corn wet-milling is steeping the corn in sulfur dioxide (0.12-0.2%, 52-55°C, 22-50 hr) to soften the kernels and facilitate separation of bran, germ and endosperm. As steeping nears completion, the sulfur dioxide content drops and lactic acid accumulates to 16-20% (dry basis) due to bacterial growth.

The steep water, containing solubles leached out of the corn, is evaporated to 40-50% solids, mixed with corn fiber, dried and sold as "corn gluten feed." Corn gluten feed is approximately 21% protein (May, 1987).

The steeped corn slurry is milled coarsely to break up the kernel. The germ is separated from the starch in flotation tanks or by hydro-cyclone separators, then washed and dried to 90% solids.

The starch slurry is screened and milled to separate fiber from the starch and the protein, referred to as corn gluten. The starch is washed, centrifuged and dried. The fiber is mixed with evaporated steep water, dried and sold as corn gluten feed. Most gluten feed is pelleted for improved handling characteristics. The protein is separated from starch by centrifugation, concentrated to 88% solids and 12% moisture and sold as animal feed.

Corn gluten meal has been found to contain 60% protein, 20-25% carbohydrate, 3.5% crude fiber, 1-2% ash and 15-18% fat (Buck et al., 1987). Gluten protein can be further purified by separating the major corn protein, zein. Zein is used primarily as a binder in formulations for coating tablets, nuts and confections (Reiners et al., 1973).

The germ is further processed by pressure and heat to rupture oil cells and facilitate the removal of oil. The germs are softened by heating to 120°C and squeezed by an oil-expeller to .13 to 20% oil. Germ is then flaked with rolls and solvent-extracted with hexane to decrease the oil content of the germ to 1.5% (May, 1987). The fraction remaining after oil is removed is referred to as wet-milled corn germ meal. Over 250 million bushels of wet-milled germ meal is produced yearly in the U.S. (May, 1987).

Wet-milled germ

Wet-milled germ meal was found to contain 30% protein, 18% starch, 26% pentosans, 2% ash, 0.7% fat and 12% cellulose (Nielsen et al., 1979). Wet-milled germ meal often is combined with corn gluten feed as a vitamin carrier because of its ability to absorb oils and water (May, 1987). Nielsen et al. (1979) reported that wet-milled germ flour had a high water hydration capacity (6.9 to 8.0 g/g meal, AACC method 56-20).

Corn Proteins

Endosperm

Whole corn contains approximately 8-10% protein. The endosperm contains 78% of the total kernel protein; 60% of the endosperm protein is zein and 26% is glutelin (Wilson, 1987). Zein is classified as a prolamin due to its solubility in alcohol. Endosperm proteins remaining after the extraction of salt- and alcohol-soluble proteins are considered glutelins. Glutelins are extracted with alkali or reducing agents.

Germ

Whole unprocessed germ (10 to 12 percent of the corn kernel) is 18% protein, 33% fat, 8% starch, 10.5% ash and 10.8% sugar (Watson, 1987). Germ proteins are classified as albumins and globulins due to their solubility in water and saline solutions, respectively. Seventy-three percent of germ proteins are salt-soluble proteins (albumins, globulins and nonprotein nitrogen) (Wilson, 1987).

Zein is low in lysine and is the limiting protein in corn. Germ proteins are nutritionally more complete than endosperm proteins. The relative protein value of corn germ flour (20% protein, 2% fat) was 0.62 and reported to be a possible source of valuable protein for human diets (Canolty et al., 1977). The protein efficiency ratio of corn germ protein was reported to be 2.04-2.56 (Tsen, 1980). Corn germ is low in isoleucine, methionine and cysteine, but contains adequate lysine (5.9%).

The heat applied during the oil-extraction process causes changes in the proteins of corn germ meals. Protein quality was markedly reduced in hominy feed when the germ was subjected to expeller processing to remove oil (Wall et al., 1971). Protein quality was better retained by solvent extraction. Flavor, appearance and stability was better in solvent-extracted germ than in expeller-processed germ. High temperatures or defatting solvents may affect the solubility of some albumins or globulins so that they are extracted in one of the glutelin fractions (Wilson, 1987).

Sulfur dioxide of wet-milling also causes breakage of disulfide bonds, particularly in glutelins (Neumann and Wall, 1984). Barbieri and Casiraghi (1983) reported that wet-milled corn germ was unsuitable for food use due to degradation of organoleptic and nutritional quality following the steeping treatment. Dry-milled corn germ was reported to be a valuable source of good quality protein and suitable for use in breads and extruded snacks (Peri et al., 1983).

Although the nutritional and functional properties of corn

proteins are comparable to other cereal flours, few uses in food have been developed.

Objectives

The objectives of this study were to investigate the cholesterol content of pork and the functionality of corn processing secondary products in meat systems of various fat percentages and to determine the components in corn responsible for any functional characteristics that are observed.

Explanation of Dissertation Format

The dissertation is divided into five parts, each a complete paper for publication in a scientific journal. Part I examines the cholesterol content in ground pork of four fat levels. Parts II and III examine the chemical, physical and sensory characteristics of ground pork with various fat levels and corn milling secondary products. The characteristics of pork frankfurters with three fat levels and corn germ flours were examined in Part IV. Part V examines the chemical and functional characteristics of dry-milled corn germ meal.

PART I.

CHOLESTEROL CONTENT AND SENSORY ANALYSIS OF GROUND PORK

AS INFLUENCED BY FAT LEVEL AND HEATING

CHOLESTEROL CONTENT AND SENSORY ANALYSIS OF GROUND PORK

AS INFLUENCED BY FAT LEVEL AND HEATING

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Running Title: Cholesterol Content of Ground Pork

ABSTRACT

Eight treatment combinations for the formulation and heating of fresh ground pork were investigated: four raw fat levels (4, 9, 18, 23%) and two internal end point temperatures (71° and 77°C). In the raw state, ground pork containing 4 or 9% fat contained less cholesterol, more moisture and was judged to be more red than samples containing 18 or 23% fat. Tenderness, juiciness and amount of mouthcoating increased as fat level in the cooked patties increased. Internal end point temperature (71° or 77°C) did not affect sensory scores of cooked pork patties. Cooked patty cholesterol content (wet weight) did not differ among the four fat levels. High-fat ground pork retained less cholesterol than low-fat ground pork.

INTRODUCTION

Consumers have been advised to lower their dietary fat and
cholesterol intake as a possible way of lowering blood cholesterol
levels (DeBakey et al., 1986). Meats which contain high fat
levels have been excluded from diets sanctioned by the American Heart
Association (1985). Ground meats (beef and pork) traditionally con-
tain substantial amounts of fat (15-30%). As a result of consumer
demand, several grocery operations have begun to offer customers
ground beef with a fat content below 10%.

Although the cholesterol content of numerous pork products has
been investigated, little attention has been focused on the cholesterol
content of ground pork containing various fat levels. Fresh pork
sausage containing 40.29% fat contained 68 mg cholesterol per 100 g
of sample in the raw state and 31.16% fat and 83 mg cholesterol per
100 g of cooked sample (USDA, 1980). The cholesterol content of a
variety of raw pork muscles ranged from 56.3 to 72.6 mg/100 g wet
weight (Tu et al., 1967).

Consumers may have a misconception that high-fat meats contain
high cholesterol levels even when cooked. Researchers have found
similar cholesterol levels in cooked ground beef containing a wide
range of fat contents. Kregel et al. (1986) and Rhee and Smith (1983)
both worked with ground beef that ranged in fat content from 8 to
28.5%. In the raw state, ground beef with 27 to 28.5% fat contained
more cholesterol than raw ground beef containing 8 to 9.5% fat.
However, cooked samples were similar in cholesterol concentration over

all fat levels studied. High-fat ground beef (28.5%) lost appreciable amounts of cholesterol to the cooking drip during broiling (Kregel et al., 1986).

Palatability characteristics of ground meats are affected by the fat level. Generally, as fat level decreases in ground beef, tenderness and juiciness sensory scores decrease (Kregel et al., 1986; Berry and Leddy, 1984; Cross et al., 1980). Using ground pork, Keeton (1983) found an increase in sensory juiciness scores as fat levels increased from 20 to 30%. However, no differences were found in patty tenderness scores among fat levels.

There is limited research investigating the cholesterol and sensory attributes of heated ground pork with fat levels below 20%. Therefore, this study was designed to evaluate effects of fat level and internal end point heating temperature on the cooking losses, cholesterol and moisture content, and sensory characteristics of ground pork.

MATERIALS AND METHODS

Eight treatment combinations for fat level and heating of fresh
ground pork were studied: four fat levels (4, 9, 18, 23%) and two
cooking end point temperatures (71° and 77°C). A randomized
complete-block design with four replications of each treatment was
used.

Lean pork and fat from the same carcasses were mixed and ground
twice (0.31 cm plate) to formulate four fat levels at the Iowa State
University Meat Laboratory. The final mixtures had mean fat contents
of 4.01, 9.34, 18.04 and 23.27% as determined by the Folch procedure
(Folch et al., 1957). The pork was vacuum-packaged in 4.4 kg packages,
mechanically frozen and held 27 to 31 days at -18°C. Before each
replication, one 4.4 kg package of each fat level was thawed 48 hr
at 4°C.

Three 100 ± 0.8 g patties (9 cm x 1.5 cm) per treatment were
formed in a manual patty maker and placed on a rack over foil in a
round broiler pan (25.5 cm x 4.5 cm). The patties were placed 18 cm
from the heat source and broiled in a Hotpoint oven (Model 20RJK11)
preheated to 175°C. Patties were turned after 4 min and removed from
the oven when an internal temperature of 71° or 77°C was reached as
determined by a thermocouple attached to an Omega HH-99K Thermocouple
Digital Thermometer. The drip of three cooked patties was collected
in glass jars and frozen at -80°C.

One cooked and one raw patty of each treatment were chopped,
packaged in 1.76 mil plastic bags and foil, and frozen at -80°C (no

longer than 18 days).

Total cooking loss was determined by combining drip and evaporative loss (Campbell et al., 1979).

Sensory Analysis

Sensory evaluation of raw and cooked pork patties was completed by an 8- to 10-member sensory panel. Training consisted of presenting the treatment extremes in two preliminary evaluation sessions. Two cooked patties of each treatment were cooled to room temperature. Each patty was cut into 10 identical wedges, and two samples were placed into randomly coded (3-digit numbers) individual styrofoam cups with lids. Cups were placed into a 60°C oven for approximately 20 min to warm the samples. Panelists received samples from all treatments and were instructed to sample randomly. Testing was conducted at individual tables.

A 17-cm line scale was used to evaluate surface color, juiciness, tenderness, pork flavor intensity and mouthcoating of the cooked patties, according to the American Meat Science Association (1983). Extremely tough, extremely dry, very light brown surface color, no pork flavor, and no mouthcoating were scored 0; extremely tender, extremely juicy, very dark brown surface color, extremely intense pork flavor, and extremely abundant mouthcoating were scored 17. One raw patty of each fat level was similarly evaluated for color and amount of fat. Grey-pink color and extremely lean fat amount were scored 0, and pink-red color and extremely abundant fat amount were scored 17 on

a 17-cm scale. Panel members were selected from students, faculty and staff of the Food and Nutrition Department, Iowa State University, who scored samples consistently for all attributes during training.

Chemical Analysis

Samples were thawed approximately 24 hr at 4°C. Moisture contents of the raw and cooked samples and cooking drip (10 g) were determined by drying meat for approximately 2 hr at 130°C in a Brabender Semiautomatic Moisture Tester (Type SAS, No. 951).

Total lipid contents of raw and cooked patties and the cooking drip were determined by a modified Folch procedure (Folch et al., 1957). Lipid content of the extract was determined gravimetrically on a 5 ml aliquot that was freed of solvent under nitrogen.

Cholesterol contents of meat samples and cooking drip were determined by the method of Searcy and Bergquist (1960) with the following modifications. A 5 ml aliquot of lipid extract prepared by the Folch procedure was evaporated to dryness in a 60°C water bath under a stream of nitrogen. Lipids were saponified with 15 ml alcoholic potassium hydroxide (15% KOH in 90% ethanol) for 10 min in a 88°C shaker water bath. After cooling, 5 ml distilled water were added, and the unsaponifiable material was extracted with 10 ml hexane. A 5 ml aliquot of hexane extract was dried under nitrogen, and cholesterol determined colorimetrically using $FeSO_4$-acetic acid and concentrated H_2SO_4 as color developing agents. A standard curve was constructed by carrying specific amounts of purified cholesterol

through saponification, extraction with hexane, and color development steps. The cholesterol content of patties was measured on a wet weight basis and calculated on a dry weight basis. The amount of cholesterol in the cooking drip was determined on the composite drip of three cooked patties.

Statistical Analysis

Analysis of variance (SAS, 1982) was used (general linear model, PROC GLM) to test the effects of replication (4), fat level (4) and internal end point temperature (2). When a significant interaction between fat level and end point temperature resulted, interaction means were reported. Main effect means were reported when no significant interactions were found. When F-values were significant, least significant differences (LSD) at a 5% level of probability were calculated.

RESULTS AND DISCUSSION

Fat, moisture and cholesterol contents and sensory characteristics of raw ground pork are presented (Table 1). Moisture content was expected to decrease as fat content increased in the raw samples. Ground pork containing 4 or 9% fat had higher moisture contents than pork patties containing 18 or 23% fat. Keeton (1983) also noted a decrease in moisture content of raw ground pork as the fat level increased from 20 to 30%.

Cholesterol content (wet-weight) was greater in raw pork patties that contained 18 or 23% fat than in pork patties that contained the two lower fat levels. Similar trends in ground beef cholesterol have been found when comparing low to high fat levels (Kregel et al., 1986; Rhee and Smith, 1983). Ground pork containing the highest fat level (23%) contained the lowest dry-weight cholesterol values. This may have resulted from lower moisture contents observed in these patties.

Generally, red-pink color intensity scores for the raw pork patties increased as the perception of amount of fat in the patties decreased. Keeton (1983) indicated that pork patties containing 20 or 23% fat tended to have a leaner appearance when compared with pork patties containing 26 or 30% fat.

Cooking loss and composition of cooked pork patties are presented (Table 2). Cooking loss among fat levels did not differ. Cross et al. (1980) reported no difference in cooking loss of ground beef ranging in fat content from 16 to 28%. Contrary results were found by Kregel

et al. (1986) who observed higher total cooking loss from 28.5%-fat ground beef when compared with ground beef containing 9.5 or 21.5% fat. Following the same trend as the raw patties, moisture content of the cooked patties decreased as fat content increased.

Cholesterol contents (wet-weight basis) of the cooked samples were not different among the four fat levels. Kregel et al. (1986) and Rhee and Smith (1983) also found that cholesterol contents of cooked ground beef patties did not vary with fat levels. Dry weight-based cholesterol content was lowest in patties containing the least moisture. Patties containing 4 or 9% fat retained more cholesterol after heating than patties containing 18 or 23% fat. Similar cholesterol retention patterns have been found for ground beef (Kregel et al., 1986; Rhee and Smith, 1983).

Heating pork patties to the higher internal end point temperature (77°C) increased total cooking loss (Table 2). Ground beef patties heated to 77°C also had greater total cooking losses than patties heated to 71°C (Kregel et al., 1986). Fat, moisture and wet and dry weight-based cholesterol contents and cholesterol retention of the pork patties did not differ between internal end point temperatures. Cholesterol has been found to be concentrated in other types of meat systems as internal end point temperature is increased (Prusa and Hughes, 1986; Kregel et al., 1986; Rhee et al., 1982).

Moisture, fat and cholesterol contents of the cooking drip collected from pork patties during cooking are presented (Table 3). As the fat level of the raw patties increased, cooking drip moisture content decreased and cooking drip lipid content increased. These

results agree with the findings of Kregel et al. (1986) and Cross

et al. (1980), who indicated that cooking loss in low-fat ground

beef patties was due primarily to moisture loss and that cooking loss

in high-fat patties was due primarily to fat loss. Generally,

percentage cholesterol in the cooking drip as compared with total

raw patty cholesterol increased as fat level of the raw patty in-

creased. In beef longissimus steaks, more cholesterol was found in

the drip from samples heated to 75°C when compared with the drip

from samples heated to 60°C (Rhee et al., 1982).

Sensory scores for cooked pork patties are presented in Table 4.

Cooked pork patties containing the two higher levels of fat received

higher scores for tenderness, juiciness, surface color and amount of

mouthcoating. Keeton (1983) found higher juiciness scores for ground

pork with fat contents of 26 and 30% than for ground pork with 20 and

23% fat. No differences in tenderness, softness, crumbliness,

elasticity or pork flavor were noted by Keeton (1983), which may be

due to the relatively narrow (10%) range of fat levels. Pork flavor

intensity scores were not different among pork patties with 9, 18 or

23% fat, but patties with 4% fat were scored lower in pork flavor.

Internal end point temperature (71° or 77°C) did not affect sensory

scores of cooked pork patties.

CONCLUSIONS

In the raw state, low-fat ground pork contained less cholesterol than high-fat ground pork. However, in the cooked state, cholesterol contents were similar among fat levels studied. Cholesterol content of the cooking drip was directly related to cholesterol loss from patties during heating. Tenderness, juiciness, cooked surface color and amount of mouthcoating increased as fat level of cooked patties increased.

REFERENCES CITED

American Heart Association. 1985. An eating plan for healthy Americans. American Heart Association, Dallas, TX. 37 pp.

American Meat Science Association. 1983. Sensory evaluation of ground beef patties. Pages 223-228 in 36th Annual Reciprocal Meat Conference of the Am. Meat Sci. Assn., Chicago, IL.

Berry, B. W., and Leddy, K. F. 1984. Effects of fat level and cooking method on sensory and textural properties of ground beef patties. J. Food Sci. 49:870-875.

Campbell, A. M., Penfield, M. P., and Griswold, R. M. 1979. The Experimental Study of Food. Houghton Mifflin Co., Boston, MA. 513 pp.

Cross, H. R., Berry, B. W., and Wells, L. H. 1980. Effects of fat level and source on the chemical, sensory and cooking properties of ground beef patties. J. Food Sci. 45:791-793.

DeBakey, M. E., Gotto, A. M., Scott, L. W., and Foreyt, J. P. 1986. Diet, nutrition, and heart disease. J. Am. Diet. Assoc. 86: 729-731.

Folch, J., Lees, M., and Stanley, G. H. S. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497-509.

Keeton, J. 1983. Effects of fat and NaCl/phosphate levels on the chemical and sensory properties of pork patties. J. Food Sci. 48:878-881.

Kregel, K. K., Prusa, K. J., and Hughes, K. V. 1986. Cholesterol content and sensory analysis of ground beef as influenced by fat level, heating and storage. J. Food Sci. 51:1162-1165.

Prusa, K. J., and Hughes, K. V. 1986. Quality characteristics, cholesterol, and sodium content of turkey as affected by conventional, convection and microwave heating. Poult. Sci. 65: 940-948.

Rhee, K. S., Dutson, T. R., Smith, G. C., Hostetler, R. L., and Reiser, R. 1982. Cholesterol content of raw and cooked beef longissimus muscles with different degrees of marbling. J. Food Sci. 47: 716-719.

Rhee, K. S., and Smith, G. C. 1983. Effect of cooking on cholesterol content of patties containing different amounts of beef, textured soy protein and fat. J. Food Sci. 48:268-269.

Searcy, R. L., and Bergquist, L. M. 1960. A new color reaction for the quantitation of serum cholesterol. Clin. Chim. Acta 5: 192-199.

Statistical Analysis System. 1982. SAS User's Guide: Statistics. SAS Inst., Inc., Raleigh, NC, 584 pp.

Tu, C., Powrie, W. D., and Fennema, O. 1967. Free and esterified cholesterol content of animal muscles and meat products. J. Food Sci. 32:30-34.

USDA. 1980. Composition of foods. U.S. Dept. Agric., Agriculture Handbook 8-7. Washington, DC. 92 pp.

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ACKNOWLEDGMENTS

Table 1. Moisture, fat, cholesterol and sensory scores of raw pork patties[a,b]

	Fat level (%)			
	4	9	18	23
Moisture (%)	73.19[c]	71.40[c]	64.26[b]	61.23[d]
Fat (%)	4.01[c]	9.34[d]	18.04[e]	23.27[f]
Cholesterol (wet weight, mg/100 g)	55.93[c]	57.49[c]	69.59[d]	65.86[d]
Cholesterol (dry weight, mg/100 g)	209.38[c]	201.56[c]	194.81[c]	170.55[d]
Color[a]	11.55[c]	11.73[c]	7.98[d]	5.95[e]
Amount of fat[a]	1.98[c]	5.93[d]	11.05[e]	14.70[f]

[a]0, grey-pink color, extremely lean fat amount to 17, pink-red color, extremely abundant fat amount.

[b]Mean of four replications.

[c-f]Means in a row not followed by a common superscript are significantly different (p < 0.01 for wet and dry weight cholesterol; p < 0.001 for all other measurements).

Table 2. Cooking loss, moisture, fat and cholesterol content of cooked pork patties[a,b]

	Fat (%)[c]				Internal temperature		
	4	9	18	23	71°C		77°C
Cooking loss (%)	31.94[c]	32.63[c]	31.73[c]	30.46[c]	30.56	***	32.81
Moisture (%)	64.99[c]	59.14[d]	52.02[e]	48.01[f]	56.21	NS	55.87
Fat (%)	3.89[c]	11.50[d]	20.75[e]	25.86[f]	15.52	NS	15.48
Cholesterol (wet weight, mg/100 g)	91.88[c]	95.58[c]	100.87[c]	92.99[c]	92.94	NS	97.72
Cholesterol (dry weight, mg/100 g)	262.56[c]	233.84[d]	210.37[e]	179.04[f]	216.81	NS	226.10
Cholesterol retention (%)	111.78[c]	112.70[c]	98.92[d]	98.15[d]	104.48	NS	106.29

[a]Means of four replications.

[b]No significant interaction between fat content and internal temperature.

[c-f]For fat level, numbers within a row not followed by a common superscript are significantly different (p < 0.001 for fat, moisture and dry weight cholesterol; p < 0.01 for cholesterol retention).

NS = not significant.

***p < 0.001.

Table 3. Moisture, fat and cholesterol contents (%) of cook drip from heated pork patties[a]

	Fat level				Internal temperature		
	4	9	18	23	71°C		77°C
Moisture	83.43[b]	83.64[b]	75.60[c]	41.73[d]	72.19	NS	70.01
Fat	0.35[b]	2.09[b]	18.87[c]	44.20[d]	15.45	NS	17.26
% drip cholesterol compared to total raw patty cholesterol	2.24[b]	2.29[b]	4.77[c]	7.09[c]	3.69	NS	4.51

[a]Means of four replications.

[b-d]Numbers within a measurement not followed by a common superscript are significantly different ($p < 0.001$).

NS = not significant.

Table 4. Sensory scores[a] for cooked pork patties[b]

	Fat level				Internal temperature		
	4	9	18	23	71°C		77°C
Tenderness	5.69[c]	8.98[d]	11.63[e]	11.59[e]	9.48	NS	9.46
Juiciness	2.06[c]	7.28[d]	10.58[e]	11.46[e]	7.98	NS	7.71
Surface color	2.36[c]	8.56[d]	11.28[e]	11.24[e]	7.94	NS	8.78
Pork flavor	8.79[c]	9.90[d]	9.75[d]	10.35[d]	9.81	NS	9.59
Mouthcoating	4.30[c]	8.71[d]	10.06[e]	10.60[e]	8.25	NS	8.59

[a]0, extremely tough, extremely dry, very light brown surface color, no pork flavor, no mouthcoating to 17, extremely tender, extremely juicy, very dark brown surface color, extremely intense pork flavor, extremely abundant mouthcoating.

[b]Means of four replications.

[c-f]Means in a row not followed by a common superscript are significantly different ($p < 0.01$ for pork flavor; $p < 0.001$ for all other attributes).

NS = not significant.

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PART II.

THE ADDITION OF CORN MILLING PRODUCTS TO GROUND PORK OF

VARIOUS FAT PERCENTAGES.

STUDY 1. DRY- AND WET-MILLED CORN GERM MEALS

THE ADDITION OF CORN MILLING PRODUCTS TO GROUND PORK OF

VARIOUS FAT PERCENTAGES.

STUDY 1. DRY- AND WET-MILLED CORN GERM MEALS

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Running Title: Corn germ meals in ground pork

ABSTRACT

Dry- and wet-milled corn germ flour at levels of 0, 2.5 and 5%
were added to ground pork of three fat percentages. Raw patties were
analyzed for fat, moisture and protein contents and color. Selected
patties, broiled to 77°C, were evaluated for proximate composition,
total cooking loss, color and Instron compression. Dry- and wet-
milled germ flour addition at the 5% level decreased cooking losses,
9 and 7.5%, respectively, when compared to control patties. Instron
compression values decreased as the amount of dry-milled germ flour
increased in the patties. The yellowness (b-value) of the interior
of cooked patties was increased by the addition of wet-milled corn
germ flour, but the lightness (L-value) was decreased.

INTRODUCTION

Corn wet- and dry-milling industries in the United States produce huge quantities of secondary protein-containing by-products each year. About 30% of the one billion bushels of corn processed for wet- and dry-milling, alcohol, tortillas and snack foods are sold inexpensively as feedstuffs (Alexander, 1987; May, 1987; Rooney and Serna-Saldivar, 1987).

Dry-milled corn germ meal is the primary by-product of the production of grits, meal and flour. Oil is removed from the germ, leaving a meal that is a good source of high-quality protein and dietary fiber (Blessin et al., 1972, 1973). A sample of defatted dry-milled germ meal was found to contain 25.3% protein, 13.8% sugars, 11.7% pentosans, 24.7% starch, 4.2% crude fiber, 0.5% ash and 0.5% fat (Inglett and Blessin, 1979).

Germ meal is a by-product of the corn wet-milling industry. Corn kernels are steeped in sulfur dioxide solutions for separation of bran, germ and endosperm. After separation, the germ is processed for recovery of corn oil. The defatted meal was found to contain 30% protein, 18% starch, 26% pentosans, 12% cellulose, 2% ash and 0.7% fat (Nielsen et al., 1979).

Dry-milled corn germ has been added to cookies, muffins, beef patties (Blessin et al., 1972, 1973), bread (Tsen et al., 1974) and pasta (Lucisana et al., 1984) for protein fortification, fiber addition and water- or fat-binding. Nielsen et al. (1973), pre-pared a protein isolate from dry-milled germ meal for potential

fortification of foods. The corn germ protein isolate (74% protein)

had potential for many food uses due to its mild flavor, solubility at

neutral and low pH and ability to stabilize an oil-in-water emulsion.

Peri et al. (1983) prepared an expanded nutrient snack by extrusion

cooking of an 85% corn germ flour/15% milk protein mixture. The

expanded product was mild-flavored and crisp in texture with a

protein efficiency ratio of 2.5.

The water-binding capacity of wet-milled corn germ meal was found

to be quite high, 6.9 to 8.0 g/g (AACC method 56-20) (Nielsen et al.,

1979). The water-binding capacity of dry-milled corn germ meal was

4.2 g/g. Water-binding capacity is an important function of protein in

meat rolls and comminuted meats. Phillips and Sternberg (1979) re-

ported that the water- and fat-binding capacity of a corn germ

protein concentrate was similar to the absorption ability of soy

protein concentrate.

Nonfat dry milk solids, sodium caseinate, soy proteins and oil-

seed and cereal flours have been utilized as fillers, binders and

extenders in cooked comminuted meat products to reduce cook shrink

and formulation costs and to improve emulsifying capacity, emulsion

stability, water-binding potential, nutritive value and slicing charac-

teristics (Mittal and Usborne, 1985). However, there is limited

research involving the use of corn flours in meats. The addition of

corn germ flours to meat may improve water- and fat-binding and improve

the quality of products such as low fat meats.

The objective of this study was to determine the usefulness of

dry-milled corn germ meal (DMG) and wet-milled corn germ meal (WMG)
in a ground meat system.

MATERIALS AND METHODS

Dry-milled corn germ meal (obtained from Illinois Cereal Mill,
Inc., Paris, IL) and wet-milled corn germ meal (obtained from CPC
International, Argo, IL) were ground to flours (35 mesh) in a food
mill. Germ flour at levels of 0, 2.5 and 5% was mixed with 2.2 kg
portions of ground pork obtained from a commercial source in a Hobart
Kitchen Aid mixer (Model K5-A) for 30 sec at speed 2. Three fat levels
of ground pork were used: 8.1, 19.5 and 31.8% fat with dry-milled
corn germ flour and 9.1, 15.3 and 18.3% fat with wet-milled corn germ
flour. Four replications of the 9 treatment combinations (3 fat
levels and 3 corn levels) for each corn germ flour were analyzed in a
randomized complete block design.

Each corn-pork mixture was vacuum-packaged in 2.2 kg packages,
frozen and held 8 to 34 days at -18°C until heating. For each replica-
tion, one 2.2 kg package of each corn-pork treatment was thawed 48 hr
at 4°C.

Raw samples of each treatment were analyzed for color by using
a HunterLab LabScan spectrocolorimeter (LS-5100). Values of the
standard tile were X = 81.60, Y = 86.68 and Z = 91.18. Raw samples
were analyzed for moisture by using a Brabender Semiautomatic Moisture
Tester (Type SAS, No. 951), fat by a modified Folch procedure (Folch
et al., 1957) and protein by a modified Kjeldahl method (Hach et al.,
1985).

Three WMG or four DMG 100 ± 0.5 g patties per treatment were
formed in a manual patty maker (9 cm x 1.5 cm) and placed on a rack

over foil in a round broiler pan (25.5 cm x 4.5 cm). The patties
were placed 18 cm from the heat source and broiled in a Hotpoint oven
(Model 20RJK11) preheated to 175°C. Patties were turned after 5 min
of heating and removed from the oven when an internal temperature
of 77°C was reached as determined by a thermocouple attached to an
Omega Engineering, Inc. (Model 115KC) thermometer. Each treatment
was broiled in random order.

Cooking losses were determined by combining drip and evaporative
losses which were calculated by weight (Campbell et al., 1979). Weights
of raw meat (excluding corn) were used for cooking loss calculations.

One cooked patty of each treatment was chopped, packaged in a
1.76 mil plastic bag overwrapped with foil and frozen at -18°C until
protein, moisture and fat analyses.

Color measurement (L, a and b values) of one cooked patty of
each treatment was made following procedures for raw samples.
Cooked samples were wrapped in plastic film and the surface of the
patty cooked last was measured for external color. Patties were
halved horizontally and wrapped in plastic film for duplicate L, a and
b values of internal color.

Three cores (2.5 cm diameter) of one cooked patty per treatment
were analyzed with an Instron Universal Testing Machine (Model 1122)
using 80% compression with a 3.5 cm diameter compression anvil. A load
cell setting of 50 kg, a crosshead speed of 100 mm/min and chart speed
of 200 mm/min were used. Peak heights of two compressions per sample
core were measured in centimeters.

Chemical Analysis

Samples for chemical analyses were thawed approximately 24 hr at 4°C. Moisture contents of the raw and cooked samples were determined by drying 10 g of each corn-pork mixture for approximately 2 hr at 130°C in a Brabender Semiautomatic Moisture Tester (Type SAS, No. 951).

Total lipid contents of raw and cooked samples were determined by a modified Folch procedure (Folch et al., 1957). Lipid content of an extract was determined gravimetrically on a 5 ml aliquot that was freed of solvent.

Protein contents of the raw and cooked samples were determined by digesting a 10 g sample in 100 ml sulfuric acid/water (50/50, v/v) solution for 4 min. Protein content was determined on a 5 ml aliquot following the Hach procedure (Hach et al., 1985).

Statistical Analysis

Analysis of variance (SAS, 1982) was used (general linear model, PROC GLM) to test the effects of replication (4), fat level (3) and corn level (3) for dry- and wet-milled germ flour treatments. When a significant interaction between fat level and corn level resulted, interaction means were reported. Main effect means were reported when no significant interactions were found. When F-values were significant, least significant differences (LSD) at a 5% level of probability were calculated.

RESULTS AND DISCUSSION

Dry-Milled Corn Germ Flour

Effects of fat

The effects of fat level on the proximate composition and color of raw ground pork are presented (Table 1). The fat content was expected to range from 8 to 32% since fat level was a preset variable. The moisture and protein contents decreased as the fat level in the raw pork increased. In a similar study, ground pork with 4 or 9% fat had higher moisture contents than pork with 18 or 23% fat (Reitmeier and Prusa, 1987). A dilution of protein may have occurred in the 32% fat treatment. High fat ground meat products have been found to contain lower protein contents (USDA, 1980).

Lightness (L-value) and yellowness (b-value) of the raw pork increased as fat level increased. A higher level of fat (30%) in beef patties resulted in greater amounts of reflected light than in patties with 15 or 25% fat (Judge et al., 1974). The increased amount of fat was probably the factor causing the difference in color.

The effects of fat level on cooked ground pork patties with DMG flour are presented (Table 1). The cooked fat contents were 9.3, 16.0 and 22.6%. As fat increased, moisture and protein contents decreased. Moisture content has been found to be inversely related to fat content in other cooked ground meat systems (Kregel et al., 1986).

Force required for 80% compression of cooked pork samples decreased as fat level increased. Huffman and Powell (1970) reported

that less shear force was required for beef patties containing 35%

fat than for patties with 15 or 25% fat.

External color values were not different among fat levels (data

not shown). Internal lightness (L-value) and yellowness (b-value)

increased and redness (a-value) decreased as fat content increased.

Effects of corn

The addition of DMG flour decreased the moisture content of

raw pork (Table 2) due to the addition of 2.5 or 5% dry material.

The incorporation of DMG flour into raw pork also decreased redness

(a-value). DMG flour addition did not influence fat or protein con-

tents of L- or b-values.

Cooked pork patties containing DMG flour contained less fat

than control patties (Table 2). Blessin et al. (1973) also noted a

decrease in fat content of broiled meat with added dry-milled corn germ

flour. This was attributed to the greater yield rather than an actual

loss of fat. Cooking loss decreased from 36.1% in the control treat-

ments to 27.1% with 5% DMG flour addition. Yield was increased from

70 to 77% when 10% defatted dry-milled germ flour was added to ground

beef patties (Blessin et al., 1973).

The first peak height from Instron compression (80%) of cooked

samples decreased with the addition of DMG flour. Beef patties with

2% soy had higher sensory tenderness scores than those without soy

(Huffman and Powell, 1970). However, in related work, beef patties

with 10% dry-milled corn germ flour were firmer and browned faster

than beef patties (20% fat) without corn (Blessin et al., 1972).

Other attributes (moisture, protein and color) of cooked pork patties were not influenced by DMG flour addition.

Wet-Milled Corn Germ Flour

Effects of fat

The effects of fat level on the proximate composition and color of raw pork are presented in Table 3. As expected, the moisture content decreased as fat level increased. Protein content was not influenced by fat level probably because of the narrow range of fat contents selected in the study. Lightness (L-value) and yellowness (b-value) of raw pork increased as fat level increased, but redness (a-value) was not affected.

Fat contents were 11.4, 18.3 and 20.4% in cooked patties with WMG flour (Table 3). The moisture and protein contents decreased as fat level increased. Cooking loss was not affected by fat level. Reitmeier and Prusa (1987) found that cooking losses did not differ among broiled pork patties containing 4, 9, 18 or 23% fat. Cross et al. (1980) also reported no difference in cooking loss of ground beef ranging in fat content from 16 to 28%.

Instron compression values decreased as fat level increased in cooked pork with WMG flour. External redness (a-value) and internal lightness (L-value) increased as fat level increased.

Effects of corn

The addition of WMG flour decreased the moisture content of raw ground pork (Table 4). WMG flour in pork decreased redness (a-value)

and increased yellowness (b-value). Fat and protein contents and lightness (L-value) of cooked patties were not influenced by WMG flour addition.

Fat and moisture contents of cooked ground pork patties were not influenced by WMG flour addition, but protein content decreased as WMG flour amount increased (Table 4). Cooking loss decreased from 31.2% with 0% WMG to 23.7% with 5% WMG.

WMG flour addition did not influence Instron compression values of the cooked patties. The external surface was more red (a-value) and yellow (b-value) and internal color was more yellow (b-value) with the addition of WMG flour. Internal lightness (L-value) decreased.

The internal redness (a-value) of cooked ground pork was influenced by corn addition (Table 5). At 9% fat, redness decreased with WMG flour addition. No differences were observed among corn levels at the 15% fat level. At 18% fat, the treatment with 2.5% WMG flour had higher redness (a-value) than the C and 5% WMG flour treatments.

CONCLUSIONS

Dry- and wet-milled corn germ flours were effective in increasing yield in broiled pork patties. DMG flour increased the tenderness, but did not affect the color of cooked pork patties. Addition of the WMG flour to ground pork did not influence Instron compression values, but did change both external and internal color of cooked patties. Both dry- and wet-milled corn germ flours have potential for use in meat systems.

REFERENCES CITED

Alexander, R. J. 1987. Corn dry milling: Processes, products, and applications. Pages 351-376 in Watson, S. A., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem., St. Paul, MN.

Blessin, C. W., Garcia, W. J., Deatherage, W. L., Cavins, J. F., and Inglett, G. E. 1973. Composition of three food products containing defatted corn germ flour. J. Food Sci. 38:602-606.

Blessin, C. W., Inglett, G. E., Garcia, W. J., and Deatherage, W. L. 1972. Defatted germ flour — Food ingredient from corn. Food Product Devel. 5:34-35.

Campbell, A. M., Penfield, M. P., and Griswold, R. M. 1979. The Experimental Study of Food. Houghton Mifflin Co., Boston, MA. 513 pp.

Cross, H. R., Berry, B. W., and Wells, L. H. 1980. Effects of fat level and source on the chemical, sensory and cooking properties of ground beef patties. J. Food Sci. 45:791-793.

Folch, J., Lees, M., and Stanley, G. H. S. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497-509.

Hach, C. C., Brayton, S. C., and Kopelove, A. B. 1985. A powerful Kjeldahl nitrogen method using peroxymonosulfuric acid. J. Agric. Food Chem. 33:1117-1123.

Huffman, D. L., and Powell, W. E. 1970. Fat content and soya level effect on tenderness of ground beef patties. Food Technol. 24:1418-1419.

Inglett, G. E., and Blessin, C. W. 1979. Food applications of corn germ protein products. J. Am. Oil Chemists' Soc. 56: 479-481.

Judge, M. D., Haugh, C. G., Zachariah, G. L., Parmelee, C. E., and Pyle. R. L. 1974. Soya additives in beef patties. J. Food Sci. 39: 137-139.

Kregel, K. K., Prusa, K. J., and Hughes, K. V. 1986. Cholesterol content and sensory analysis of ground beef as influenced by fat level, heating and storage. J. Food Sci. 51:1162-1165.

Lucisano, M., Casiraghi, E. M., and Barbieri, R. 1984. Use of defatted corn germ flour in pasta products. J. Food Sci. 49: 482-497.

May, J. B. 1987. Wet milling: Process and products. Pages 377-397 in Watson, S. A., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem., St. Paul, MN.

Mittal, G. S., and Usborne, W. R. 1985. Meat emulsion extenders. Food Technol. 39:121-130.

Nielsen, H. C., Inglett, G. E., Wall, J. S., and Donaldson, G. L. 1973. Corn germ protein isolate — Preliminary studies on preparation and properties. Cereal Chem. 50:435-443.

Nielsen, H. C., Wall, J. S., and Inglett, G. E. 1979. Flour containing protein and fiber made from wet-mill corn germ with potential food use. Cereal Chem. 56:144-146.

Peri, C., Barbieri, R., and Casiraghi, E. M. 1983. Physical, chemical and nutritional quality of extruded corn germ flour and milk protein blends. J. Fd. Technol. 18:43-52.

Phillips, R. D., and Sternberg, M. 1979. Corn protein concentrate: Functional and nutritional properties. J. Food Sci. 44:1152-1161.

Reitmeier, C. A., and Prusa, K. J. 1987. Cholesterol content and sensory analysis of ground pork as influenced by fat level and heating. J. Food Sci. 52:916-918.

Rooney, L. W., and Serna-Saldivar, S. O. 1987. Food uses of whole corn and dry-milled fractions. Pages 399-429 in Watson, S. A., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem., St. Paul, MN.

Statistical Analysis System. 1982. SAS User's Guide. Statistics. SAS Inst., Inc., Raleigh, NC. 584 pp.

Tsen, C. C., Mojibian, C. N., and Inglett, G. E. 1974. Defatted corn-germ flour as a nutrient fortifier in bread. Cereal Chem. 51:262-271.

U.S. Department of Agriculture. 1980. Composition of foods. Agric. Handbook No. 8-7. 92 pp.

ACKNOWLEDGMENTS

Table 1. Effects of fat on chemical and physical attributes of ground pork with dry-milled corn germ flour[a]

Attribute	Raw pork Fat level (%)			Cooked pork Fat level (%)		
	8	19	32	8	19	32
Fat (%)	8.1^b	19.5^c	31.8^d	9.3^b	16.0^c	22.6^d
Moisture (%)	72.4^b	61.5^c	53.3^d	63.2^b	56.6^c	51.7^d
Protein (%)	21.1^b	17.0^c	14.8^d	26.2^b	25.9^b	19.7^c
Color: L	43.6^b	47.1^c	50.9^d	49.9^b	54.0^c	56.2^d
a	9.1^b	8.8^b	8.7^b	5.9^b	4.3^c	4.2^c
b	9.7^b	10.2^c	11.1^d	10.1^b	10.5^{bc}	10.8^b
Cooking loss (%)	—	—	—	25.4^b	32.5^c	37.9^d
Instron (cm): Peak 1	—	—	—	8.9^b	7.1^c	5.9^c
Peak 2	—	—	—	6.3^b	4.8^c	4.2^c

[a]Means of four replications.

[b-d]Means in each row for raw and cooked treatments not followed by a common superscript are significantly different ($p < 0.001$ for raw pork attributes; $p < 0.05$ for b-value, $p < 0.01$ for a-value, $p < 0.001$ for other cooked pork attributes).

Table 2. Effects of corn on chemical and physical attributes of ground pork with dry-milled corn germ flour (DMG)[a]

Attribute	Raw pork DMG level (%)			Cooked pork DMG level (%)		
	0	2.5	5	0	2.5	5
Fat (%)	19.5[b]	20.3[b]	19.5[b]	16.6[b]	15.9[bc]	15.4[c]
Moisture (%)	63.1[b]	62.4[c]	61.7[d]	56.5[b]	57.6[b]	57.5[b]
Protein (%)	17.8[b]	17.5[b]	17.7[b]	25.6[b]	24.2[b]	22.0[b]
Color: L	46.7[b]	47.3[b]	47.6[b]	53.2[b]	54.4[b]	52.5[b]
a	9.6[b]	8.8[c]	8.2[c]	4.3[b]	4.9[b]	5.1[b]
b	10.1[b]	10.3[b]	10.5[b]	10.5[b]	10.3[b]	10.6[b]
Cooking loss (%)	—	—	—	36.1[b]	32.7[c]	27.1[d]
Instron (cm): Peak 1	—	—	—	8.0[b]	7.5[bc]	6.4[c]
Peak 2	—	—	—	5.6[b]	5.1[b]	4.6[b]

[a]Means of four replications.

[b-d]Means in each row for raw and cooked treatments not followed by a common superscript are significantly different (p < 0.01 for a-value, p < 0.001 for moisture of raw pork; p < 0.05 for moisture and Instron peak 1, p < 0.001 for cooking loss of cooked pork).

Table 3. Effects of fat on chemical and physical attributes of ground pork with wet-milled corn germ flour[a]

| | | Raw pork | | | Cooked pork | |
| | | Fat level (%) | | | Fat level (%) | |
Attribute		9	15	18	9	15	18
Fat (%)		9.1^b	15.3^c	18.3^d	11.4^b	18.3^c	20.4^d
Moisture (%)		72.5^b	66.1^c	63.3^d	61.2^b	56.1^c	55.3^c
Protein (%)		17.8^b	18.2^b	17.3^b	23.5^b	22.4^c	21.6^c
External color:	L	41.7^b	44.1^c	47.0^d	33.7^b	34.5^b	32.8^b
	a	6.3^b	6.9^b	6.5^b	4.4^b	4.4^b	4.9^c
	b	9.5^b	10.1^c	10.6^d	7.2^b	7.2^b	8.0^b
Internal color:	L	—	—	—	47.7^b	50.0^c	51.5^d
	b	—	—	—	10.2^b	10.3^b	10.6^b
Cooking loss (%)		—	—	—	26.4^b	26.5^b	28.6^b
Instron (cm):	Peak 1	—	—	—	10.6^b	7.4^c	6.8^c
	Peak 2	—	—	—	7.8^b	5.3^c	4.9^c

[a]Means of four replications.

[b-d]Means in each row for raw and cooked treatments not followed by a common superscript are significantly different ($p < 0.001$ for raw pork attributes; $p < 0.05$ for protein and external a-value, $p < 0.001$ for other cooked pork attributes).

Table 4. Effects of corn on chemical and physical attributes of ground pork with wet-milled corn germ flour (WMG)[a]

Attribute		Raw pork WMG level (%)			Cooked pork WMG level (%)		
		0	2.5	5	0	2.5	5
Fat (%)		14.6^b	13.5^b	14.6^b	16.1^b	16.7^b	17.3^b
Moisture (%)		68.5^b	67.5^c	65.9^d	58.6^b	57.9^b	56.2^b
Protein (%)		18.2^b	17.8^b	17.4^b	23.6^b	22.3^c	21.6^c
External color:	L	44.0^b	44.5^b	44.3^b	33.5^b	33.4^b	34.1^b
	a	7.9^b	6.2^c	5.5^c	4.3^b	4.7^c	4.7^c
	b	9.4^b	10.1^c	10.7^d	6.3^b	7.6^c	8.5^c
Internal color:	L	—	—	—	51.2^b	49.0^c	49.0^c
	b	—	—	—	10.0^b	10.5^c	10.6^c
Cooking loss (%)		—	—	—	31.2^b	26.7^c	23.7^d
Instron (cm):	Peak 1	—	—	—	8.4^b	7.8^b	8.6^b
	Peak 2	—	—	—	6.0^b	5.7^b	6.3^b

[a]Means of four replications.

[b-d]Means in each row for raw and cooked treatments not followed by a common superscript are significantly different (p < 0.001 for raw pork attributes; p < 0.05 for a-value, p < 0.01 for protein, external b-value, internal L- and b-values, and p < 0.001 for cooking loss of cooked pork).

Table 5. Internal redness (a-value) of cooked ground pork with wet-milled corn germ flour (WMG)[a]

WMG level (%)	Fat level (%)		
	9	15	18
0	5.3^e	4.8^{cde}	3.9^b
2.5	4.7^{cde}	4.5^{bcd}	5.0^{de}
5	4.4^{bcd}	4.3^{bcd}	4.1^{bc}

[a]Means of four replications.

[b-e]Means not followed by a common superscript are significantly different ($p < 0.05$).

PART III.

THE ADDITION OF CORN MILLING PRODUCTS TO

GROUND PORK OF VARIOUS FAT PERCENTAGES.

STUDY 2. CORN GLUTEN MEAL AND ZEIN

THE ADDITION OF CORN MILLING PRODUCTS TO GROUND PORK OF VARIOUS FAT PERCENTAGES.

STUDY 2. CORN GLUTEN MEAL AND ZEIN

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ABSTRACT

Corn gluten meal and zein at levels of 0, 2.5 and 5% were added to ground pork of three fat percentages. Raw patties were analyzed for fat, moisture and protein contents and color. Selected patties, broiled to 77°C, were evaluated for proximate composition, total cooking loss, color and Instron compression. Five percent zein added to ground pork reduced cooking loss 4.2% when compared to ground pork without zein. Corn gluten meal addition to pork did not influence yield. Instron compression values increased with the addition of zein and corn gluten meal. The yellowness (b-value) of the interior of cooked pork patties was increased by the addition of corn gluten meal and zein. Zein addition also increased the lightness (L-value) of cooked pork patties. The addition of zein to ground pork patties decreased sensory tenderness and pork flavor intensity and increased off-flavor intensity.

INTRODUCTION

Corn gluten and zein are generally recognized as safe (GRAS) as direct human food ingredients (Federal Register, 1985) but are not widely used in foods. Zein is used primarily as a binder in formulations for coating tablets, nuts and confections (Reiners et al., 1973). Over 1.5 million pounds of gluten meal are sold in the U.S. each year as animal feed (May, 1987).

Corn gluten meal and zein are by-products of the corn wet-milling industry. The meal is separated from germ, bran and starch by steeping, grinding, washing and centrifugation. Corn gluten meal has been found to contain 60% protein, 20-25% carbohydrate, 3.5% crude fiber, 1-2% ash and 15-18% fat (Buck et al., 1987). Further processing of corn gluten meal separates zein, which comprises 68% of corn gluten meal protein.

Concentrated cereal and legume proteins such as wheat gluten, pea protein isolate and textured navy bean protein concentrate have been added to meats as binders and extenders (Mittal and Usborne, 1985). Corn meal is added to chili con carne to aid fat retention in the product (Rakosky, 1970). The addition of corn proteins to meat patties may improve water- and fat-binding and maintain or improve product quality.

The objective of this study was to investigate the attributes of ground pork patties extended with corn gluten meal (CGM) and zein.

MATERIALS AND METHODS

Corn gluten meal and zein (obtained from Sigma Chemical Co.)
at levels of 0, 2.5 and 5% were mixed with 2.2 kg portions of ground
pork of fat levels 6.5, 19.1 and 31.8% for gluten meal treatments and
14.0, 19.0 and 28.6% for zein treatments. Four replications of nine
treatment combinations for each corn by-product were analyzed in a
randomized complete block design.

Each corn-pork mixture was packaged as described in Study 1.
Zein-pork samples were frozen 6 days at -18°C until heating; corn
gluten meal-pork samples were frozen 2 days before heating. Prior
to each replication, one 2.2 kg package of each treatment was thawed
48 hr at 4°C.

Raw and cooked samples of each treatment were analyzed for color,
moisture, fat and protein as described in Study 1.

Patties containing corn gluten meal or zein were broiled by
procedures described in Part 1. Cooked samples of each corn gluten
meal-pork or zein-pork treatment were analyzed for external and
internal color, Instron compression values and moisture, fat and protein
contents by methods indicated in Study 1.

Sensory Analysis of Pork Patties with Zein

Sensory evaluation of cooked pork patties with zein was completed
by a 9-member trained sensory panel. Panelists were presented sample
extremes in two training sessions. Panel members were selected from

students and faculty of the Food and Nutrition Department, Iowa
State University.

Two broiled patties of each treatment were cooked to room tempera-
ture, then cut into 10 identical wedges. Two randomly selected wedges
were placed into individual styrofoam cups that were coded with randomly
selected 3-digit numbers. Cups with lids were placed in a 60°C oven
for 20 min to warm the samples.

Panelists received samples from all treatments and were instructed
to sample randomly. Testing was conducted in individual booths. A
17-cm line scale was used to evaluate surface color, juiciness, tender-
ness, pork flavor intensity and off-flavor intensity. Very light brown,
extremely dry, extremely tough, no pork flavor and no off-flavor were
scored 0; very dark brown, extremely juicy, extremely tender, extremely
intense pork flavor and extremely intense off-flavor were scored 17.

Chemical Analysis

Methods for moisture, fat and protein analysis of raw and cooked
pork patties with corn gluten meal or zein are described in Study 1.

Statistical Analysis

Analysis of variance (SAS, 1982) was used (general linear model,
PROC GLM) to test the effects of replication (4), fat level (3) and
corn level (3) for corn gluten meal and zein treatments. When a signifi-
cant interaction between fat level and corn level resulted, interaction
means were reported. Main effect means were reported when no

significant interactions were found.

Sensory evaluation data were analyzed by analysis of variance in a split-plot design to test effects of replication (4), fat level (3), corn level (3) and panelist (9). When there were no interactions between fat level and corn level, main effect means were reported. When F-values were significant, least significant differences (LSD) at a 5% level of probability were calculated.

RESULTS AND DISCUSSION

Corn Gluten Meal

Raw pork

The effects of fat level and corn level on protein content and color of raw ground pork with corn gluten meal (CGM) are presented (Table 1). Protein content decreased as the fat level increased from 6.5 to 31.8%. Increased fat in the meat resulted in increased lightness (L-value) and yellowness (b-value) and decreased redness (a-value) of raw ground pork. In a similar study, red-pink color intensity sensory scores for raw pork patties increased as the amount of fat decreased (Reitmeier and Prusa, 1987).

The addition of CGM increased the protein content of raw ground pork. Gluten meal is 60% protein which may account for the increase in protein content. CGM addition to pork increased lightness (L-value) and yellowness (b-value), but decreased redness (a-value).

The fat and moisture contents of raw pork with CGM were influenced by corn addition (Table 2). At the 32% fat level, pork with 2.5% CGM had more fat than the 5% CGM treatment. In patties with 6.5% fat, moisture content decreased with each corn addition. In patties with 19% fat, only corn addition at the 5% level decreased the moisture content. At 32% fat, samples containing CGM had less moisture than control samples.

Cooked pork

The chemical and physical attributes of cooked pork patties with CGM are presented (Table 3). The fat contents after cooking were 9.2,

20.0 and 26.3%. Moisture and protein contents decreased and cooking

loss increased as the fat level increased. Kregel et al. (1986)

reported higher cooking loss from 28.5% fat ground beef when compared

with ground beef containing 9.5 or 21.5% fat. Instron compression

values were greatest for patties with 19% fat, followed by 32% fat and

6.5% fat treatments. External and internal lightness (L-value) and

yellowness (b-value) increased and external redness (a-value) increased

as fat content increased.

Fat and moisture contents decreased with CGM addition, while protein

content increased. Cooking loss was not affected by corn addition.

The force required for 80% compression increased with CGM addition.

Thirty percent CGM increased the firmness of bread, but decreased the

firmness of pasta (Buck et al., 1987).

CGM addition to pork increased external redness (a-value) and

internal yellowness (b-value) of cooked patties. In agreement, cookies,

bread and pasta also were more red and more yellow with the addition

of 30% CGM than control products without CGM (Buck et al., 1987).

Zein

Raw pork

The influence of fat level and zein addition on raw pork is presented

(Table 4). The mean fat contents of raw ground pork with zein were 14.0,

19.0 and 28.6%. At the 14% fat level, pork with zein had more fat

than the control. At the 19% fat level, the zein treatments had more

fat than treatments without zein. In the 29% fat treatment, pork

with 2.5% zein had lower fat content than the 5% zein treatment.

As expected, moisture and protein contents decreased as fat level increased (Table 5). Lightness (L-value) and yellowness (b-value) of the pork patties increased with increasing amount of fat.

The addition of zein to raw ground pork resulted in decreased moisture and increased protein contents. Zein is 95% protein which accounts for the increase in protein content. Yellowness (b-value) color values of pork increased with zein addition.

Cooked pork

The fat contents of the cooked patties were 17.1, 20.0 and 21.6% (Table 6). As in treatments with CGM, moisture and protein contents decreased as fat level increased. Cooking loss also increased with increasing fat content. Instron compression values decreased as fat level of cooked pork increased. However, color of patties with zein was not influenced by fat content.

Fat content increased and moisture content decreased in cooked pork patties with zein addition. Protein content was not affected by addition of zein.

Cooking loss decreased slightly when 5% zein was added. Zein addition to pork patties increased the force required for 80% compression. Both external and internal lightness (L-value) of patties with 5% zein increased. Internal yellowness (b-value) also increased with zein addition.

External yellow (b-value) color of cooked pork patties was influenced by zein addition (Table 7). At the 14% fat level, yellow

color was lowest in the 2.5% zein treatment. Yellow color was
highest in the treatment with 2.5% zein and 19% fat. Zein addition
did not influence yellowness of cooked pork at the highest fat level.

Sensory Evaluation of Cooked Pork with Zein

The sensory evaluation results of cooked ground pork with zein
are presented (Table 8). The surface color of cooked pork patties
with zein was influenced slightly by fat level. HunterLab spectro-
colorimeter values were not different for lightness and redness (Table 6),
but yellow (b-value) color was affected by zein (Table 7).

The juiciness of cooked ground pork with zein was influenced by
zein level. At 14 and 29% fat levels, juiciness decreased with zein
addition. Juiciness scores were not different for 0 and 2.5% zein
treatments, but decreased at the 5% zein level.

Sensory tenderness scores of the ground pork increased as fat
level increased, but decreased as zein level increased. Similar
results were found from the Instron compression values (Table 6).
Higher sensory scores for tenderness of broiled pork patties with 18
and 23% fat than for patties with 4 and 9% fat have been reported
(Reitmeier and Prusa, 1987).

The pork flavor intensity and off-flavor intensity of cooked
pork with zein were not influenced by level of fat. However, with
the addition of zein, pork flavor intensity decreased and off-flavor
intensity increased.

The addition of CGM (20%) to bread, pasta and extruded puffs

resulted in less desirable flavor ratings by sensory panelists (Buck et al., 1987). However, no off-flavors were noted in baked products with a lower percentage (3%) of corn gluten meal added (Feldberg, 1965). CGM in raisin bread had no effect on flavor, but in corn bread, devil's food cake, egg bread and cheese bread, the CGM treatment was preferred for flavor (Feldberg, 1965). Off-flavors may be a factor to consider with corn-extended products.

CONCLUSIONS

Corn gluten meal and zein were not as effective as dry- and wet-milled corn germ meals (Reitmeier and Prusa, 1988) in increasing yield in broiled pork patties. The properties of these corn fractions may be influenced by the characteristics of zein, a water-insoluble protein. Zein did not improve or maintain the sensory characteristics of ground pork patties.

REFERENCES CITED

Buck, J. S., Walker, C. E., and Watson, K. S. 1987. Incorporation of corn gluten meal and soy into various cereal-based foods and resulting functional, sensory, and protein quality. Cereal Chem. 64:264-269.

Federal Register. 1985. Wheat gluten, corn gluten, and zein; affirmation of GRAS status. Food and Drug Administration, Vol. 50, No. 44, p. 8997.

Feldberg, C. 1965. Corn gluten, a new ingredient for bakery products. Cereal Sci. Today 10:18-19.

Kregel, K. K., Prusa, K. J., and Hughes, K. V. 1986. Cholesterol content and sensory analysis of ground beef as influenced by fat level, heating and storage. J. Food Sci. 51:1162-1165.

May, J. B. 1987. Corn wet milling: Process and products. Pages 377-397 in Watson, S. A., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology, Am. Assoc. Cereal Chem., St. Paul, MN.

Mittal, G. S., and Usborne, W. R. 1985. Meat emulsion extenders. Food Technol. 39:121-130.

Rakosky, J. 1970. Soy products for the meat industry. J. Agr. Food Chem. 18:1005-1009.

Reiners, R. A., Wall, J. S., and Inglett, G. E. 1973. Corn proteins: Potential for their use. Pages 285-302 in Symposium Proceedings, 58th Annual Meeting, Am. Assoc. Cereal Chem., St. Paul, MN.

Reitmeier, C. A., and Prusa, K. J. 1987. Cholesterol content and sensory analysis of ground pork as influenced by fat level and heating. J. Food Sci. 52:916-918.

Reitmeier, C. A., and Prusa, K. J. 1988. The addition of corn milling products to ground pork of various fat percentages. Study 1. Dry- and wet-milled corn germ meals. Submitted.

Statistical Analysis System. 1982. SAS User's Guide: Statistics. SAS Inst., Inc., Raleigh, NC. 584 pp.

ACKNOWLEDGMENTS

Table 1. Protein content and color of raw ground pork with corn gluten meal[a]

		Fat level (%)			Corn gluten meal level (%)		
		6.5	19	32	0	2.5	5
Protein (%)		22.2^b	20.4^c	17.3^d	18.8^b	20.0^c	21.0^d
Color:	L	41.6^b	50.6^c	57.3^d	48.2^b	50.5^c	50.8^c
	a	10.2^b	8.4^c	7.4^d	9.6^b	8.4^c	7.9^c
	b	9.2^b	11.7^c	12.6^d	10.2^b	11.1^c	12.2^d

[a]Means of four replications.

[b-d]Means in a row for fat level and corn level not followed by a common superscript are significantly different ($p < 0.001$ for all attributes except $p < 0.05$ for L-value in corn level).

Table 2. Fat and moisture contents of raw ground pork with corn
          gluten meal[a]

| Corn gluten meal level (%) | Fat | | | Moisture | | |
| | Fat level (%) | | | Fat level (%) | | |
	6.5	19	32	6.5	19	32
0	6.5^b	19.6^c	31.1^{de}	72.6^h	61.7^e	53.1^c
2.5	6.7^b	18.3^c	33.4^e	70.7^g	61.8^e	49.8^b
5	6.4^b	19.5^c	30.8^d	69.4^f	58.7^d	50.3^b

[a]Means of four replications.

[b-h]Means for fat and moisture not followed by a common
superscript are significantly different ($p < 0.05$).

Table 3. Chemical and physical attributes of cooked ground pork with corn gluten meal[a]

Attribute	Fat level (%)			Corn gluten meal level (%)		
	6.5	19	32	0	2.5	5
Fat (%)	9.2^b	20.0^c	26.3^d	18.8^b	19.2^b	17.5^c
Moisture (%)	56.7^b	49.9^c	45.2^d	52.6^b	49.4^c	49.8^c
Protein (%)	30.7^b	28.6^c	27.6^c	27.8^b	29.0^{bc}	30.0^c
Cooking loss (%)	32.3^b	32.8^b	38.3^c	35.1^b	35.8^b	32.5^b
Instron (cm): Peak 1	9.4^b	13.2^c	11.1^d	9.3^b	11.1^c	13.3^d
Peak 2	7.3^b	9.9^c	8.4^d	7.0^b	8.4^c	10.2^d
External color: L	35.9^b	38.8^b	43.4^c	41.9^b	37.6^b	38.7^b
a	3.6^b	4.9^c	5.6^d	4.3^b	4.8^c	5.0^d
b	5.4^b	8.4^c	9.7^c	8.1^b	7.5^b	7.9^b
Internal color: L	48.9^b	55.0^c	59.9^d	55.3^b	54.0^b	54.4^b
a	5.2^b	4.0^b	4.5^b	4.2^b	4.8^b	4.7^b
b	10.2^b	11.7^c	12.6^d	10.4^b	11.5^c	12.6^d

[a]Means of four replications.

[b-d]Means in a row for fat level and corn level not followed by a common superscript are significantly different ($p < 0.001$ for all attributes except $p < 0.01$ for protein and external L-value within fat level and moisture within corn level and $p < 0.05$ for protein and external a-value within corn level).

Table 4. Fat content of raw ground pork with zein[a]

Zein level (%)	Fat level (%)		
	14	19	29
0	13.0^b	16.7^d	28.7^{fg}
2.5	13.7^{bc}	20.7^e	27.4^f
5	15.4^{cd}	19.7^e	29.8^g

[a]Means of four replications.

[b-g]Means not followed by a common superscript are significantly different (p < 0.05).

Table 5. Proximate analysis and color of raw ground pork with zein[a]

	Fat level (%)			Zein level (%)		
	14	19	29	0	2.5	5
Moisture (%)	71.9^b	64.2^c	57.2^d	66.3^b	64.3^c	62.7^c
Protein (%)	20.4^b	18.3^c	17.6^c	16.7^b	18.8^c	20.7^d
Color: L	35.1^b	38.5^c	41.0^c	37.1^b	37.2^b	40.3^b
a	9.0^b	9.2^b	8.7^b	8.7^b	9.5^b	8.8^b
b	11.2^b	11.8^{bc}	12.4^c	11.0^b	11.8^c	12.6^d

[a] Means of four replications.

[b-d] Means in a row for fat level and corn level not followed by a common superscript are significantly different (p < 0.001 for all attributes except p < 0.01 for L- and b-values within fat level and moisture within corn level).

Table 6. Chemical and physical attributes of cooked ground pork with zein[a]

Attribute	Fat level (%)			Zein level (%)		
	14	19	29	0	2.5	5
Fat (%)	17.1[b]	20.0[c]	21.6[c]	17.5[b]	19.7[c]	21.4[c]
Moisture (%)	60.6[b]	56.7[c]	54.6[d]	59.2[b]	57.6[b]	55.1[c]
Protein (%)	30.8[b]	31.5[b]	26.1[c]	27.8[b]	30.6[b]	30.1[b]
Cooking loss (%)	31.8[b]	32.9[b]	37.2[c]	35.6[b]	34.8[b]	31.4[c]
Instron (cm): Peak 1	11.1[b]	9.2[c]	7.9[c]	7.9[b]	8.9[b]	11.3[c]
Peak 2	7.9[b]	6.6[c]	5.6[c]	5.5[b]	6.4[b]	8.1[c]
External color: L	29.3[b]	31.2[b]	31.4[b]	29.8[b]	27.7[b]	34.4[c]
a	5.7[b]	5.6[b]	5.9[b]	5.5[b]	6.1[b]	5.6[b]
Internal color: L	49.7[b]	50.3[b]	49.8[b]	50.7[b]	48.0[c]	51.2[b]
a	4.5[b]	5.2[b]	4.9[b]	5.1[b]	4.8[b]	4.8[b]
b	10.8[b]	10.9[b]	11.4[b]	10.4[b]	11.2[c]	11.6[c]

[a]Means of four replications.

[b-d]Means in a row for fat level and corn level not followed by a common superscript are significantly different (p < 0.001 for all attributes except p < 0.01 for peak 2 within fat level and cooking loss and external L-value and p < 0.05 for internal L-value within corn level).

Table 7. External yellow (b-value) color of cooked ground pork with zein[a]

Zein level (%)	Fat level (%)		
	14	19	29
0	9.3^{cd}	8.0^{bc}	9.9^{d}
2.5	7.4^{b}	10.3^{d}	9.4^{cd}
5	9.1^{cd}	9.4^{cd}	9.1^{cd}

[a]Means of four replications.

[b-d]Means not followed by a common superscript are significantly different ($p < 0.05$).

Table 8. Sensory evaluation of cooked ground pork with zein[a]

Attribute		Fat level (%)			Means within zein level
		14	19	29	
Surface color	0% zein	8.8^{cd}	9.5^{d}	7.8^{bc}	
	2.5% zein	9.3^{d}	7.1^{b}	8.6^{cd}	
	5% zein	9.1^{cd}	8.1^{bcd}	8.6^{cd}	
Juiciness	0% zein	10.5^{e}	11.1^{e}	13.0^{f}	
	2.5% zein	6.7^{c}	10.7^{e}	10.1^{e}	
	5% zein	5.3^{b}	7.1^{c}	8.6^{d}	
Tenderness	0% zein	12.8	13.1	15.0	13.6^{b}
	2.5% zein	10.1	12.9	12.8	11.9^{c}
	5% zein	8.4	10.2	11.6	10.1^{d}
		$\overline{10.4}^{b}$	$\overline{12.1}^{c}$	$\overline{13.1}^{d}$	
Pork flavor intensity	0% zein	9.0	10.3	10.1	9.8^{b}
	2.5% zein	3.5	3.2	3.9	3.5^{c}
	5% zein	2.8	4.0	2.7	3.2^{c}
		$\overline{5.1}^{b}$	$\overline{5.9}^{b}$	$\overline{5.6}^{b}$	
Off-flavor intensity	0% zein	3.7	3.2	2.4	3.1^{b}
	2.5% zein	11.3	11.7	11.3	11.4^{c}
	5% zein	13.3	13.8	12.8	13.3^{d}
		$\overline{9.4}^{b}$	$\overline{9.6}^{b}$	$\overline{8.8}^{b}$	

[a]Means of four replications.

[b-f]Means within each attribute not followed by a common super-script are significantly different ($p < 0.05$ for surface color and juiciness and $p < 0.001$ for tenderness, pork flavor intensity and off-flavor intensity).

PART IV.

THE ADDITION OF DRY- AND WET-MILLED CORN GERM

FLOURS TO FRANKFURTERS OF THREE FAT LEVELS

THE ADDITION OF DRY- AND WET-MILLED CORN GERM

FLOURS TO FRANKFURTERS OF THREE FAT LEVELS

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Running Title: Corn germ flours in frankfurters

ABSTRACT

Chemical, physical and sensory properties of cooked frankfurters of three fat levels with 0 and 3.5% dry-milled corn germ (DMG) flour and 0% and 3.5% wet-milled corn germ (WMG) flour added were investigated. As fat level increased, cooking losses increased and Instron compression values decreased in cooked frankfurters with DMG and WMG flours. Addition of DMG flour decreased fat content and lightness (L-value) and increased yellowness (b-value) of cooked frankfurters. Sensory evaluation indicated that DMG flour in frankfurters decreased tenderness, juiciness and cured flavor intensity. The addition of DMG flour increased chewiness of frankfurters. WMG flour addition decreased fat and protein contents and lightness (L-value) and increased yellowness (b-value), Instron compression values and cooking loss. Cured flavor intensity decreased and off-flavor intensity increased with the addition of WMG flour to frankfurters.

INTRODUCTION

Legume and cereal proteins have been added to a variety of emulsified meat products to increase water- and fat-binding and to increase product stability. Soy protein, sodium caseinate and wheat gluten are commonly used to increase cooking yield of frankfurters (Mittal and Usborne, 1985). Binders and extenders are permitted in frankfurters at a level of 3.5%. In nonstandard products, there is no restriction on the amount of added binder other than amount "sufficient for purpose" (Lauck, 1975).

Corn millers produce about 43 million bushels of corn germ as a by-product of grit, meal and flour manufacture (Alexander, 1987). Oil is removed from germ meal by pressing and/or hexane extraction. Wet-milled corn germ meal remains after corn is processed for removal of starch and oil. Over 250 million bushels of wet-milled germ meal is produced yearly in the U.S. (May, 1987). A food use for corn milling by-products would increase the value of meals that are now sold inexpensively for animal feed.

Researchers indicated that high-protein corn by-products have potential for use in meats (Blessin et al., 1973). Nielsen et al. (1979) reported water-binding capacity of 4.2 g/g (AACC method 56-20) for dry-milled corn germ meal and 6.9 to 8.0 g/g for wet-milled corn germ (Nielsen et al., 1979). A corn protein concentrate had a water absorption ability similar to that of soy concentrate (Phillips and Sternberg, 1979).

The addition of corn germ meals to comminuted meats may improve

water- and fat-binding capacities and may improve sensory characteristics of cooked products. The objective of this study was to determine the usefulness of dry- and wet-milled corn germ meals as extenders in frankfurters.

MATERIALS AND METHODS

Dry-milled corn germ meal was obtained from Illinois Cereal Mills, Inc., Paris, IL and was found to contain 17.38% protein, 30.68% starch, 5.34% crude fiber and 7.3% moisture. Wet-milled corn germ meal, obtained from A. E. Staley Manufacturing, Inc., Decatur, IL was found to contain 24.09% protein, 18.18% starch, 10.79% crude fiber and 10.32% moisture. Both meals were ground to flours (35-mesh) in a food mill.

Germ flour at levels of 0 and 3.5% was mixed with 681 g portions of ground pork in a Hobart KitchenAid mixer for 30 sec at speed 2. Three fat levels of ground pork were used: 7.9, 13.2 and 21.9% fat with dry-milled corn germ (DMG) flour and 11.0, 17.9 and 32.7% fat with wet-milled corn germ (WMG) flour. Four replications of the six treatment combinations (3 fat levels and 2 corn levels) for each corn germ flour were analyzed in a randomized complete block design.

Each corn-pork mixture was vacuum-packaged, frozen and held at -18°C until cooking. Prior to each replication, one 681 g package of each treatment was thawed 48 hr at 4°C.

Frankfurter batter was prepared for each treatment by the fol-' lowing formulation: 681 g ground pork, 157.5 g ice water, 18.8 g salt, 6.8 g sugar, 1.5 g white pepper, 0.6 g nutmeg, 1.7 g 'Modern Cure' (6.25% sodium nitrite), 0.5 g sodium ascorbate, 4.1 g dry mustard, and 1.0 g liquid smoke,

The pork, salt and ice water were mixed one min in a KitchenAid (Model KFP700) food processor. Spices and liquid smoke were added

and the batter was blended to a final temperature of 13°C. The batter was packaged and chilled 18 hr at 4°C.

A 1 cm diameter horn on a Hobart KitchenAid (Model K5-A) mixer was used to stuff 40 g ± 1 g batter into 50 ml centrifuge tubes. Each treatment of 16 tubes was cooked separately by placing tubes into racks and placing racks into boiling water. Frankfurters were cooked to an end point temperature of 77°C determined by a thermocouple attached to an Omega Engineering, Inc. (Model 115KC) thermometer. Each treatment was cooked in random order.

Total cooking losses were calculated by weights of raw batter and cooked frankfurters (Campbell et al., 1979). Weights of raw batter (excluding corn) were used for cooking loss calculations. The cooked frankfurters were refrigerated (2 to 5 hr) until sensory analysis.

Six 2 cm segments of each treatment were measured in duplicate for color (L, a, b) using a HunterLab LabScan spectrocolorimeter (Model LS-5100). Values of the standard tile were X = 81.60, Y = 86.68 and Z = 91.18.

Six 2 cm segments of each treatment were analyzed for 80% compression with an Instron Universal Testing Machine (Model 1122). Samples at room temperature were compressed twice to 80% of the original height (2 cm) with a 3.5 cm dia compression anvil. A load cell setting of 10 kg, crosshead speed of 10 mm/min and chart speed of 200 mm/min were used. The heights of the initial fracture peak, the first 80% compression peak and the second 80% compression peak were measured (cm).

Samples of each treatment for compositional analysis were ground

through a 0.31 cm plate. Samples for moisture, fat and protein analyses were packaged, labelled, and frozen at -18°C until analysis.

Chemical Analysis

Moisture, crude lipid, and protein (N x 6.25) contents of the raw and cooked frankfurter samples were determined by AOAC procedures, sections 24.002, 24.005, and 24.027, respectively (AOAC, 1984).

Sensory Evaluation

Sensory evaluation of cooked frankfurters with DMG flour was completed by a 12-member trained sensory panel. A 10-member panel evaluated cooked frankfurters with WMG flour. Training consisted of presenting the treatment extremes in three preliminary evaluation sessions. Panel members were selected from students in the Food and Nutrition Department, Iowa State University. Four replications of the six DMG and six WMG treatments were analyzed in split-plot designs.

Fifteen frankfurters of each treatment were cut into 2 cm segments, excluding 2 cm of each end. Two randomly selected segments were placed into individual styrofoam cups that were coded with randomly selected 3-digit numbers. Samples in cups with lids were heated 30 min in a 60°C oven before evaluation. Panelists received samples from all treatments and were instructed to sample randomly. Testing was conducted in individual booths.

Initial tenderness, chewiness, juiciness, cured meat flavor and off-flavor were evaluated on a 17-cm intensity line scale. Tough,

extremely chewy, dry, no cured meat flavor and no off-flavor were scored 0; tender, not chewy, juicy, intense cured meat flavor and intense off-flavor were scored 17.

Statistical Analysis

Analysis of variance (SAS, 1982) was used (general linear model, PROC GLM) to test the effects of replication (4), fat level (3) and corn level (2) on proximate analyses, cooking loss, Instron compression and color data. When a significant interaction between fat level and corn level resulted, interaction means were reported. Main effect means were reported when no significant interactions were found.

Sensory evaluation data were analyzed by analysis of variance (SAS, 1982) to test the effects of replication (4), fat level (3), corn level (2) and panelist (10 or 12) using a split-plot design. If no significant interactions were found between corn and fat level, main effects means are reported. When F-values were significant, least significant differences (LSD) at a 5% probability level were calculated.

RESULTS AND DISCUSSION

Effects of Fat

The effects of fat level on proximate analysis, cooking loss, Instron compression values and color of frankfurters containing dry-milled corn germ flour and wet-milled corn germ flour are presented (Table 1). As fat level increased, moisture content decreased. Sofos and Allen (1977) reported increases in protein and moisture contents as fat levels in frankfurters decreased. Cooking loss of cooked frankfurters increased as fat content increased possibly due to the instability of the emulsion. Increased shrinkage was correlated with decreasing fat content in frankfurters prepared with beef or pork fat (Townsend et al., 1971). Sofos and Allen (1977) reported higher cooking losses in frankfurters with low fat (15%) and high soy (35%) contents than with high fat (30%) and low soy (20%) contents. Kregel et al. (1986) noted higher cooking loss from ground beef with 28.5% fat than from ground beef with 9 or 21.5% fat. Higher cooking losses also were reported in high fat ground pork when compared to ground pork with lower fat contents (Reitmeier and Prusa, 1988).

Instron force required for initial fracture and for 80% compression decreased as the fat content of frankfurters increased. Rakosky (1970) stated that firmness of a sausage product is dependent on the amount of lean meat in the mixture whereas fat softens the product and makes it more tender. Other researchers also have reported that low levels of fat in frankfurters increased product firmness (Sofos and Allen, 1977; St. John et al., 1986; Lee et al., 1987).

As expected, the color of cooked frankfurters with DMG and WMG

flours was influenced by fat, i.e., lightness (L-value) and yellow-

ness (b-value) increased and redness (a-value) decreased as fat level

increased.

The protein contents of frankfurters with 0 or 3.5% DMG flour and

0 or 3.5% WMG flour are presented (Table 2). The protein contents of

frankfurters with 13 and 22% fat were lower than the protein content of

frankfurters with 8% fat. DMG flour addition did not influence protein

content. Protein content also decreased as fat level increased in the

WMG flour study. WMG flour increased protein content only in the 18

and 33% fat treatments.

Effects of Corn

The addition of 3.5% DMG flour to frankfurters decreased fat con-

tent and lightness (L-value) and increased yellowness (b-value)

(Table 3). Moisture content, redness (a-value), cooking loss and

Instron compression values of frankfurters were not influenced by the

addition of DMG flour. The addition of textured navy bean protein

concentrate also reduced fat content but increased protein content of

raw frankfurters (Patel et al., 1980). Terrell et al. (1979) reported

no differences in protein content between frankfurter-like products

with 10 or 30% oilseed proteins and control products.

Wet-milled corn germ flour addition to frankfurters resulted in

a lower fat content when compared to the control frankfurters (Table 3).

Cooking loss increased from 8.7 to 17.1% when WMG flour was added to

frankfurters. Low cooking yields are the result of poor emulsion

stability (Smith et al., 1973). The loss of fat probably indicates

a decrease in stability of the emulsion. In contrast, Lin and Zayas

(1987) reported that 4% corn protein increased cooking yield by de-

creasing fat and moisture loss in a cooked sausage batter. The addi-

tion of 3.5% vital wheat gluten or soy protein concentrate to frank-

furters did not influence yield or texture (Keeton et al., 1984).

The force required for 80% compression of frankfurters increased

with WMG flour addition. The WMG flour may be binding water effectively,

but not contributing to the emulsion stability. The loss of fat

probably contributes to increased compression values. In a

similar study, Instron shear force decreased with the addition

of 4% corn protein but color and hardness were not different (Lin

and Zayas, 1987). High levels of soy in meat products caused an

increase in tenderness (Sofos et al., 1977). Frankfurters with textured

navy bean protein concentrate (10, 20 or 30% lean replacement) were

characterized by higher processing shrinkage and softer textures than

control samples (Patel et al., 1980). The addition of peanut protein

to comminuted meat loaves decreased compression strength and increased

crumbliness of the meat (Torgersen and Toledo, 1977).

The L-value (lightness) was lower and yellow color (b-value) was

more intense in frankfurters with WMG flour than in control samples

(Table 3). Franks extended with textured navy bean protein concentrate

were lighter due to the tan color of the concentrate (Patel et al.,

1980). Weiners with soy or sunflower flour were given lower color

scores than all-meat samples (Lin et al., 1975). Compared to all-meat

controls, frankfurters with 5, 10 and 15% cottonseed proteins had less cured color, had a softer texture and were less desirable as judged by sensory panelists (Terrell et al., 1981). WMG flour addition did not affect the moisture content or redness (a-value) of cooked frankfurters.

Sensory Evaluation

The results of sensory evaluation of frankfurters with DMG flour are presented (Table 4). An increase in the fat level increased tenderness and juiciness, decreased chewiness and cured flavor intensity, but did not influence off-flavor intensity.

Other researchers have reported the effects of fat on sensory characteristics of frankfurters. When the fat level increased from 27 to 31% in beef-pork frankfurters, juiciness increased (Lee et al., 1987). Frankfurters with 22% fat were more springy than frankfurters with 28% fat (St. John et al., 1986). Baker et al. (1969) reported no differences in the flavor of chicken frankfurters due to fat level (20, 25, 30 or 35%) in the formula.

The addition of 3.5% DMG flour to frankfurters decreased tenderness, juiciness and cured flavor intensity. Chewiness of frankfurters was increased by DMG flour addition. Off-flavor intensity was not influenced by DMG flour addition. Soy addition to weiner-type products increased tenderness (Sofos et al., 1977), as did most cereal and oilseed addition (Patel et al., 1980; Torgersen and Toledo, 1977; Lin et al.,

1975; Terrell et al., 1981). Soy protein concentrate (3.5%) decreased the flavor intensity of frankfurters (Keeton et al., 1984).

The sensory evaluation results of WMG addition to frankfurters with 11, 18 and 33% fat are presented (Table 5). Tenderness increased as fat level increased. Tenderness did not differ between 0 and 3.5% corn treatments at 11 and 18% fat levels. However, tenderness decreased at the 33% fat level when WMG flour was added.

Chewiness decreased as fat level of frankfurters increased. Chewiness of the frankfurters increased with WMG flour addition only at the 33% fat level.

WMG flour addition decreased juiciness of frankfurters at all fat levels. Generally, juiciness of control frankfurters increased as fat level increased. However, juiciness of frankfurters containing WMG flour decreased as fat level increased.

Cured flavor intensity of frankfurters decreased only at the 33% fat level. Fat level did not affect off-flavor intensity of the samples. The addition of WMG flour to frankfurters decreased cured flavor intensity and increased off-flavor intensity. The addition of 3.5% vital wheat gluten or soy protein concentrate contributed some off-flavors to frankfurters (Keeton et al., 1984). Textured navy bean protein concentrate introduced an off-flavor which masked the meaty and spicy flavor desirable in frankfurters (Patel et al., 1980).

CONCLUSIONS

Germ flour addition to frankfurters did not improve yield or sensory attributes of the cooked products. WMG flour nearly doubled the weight loss of frankfurters during cooking. The flours may be binding water but not contributing to the stability of the emulsion. Further study is needed to determine the water- and fat-binding abilities of the components in the germ flours and their interactions in meat emulsions.

Corn germ flours decreased the fat content and altered the color of cooked frankfurters. Frankfurters with DMG flour were less tender, drier, more chewy and had less cured flavor than the control frankfurters. DMG flour did not contribute off-flavors to the frankfurters. WMG flour decreased cured flavor intensity and increased off-flavor intensity of cooked frankfurters. The off-flavors may be a problem when incorporating germ flour into meat systems.

REFERENCES CITED

Alexander, R. J. 1987. Corn dry milling: Processes, products, and applications. Pages 351-376 in Watson, S. A., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem., St. Paul, MN.

Assoc. Official Anal. Chem. 1984. Official Methods of Analysis. 14th ed. The Association, Arlington, VA.

Baker, R. C., Darfler, J., and Vadehra, D. V. 1969. Type and level of fat and amount of protein and their effect on the quality of chicken frankfurters. Food Technol. 23:808-811.

Blessin, C. W., Garcia, W. J., Deatherage, W. L., Cavins, J. F., and Inglett, G. E. 1973. Composition of three food products containing defatted corn germ flour. J. Food Sci. 38:602-606.

Campbell, A. M., Penfield, M. P., and Griswold, R. M. 1979. The Experimental Study of Food. Houghton Mifflin Co., Boston, MA. 513 pp.

Keeton, J. T., Foegeding, E. A., and Patana-Anake, C. 1984. A comparison of nonmeat proteins, sodium tripolyphosphate and processing temperature effects on physical and sensory properties of frankfurters. J. Food Sci. 49:1462-1465.

Kregel, K. K., Prusa, K. J., and Hughes, K. V. 1986. Cholesterol content and sensory analysis of ground beef as influenced by fat level, heating and storage. J. Food Sci. 51:1162-1165.

Lauck, R. M. 1975. The functionality of binders in meat emulsions. J. Food Sci. 40:736-740.

Lee, C. M., Whiting, R. C., and Jenkins, R. K. 1987. Texture and sensory evaluations of frankfurters made with different formulations and processes. J. Food Sci. 52:896-900.

Lin, M. J. Y., Humbert, E. S., Sosulski, F. W., and Card, J. W. 1975. Quality of weiners supplemented with sunflower and soy products. J. Inst. Can. Sci. Technol. Aliment. 8(2):97-101.

Lin, C. S., and Zayas, J. 1987. Influence of corn germ protein on yield and quality characteristics of comminuted meat products in a model system. J. Food Sci. 52:545-548.

May, J. B. 1987. Wet milling: Process and products. Pages 377-397 in Watson, S. E., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem., St. Paul, MN.

Mittal, G. S., and Usborne, W. R. 1985. Meat emulsion extenders. Food Technol. 39:121-130.

Nielsen, H. C., Wall, J. S., and Inglett, G. E. 1979. Flour containing protein and fiber made from wet-mill corn germ, with potential food use. Cereal Chem. 56:144-146.

Patel, K. M., Merkel, R. A., Reynolds, A. E., and Youngs, C. G. 1980. Texturized navy bean protein concentrate as a meat extender in frankfurters. J. Inst. Can. Sci. Technol. Aliment. 13(1):5-9.

Phillips, R. D., and Sternberg, M. 1979. Corn protein concentrate: Functional and nutritional properties. J. Food Sci. 44:1152-1155.

Rakosky, J. 1970. Soy products in the meat industry. J. Agr. Food Chem. 18(6):1005-1009.

Reitmeier, C. A., and Prusa, K. J. 1988. The addition of corn milling products to ground pork of various fat percentages. Study 1. Dry- and wet-milled corn germ meals. Study 2. Corn gluten meal and zein. Submitted.

Statistical Analysis System. 1982. SAS User's Guide: Statistics. SAS Inst., Inc., Raleigh, NC. 584 pp.

Smith, G. C., Juhn, H., Carpenter, Z. L., Mattil, K. F., and Cates, C. M. 1973. Efficacy of protein additives as emulsion stabilizers in frankfurters. J. Food Sci. 38:849-855.

Sofos, J. N., and Allen, C. E. 1977. Effects of lean meat source and levels of fat and soy protein on the properties of weiner-type products. J. Food Sci. 42:875-878.

Sofos, J. N., Nada, I., and Allen, C. E. 1977. Effects of soy proteins and their levels of incorporation on the properties of weiner-type products. J. Food Sci. 42:879-884.

St. John, L. C., Buyck, M. J., Keeton, J. T., Leu, R., and Smith, S. B. 1986. Sensory and physical attributes of frankfurters with reduced fat and elevated monounsaturated fats. J. Food Sci. 51:1144-1146.

Terrell, R. N., Brown, J. A., Carpenter, Z. L., Mattil, K. F., and Monagle, C. W. 1979. Effects of oilseed proteins, at two replacement levels, on chemical, sensory and physical properties of frankfurters. J. Food Sci. 44:865-868.

Terrell, R. N., Swasdee, R. L., Wan, P. J., and Lusas, E. W. 1981. Cottonseed proteins in frankfurters: Effect on pH, cured color, and sensory and physical properties. J. Food Sci. 46:845-849.

Torgersen, H., and Toledo, R. T. 1977. Physical properties of protein preparations related to their functional characteristics in comminuted meat systems. J. Food Sci. 42:1615-1620.

Townsend, W. E., Ackerman, S. A., Witnauer, L. P., Palm, W. E., and Swift, C. E. 1971. Effects of types and levels of fat and rates and temperatures of comminution on the processing and characteristics of frankfurters. J. Food Sci. 36:261-265.

ACKNOWLEDGMENTS

Table 1. Effects of fat on chemical and physical attributes of frank-
furters with dry- and wet-milled corn germ flour[a]

Attribute	Dry-milled germ Fat level (%)			Wet-milled germ Fat level (%)		
	8	13	22	11	18	33
Fat (%)	6.3^b	11.6^b	16.8^d	8.9^b	14.5^c	22.1^d
Moisture (%)	70.4^b	66.3^c	61.3^d	69.5^b	64.3^c	55.8^d
Cooking loss (%)	4.4^b	9.5^b	17.6^c	4.2^b	10.9^c	23.8^d
Instron (cm):						
Fracture peak	16.0^b	9.7^c	6.5^d	17.1^b	10.8^c	5.3^d
Peak 1	15.6^b	11.7^c	10.6^b	15.9^b	13.1^c	12.3^c
Peak 2	9.4^b	7.6^c	7.3^c	11.3^b	10.5^b	9.3^b
Color: L	49.4^b	50.7^c	52.5^d	49.8^b	50.0^b	56.7^c
a	7.3^b	6.7^c	6.4^d	7.6^b	7.4^b	6.1^c
b	7.9^b	8.4^c	8.5^c	8.6^b	8.8^b	9.5^c

[a]Means of four replications.

[b-d]Means in a row for DMG or WMG not followed by a common super-
script are significantly different ($p < 0.05$ for peak 2, $p < 0.01$
for cooking loss, peak 1 and b-value, $p < 0.001$ for other attributes
of DMG treatments; $p < 0.01$ for peak 1, $p < 0.001$ for other WMG at-
tributes.

Table 2. Protein contents of frankfurters with dry- or wet-milled corn germ flour[a]

Dry-milled germ level (%)	Fat level (%)			Means within corn level
	8	13	22	
0	17.1	16.4	15.7	18.2^b
3.5	17.3	16.1	15.4	18.1^b
	$\overline{17.2}^b$	$\overline{16.3}^c$	$\overline{15.5}^c$	

Wet-milled germ level (%)	Fat level (%)			Means within corn level
	11	18	33	
0	15.9^d	15.1^c	13.4^b	14.8
3.5	16.3^{de}	16.5^e	15.8^d	16.2
	$\overline{16.1}$	$\overline{15.8}$	$\overline{14.6}$	

[a]Means of four replications.

[b-e]Means for DMG and WMG treatments not followed by a common superscript are significantly different (p < 0.05).

Table 3. Effects of corn on chemical and physical attributes of frankfurters with dry- and wet-milled corn germ flour[a]

Attribute	Dry-milled germ Corn level (%)		Wet-milled germ Corn level (%)	
	0	3.5	0	3.5
Fat (%)	12.3^b	10.9^c	16.5^b	13.8^c
Moisture (%)	66.1^b	65.9^b	62.9^b	63.5^b
Cooking loss (%)	10.8^b	10.1^b	8.7^b	17.1^c
Instron (cm):				
Fracture peak	10.4^b	11.2^b	11.6^b	10.6^b
Peak 1	12.4^b	12.9^b	11.7^b	15.8^c
Peak 2	8.1^b	8.2^b	9.3^b	11.4^c
Color: L	51.3^b	50.4^c	54.6^b	49.7^c
a	6.9^b	6.8^b	7.0^b	7.0^b
b	8.0^b	8.6^c	8.2^b	9.7^c

[a]Means of four replications.

[b-c]Means in a row for DMG or WMG not followed by a common superscript are significantly different ($p < 0.05$ L-value, $p < 0.01$ for fat and b-value for DMG treatments; $p < 0.05$ for peak 2 and $p < 0.001$ for other WMG attributes).

Table 4.   Sensory evaluation of frankfurters with dry-milled corn germ flour (DMG)[a]

Attribute	Fat level (%)			DMG level (%)	
	8	13	22	0	3.5
Tenderness	9.6^b	12.4^c	14.0^d	12.4^b	11.5^c
Chewiness	9.3^b	11.2^c	12.7^d	11.5^b	10.6^c
Juiciness	8.4^b	10.4^c	10.6^c	10.5^b	9.1^c
Cured flavor	9.1^{bc}	9.5^c	8.5^b	9.5^b	8.5^c
Off-flavor	5.2^b	4.7^b	4.9^b	5.2^b	4.7^b

[a]Means of four replications by 12 panelists.

[b-d]Means in a row for fat or corn level not followed by a common superscript are significantly different ($p < 0.01$ for cured flavor within fat level; $p < 0.001$ for all other attributes).

Table 5. Sensory evaluation of frankfurters with wet-milled corn germ flour (WMG)[a]

Attribute		Fat level (%)			Means within WMG level
		11	18	33	
Tenderness	0% WMG	10.0^b	11.5^c	14.1^e	11.9
	3.5% WMG	9.5^b	11.7^{cd}	12.1^{cd}	11.1
Chewiness	0% WMG	10.0^{bc}	11.2^d	12.5^e	11.2
	3.5% WMG	9.7^b	10.7^{cd}	10.4^{bcd}	10.3
Juiciness	0% WMG	10.2^d	11.7^e	12.6^e	11.5
	3.5% WMG	8.4^c	7.7^c	6.1^b	7.4
Cured flavor	0% WMG	10.5	10.7	9.0	10.1^b
	3.5% WMG	9.3 $\overline{9.9^b}$	8.3 $\overline{9.5^b}$	7.7 $\overline{8.4^c}$	8.4^c
Off-flavor	0% WMG	4.3	3.9	3.8	4.0^b
	3.5% WMG	7.5 $\overline{5.9^b}$	6.7 $\overline{5.3^b}$	7.2 $\overline{5.5^b}$	7.1^c

[a] Means of four replications by 10 panelists.

[b-e] Means not followed by a common superscript are significantly different (p < 0.05 for tenderness, chewiness and juiciness; p < 0.001 for cured flavor and off-flavor).

PART V.

PROTEIN EXTRACTION AND PENTOSAN CONTENT OF

DRY-MILLED CORN GERM MEAL

PROTEIN EXTRACTION AND PENTOSAN CONTENT OF

DRY-MILLED CORN GERM MEAL

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ABSTRACT

The protein, starch, crude fiber and pentosan contents and water hydration and oil-binding capacities of dry-milled corn germ meal were investigated. Fifty-five percent of the total germ protein was extracted from dry-milled corn germ meal (17.38% protein, 30.68% starch, 5.34% crude fiber, and 9.1% pentosans) with 0.1 N sodium hydroxide. Sixteen protein bands were separated by polyacrylamide gel electrophoresis. The dry-milled germ residue remaining after protein extraction (7.9% protein, 7.7% starch, 6.4% crude fiber, and 9.6% pentosans) was found to have a higher water hydration capacity (3.6 ml/g) than the extracted, dried protein (1.3 ml/g, 50.5% protein, 4.4% starch, 0.03% crude fiber).

INTRODUCTION

Protein concentrates from soy, oats, peas, rice, safflower, potato, peanut and other plant materials have been studied as nutritive and functional food additives (Mittal and Usborne, 1985). An alkaline extraction of protein from corn endosperm yielded a concentrate with 65% protein (Wu and Sexson, 1976). Protein concentrates from corn gluten meal also have been prepared (Neumann and Wall, 1984; Phillips and Sternberg, 1979). Phillips and Sternberg (1979) reported that a corn gluten meal concentrate with 67% protein had water- and fat-binding properties similar to those of soy concentrate.

The primary protein extracted from endosperm and gluten meal is zein. Zein is classified as an alcohol-soluble protein with little ability to absorb water or fat. However, corn germ protein is composed primarily of albumins and globulins, classified as water- and salt-soluble proteins, respectively. These proteins have a more complete amino acid composition and may have better functional properties than zein. Proteins remaining after the extraction of salt- and alcohol-soluble proteins are considered glutelins.

A protein isolate (73% protein) prepared from corn germ was able to stabilize an oil-in-water emulsion (Nielsen et al., 1973). The ability to bind fat is an important property of a protein intended for use as an extender in meat emulsions.

Corn germ meal is a secondary product of the dry- and wet-milling industries. Oil is extracted from the germ by pressing or hexane extraction. The heat of drying denatures the corn proteins. Amounts of

protein in defatted corn or endosperm extracted with 0.5 N sodium chloride were markedly reduced in meals heated to 143°C (Wall et al., 1975). Some electrophoretic bands were diminished in intensity suggesting that these proteins are more susceptible to the denaturing action of heat (Wall et al., 1975). Heat caused a decrease in the saline-soluble proteins of germ due to conformational changes in the protein and intermolecular disulfide bond formation (Wall et al., 1975).

Heating of germ during drying also reduces protein quality, but protein quality is better retained by solvent extraction than by expeller processing (Wall et al., 1971).

Dry-milled corn germ meal is 18% hemicellulose, 7% cellulose and 1% lignin (Watson, 1987). Pentosans are the predominant components of hemicellulose and have been found to bind large amounts of water.

Although researchers (Blessin et al., 1973; Lin and Zayas, 1987; Nielsen et al., 1973) have indicated that germ meals and germ proteins may be useful as binders in meats, germ meals have not been extensively studied. Previous work has shown that dry-milled corn germ meal in ground pork decreased cooking loss 9% when compared to control patties (Reitmeier and Prusa, 1988).

The objective of this study was to determine the extractability of the proteins in dry-milled corn germ meal and the functional properties and pentosan content of the residue remaining after protein extraction.

MATERIALS AND METHODS

Proximate Analysis

Dry-milled corn germ meal (Illinois Cereal Mills, Inc., Paris, IL) was analyzed for proximate composition. Moisture content was determined by drying 10 g meal 4 hr at 110°C in a Brabender Semiautomatic Moisture Tester (Type SAS, No. 951). Protein and crude fiber were determined by AOAC methods 2.057 and 7.066, respectively (AOAC, 1984), and starch was determined by Corn Refiners' Association method G-28 (CRA, 1986).

Protein Extraction

Water, sodium chloride and sodium hydroxide as solvents

Protein was extracted sequentially from dry-milled corn germ meal with water (pH 7.1), 0.5 N sodium chloride (pH 6.7) and 0.1 N sodium hydroxide (pH 12.5) (Figure 1). Meal and solvent (1:20) were stirred 1 hr at 21°C, then centrifuged at 10,000 x g, 25 min, 21°C. The extracts of water (H_2O), sodium chloride (NaCl) and sodium hydroxide (NaOH) were decanted and analyzed for soluble protein content (Hach et al., 1985). One extraction with each solvent was replicated seven times.

Solvent (90 ml) containing the extracted protein was adjusted to isoelectric pH 4.7 (Nielsen et al., 1973) with hydrochloric acid to precipitate the protein and centrifuged 25 min at 10,000 x g, 21°C. The supernantants were decanted and analyzed for soluble protein content. The protein precipitate was dried, weighed and analyzed for protein content (Hach et al., 1985).

Sodium hydroxide as solvent

Sodium hydroxide was selected for further study because it extracted more protein from dry-milled corn germ meal than water or sodium chloride. Extractions with sodium hydroxide at concentrations of 0.05, 0.1 and 0.2 N, ratios of meal to solvent of 1:10, 1:20 and 1:30, temperatures of 4°, 21° and 37°C and stirring times of 1, 2 and 3 hr were compared. Each variable was tested separately, using 0.1 N, 1:20 ratio, 21°C or 1 hr of stirring for the variables not tested. After each treatment, samples were centrifuged 25 min at 10,000 x g, 21°C. Percent protein in the extracts (soluble) and the dried residues was determined. One extraction of each treatment was replicated three times.

Based on parameters evaluated, optimum conditions for maximum extraction of protein from dry-milled corn germ meal were selected. Three extractions of the same germ meal sample were made. Samples were centrifuged 25 min at 10,000 x g, 21°C. The extract was decanted and analyzed for protein content. The residue was dried 18 hr at 90°C, then ground to a flour (35-mesh) in a food mill. Protein and pentosan contents and water hydration and oil-binding capacities of the dried residue were measured. The protein was precipitated from the extract by adjusting the pH to 4.7 and centrifuging 25 min at 10,000 x g, 21°C. The protein precipitate was dried, ground to a flour (35-mesh) and analyzed for protein and pentosan contents and water hydration and oil-binding capacities.

Water Hydration and Oil-Binding Capacities

The water hydration and oil-binding capacities of dry-milled corn germ meal were determined. The corn germ meal was ground to a flour (35-mesh) and dried. The water hydration and oil-binding capacities of wet-milled corn germ meals (A. E. Staley Manufacturing, Inc., Decatur, IL and Corn Products, CPC International, Inc., Argo, IL), corn gluten meal and zein (Sigma Chemical Co.), soy protein isolate (Pro-Fam, lot No. 51814), sodium caseinate (roller dried milk protein EM-HV, DMV, Veghel Holland, lot No. 102255-01) and vital wheat gluten (Midwest Grain Products, Inc.) were determined for comparison to the corn fractions. Water hydration capacity was determined by AACC method 88-04 (AACC, 1984), and reported as ml water bound by 1 g flour.

Oil-binding capacities of the protein products were determined by the method of Lin and Humbert (1974). One g dried flour and 6 ml corn oil were mixed 1 min with a spatula in a 50 ml centrifuge tube. After 30 min, the tube was centrifuged at 6420 x g for 25 min. The free oil was decanted, measured (ml) and reported as percent oil bound by 1 g flour.

Four replications of water hydration and oil-binding capacities for corn fractions and protein extenders were made. Water hydration and oil-binding capacities of the protein extracted and dried from dry-milled germ meal and the residue remaining after protein extraction (3 extractions with sodium hydroxide) were measured.

Pentosan Content

Pentosan contents of germ flour and residue were determined by a colorimetric assay with orcinol (Hashimoto et al., 1987a). Approximately 10 mg flour was digested in 2 ml 2 N hydrochloric acid 2.5 hr at 100°C. When cool, 2 ml of 2 N sodium carbonate (Na_2CO_3) was added to neutralize the solution. Two ml of a suspension of dry baker's yeast (5 mg/ml sodium phosphate buffer, pH 7.0) were used to remove fermentable sugars from the digest. Samples were incubated 1 hr at 37°C, 18 hr at 21°C and then centrifuged at 10,000 x g, 10 min. An aliquot of supernatant (0.25 ml) was mixed with 2.75 ml water, 3 ml ferric chloride (0.1% $FeCl_3$ in concentrated hydrochloric acid, w/v) and 0.3 ml orcinol (1% in 100% ethanol, w/v). Samples were heated 30 min at 100°C, cooled and read at 670 nm on a Gilford 240 spectrophotometer. Percent xylose was determined using a standard curve with 13.71, 34.26, 68.49, 102.75, 137.01 µg xylose/ml (r = 0.998). Pentosans were calculated from percent xylose (% xylose x 0.88 = % pentosans). The pentosan contents of whole wheat flour (General Mills, Inc., Minneapolis, MN), wheat bran (Hodgson Mill, Gainesville, MO), corn bran ('Golden Harvest', Natural Sales Co., Pittsburgh, PA) and wet-milled corn germ flour (A. E. Staley Manufacturing, Inc., Decatur, IL) were measured for comparison.

Electrophoresis

Samples (0.7 ml) containing 4.11, 3.33 and 5.82 mg protein in 0.05 N potassium hydroxide (KOH) (pH 12.3) from the water, sodium chloride and sodium hydroxide extractions, respectively, were mixed with 0.1 ml

2-mercaptoethanol and 0.2 ml tracking dye (bromphenol blue in 2.5 ml 1 M 2[N-morpholine] ethane sulfonic acid, pH 6.5, 12.5 ml 20% sodium dodecyl sulfate (SDS) in water, 25 g sucrose and water to 50 ml volume), and heated at 80°C, 1 hr. Protein samples were stored at -18°C and thawed 2 hr before application to the gel. Thirty μl of sample (containing 123, 100 and 175 μg protein for water, sodium chloride and sodium hydroxide extractions, respectively) were applied to the gel.

Slab (16 x 20 cm) polyacrylamide gels at 10% concentration (15 ml acrylamide-bisacrylamide, 19.5 ml water, 9.0 ml 1.5 M Tris-HCl buffer, pH 8.8, 0.225 ml 20% SDS, and 0.45 ml 0.1 M ethylene diamine tetraacetic acid (EDTA)) were prepared. The gels were overlaid with 3 cm stacking gel of 3.2% polyacrylamide (4.8 ml acrylamide-bisacrylamide, 29.7 ml water, 9.0 ml 1.5 M Tris-HCl buffer, pH 8.8, 0.225 ml 20% SDS and 0.45 ml 0.1 M EDTA).

The ratio of acrylamide to bisacrylamide was 30:1. Polymerization was initiated with 10% ammonium persulfate (0.45 ml) and 6.6 N,N',N'-tetramethylethylene diamine (0.03 ml). The running and stacking gels were prepared on the day of the run.

Electrophoretic separation in Tris-glycine buffer (pH 7.2) occurred at 11 mA (1 hr 45 min) and 25 mA (4 hr) with 15°C water cooling. Gels were fixed in Coomassie Brilliant Blue stain (1 g/l methanol: acetic acid:water, 530:400:70, respectively). Destaining was done with three changes of water, methanol and acetic acid (530:400:70). Gels were stored in 7% acetic acid at 4°C, SDS-polyacrylamide gel electrophoresis (SDS-PAGE) then photographed. Separations of each protein sample were repeated three times.

The approximate molecular weights of proteins in corn germ meals were computed from linear regressions of the migration distance (R_f) versus the logarithm of the molecular weight plots of the SDS-PAGE standard (SDS-7, Sigma Chemical Co.). The standard contained bovine albumin (M.W. 66,000), ovalbumin (M.W. 45,000), glyceraldehyde-3-phosphate dehydrogenase (M.W. 36,000), carbonic anhydrase (M.W. 29,000), trypsinogen (M.W. 24,000), trypsin inhibitor (M.W. 20,000) and α-lactalbumin (M.W. 14,200). The correlation coefficient between log M.W. and R_f was -0.996.

RESULTS AND DISCUSSION

Proximate Analysis

Dry-milled corn germ meal used in this study contained 17.38% protein, 30.68% starch, 5.34% crude fiber and 7.3% moisture. Wet-milled germ meal from Corn Products Co. contained 23.57% protein, 12.89% starch, 15.40% crude fiber and 9.9% moisture. Wet-milled germ meal from A. E. Staley Manufacturing, Inc. was found to contain 24.09% protein, 18.18% starch, 10.79% crude fiber and 10.32% moisture.

Protein Extraction

Water, sodium chloride and sodium hydroxide as solvents

The results of the sequential extraction of protein from dry-milled corn germ meal with water, sodium chloride and sodium hydroxide are presented (Table 1). Sodium hydroxide extracted the most protein followed by water and sodium chloride. Seventy-four percent of the sodium hydroxide-extracted protein was precipitated at pH 4.7 compared to 15 and 11% for water and sodium chloride treatments, respectively.

In contrast, Paulis and Wall (1969) reported that 0.5 M sodium chloride extracted more nitrogen (17%) from corn germ than water (7%) or other solvents. The maximum amount of protein in corn germ was solubilized by a sodium hydroxide solution without added sodium chloride (Nielsen et al., 1973). Landry and Moureaux (1980) indicated that water, as the first extractant of endosperm protein may lead to the insolubilization of some albumins which were later extracted

in the sodium chloride solution and some of the globulins were extracted with the glutelin fraction.

Sodium hydroxide as solvent

The results of alkaline extraction of protein from dry-milled germ meal under various conditions are presented (Table 2). A 0.2 N concentration of NaOH removed the least amount of protein from the germ meal. Temperature and time of extraction did not greatly influence percentage of protein extracted. In a similar study, blending extracted more protein than stirring due to an increase in heat (Nielsen et al., 1973). However, Foster et al. (1950) reported higher protein extraction yields at room temperature. Conditions selected for subsequent protein extractions were 0.1 N sodium hydroxide, 1:20 ratio of germ to solvent and 21°C for 1 hr.

The first sodium hydroxide extraction removed the most protein (Table 3). The residue remaining after three extractions was found to contain 7.90% protein, 7.69% starch and 6.4% crude fiber. More than 50% of the total protein in the germ was extracted. Nielsen et al. (1973) reported that 52% protein was extracted with 0.025 M sodium hydroxide (pH 8.7). The dried protein precipitate was found to contain 50.47% protein, 4.43% starch and 0.03% crude fiber.

Water Hydration and Oil-Binding Capacities

The water hydration and oil-binding capacities of dry-milled germ flour, protein extracted from dry-milled germ and residue, other corn

fractions and three commonly used meat extenders are presented (Table 4). The water hydration capacity of dry-milled corn germ flour was lower than the hydration capacity of wet-milled germ flours, sodium caseinate and soy protein isolate.

The water hydration capacity of the protein precipitate from dry-milled corn germ meal was 1.4 ml/g. The residue remaining after protein extraction had a water hydration capacity of 3.6 ml/g.

The water hydration capacity of wet-milled corn germ flours and gluten meal was greater than or comparable to the water hydration capacity of sodium caseinate, soy protein isolate and vital wheat gluten. Wet-milled germ flour (CPC), gluten meal and zein bound more oil than soy protein isolate.

Nielsen et al. (1979) reported that the hydration capacities (AACC method 56-20) of dry- and wet-milled corn germ meal were 4.2 and 6.8-8.0 g/g, respectively. Method 56-20 is for hydration capacity of pregelatinized cereal products and uses an excess of water. The hydration capacity of a protein concentrate from corn endosperm was reported to be 4.2 g/g (Wu and Sexson, 1976).

Pentosan Content

The pentosan contents of the corn fractions are presented (Table 5). The pentosan contents of dry-milled germ meal and residue after protein extraction were similar. The alkaline extraction treatment may have changed the cell wall components to bind more water. Alteration of the cell wall structure may explain the higher water

hydration capacity for the residue (3.6 ml/g) than for the dry-milled

germ flour (1.6 ml/g). Pentosans and some cellulose fractions are

alkali-soluble (Pomeranz, 1985).

Dry-milled corn germ was reported to contain 12.5% pentosans

(Garcia et al., 1972). Inglett and Blessin (1979) reported that

dry-milled germ (25.3% protein, 4.2% fiber, 24.7% starch, 13.8%

sugars, 0.5% fat, 10.3% ash) contained 11.7% pentosans.

The pentosan content of wet-milled corn germ flours was found to

be 22.1 to 28.8% (Nielsen et al., 1979). Hashimoto et al. (1987b)

reported 6.71% pentosans in whole wheat flour and 34.72% pentosans in

corn bran. Cerning and Guilbot (1973) reported 26.35% xylose in wheat

bran.

Electrophoresis

The calculated molecular weights of proteins extracted from dry-

milled corn germ meal with water, 0.1 N sodium chloride and 0.5 N sodium

hydroxide are presented in Table 6. A photograph of SDS-PAGE

separation of the proteins is presented in Figure 2.

Albumins and globulins constitute 28 and 24%, respectively, of

the germ protein (Paulis and Wall, 1969). Results of gel electro-

phoretic investigations of albumins and globulins of corn indicate

that the water- and salt-soluble fractions are very heterogeneous

(Cross and Adams, 1983). Separation of albumins and globulins from

corn germ is not distinct and yields vary with the method of extraction,

particularly with the addition of reducing agents (Paulis and Wall,

1969; Paulis et al., 1975; Wilson et al., 1981).

SDS-PAGE techniques separated both albumin and globulin fractions of corn germ into 20 different components (Lasztity, 1984). Prominent components of albumins and globulins separated by SDS-PAGE have molecular weights of 12,000, 25,000, 41,000 and 62,000 (Paulis et al., 1975).

Some of the bands of the soluble proteins of corn germ are identical with the bands of reduced glutelins (Lasztity, 1984). Five to fifteen percent of the insoluble glutelins of corn may be linked to cell wall components (Lasztity, 1984).

The molecular weights of the proteins extracted with water, sodium chloride and sodium hydroxide are similar, with a few additional proteins in the sodium hydroxide extraction. The heat and drying during processing of germ meal may have denatured the proteins so that the classification by solubility probably is not valid. The proteins extracted from dry-milled corn germ meal with water or sodium chloride and separated by SDS-PAGE may be albumins and globulins. The additional bands resolved in the alkali-extracted treatment may be albumins, globulins or glutelins separated from cell wall components.

CONCLUSIONS

Dry-milled corn germ residue had a higher water hydration capacity than the water hydration capacities of the untreated germ meal and the alkaline-extracted protein. The sodium hydroxide extraction treatment may have affected the components of the germ meal. The pentosan and crude fiber contents of the germ and residue were similar, but the material in the residue may have been modified by alkali to bind more water.

REFERENCES CITED

American Association of Cereal Chemists. 1983. Approved methods of the American Association of Cereal Chemists', 8th ed. The Association: St. Paul, MN.

Association of Official Analytical Chemists. 1984. Official methods of analysis, 14th ed. The Association: Arlington, VA.

Blessin, C. W., Garcia, W. J., Deatherage, W. L., Cavins, J. F., and Inglett, G. E. 1973. Composition of three food products containing defatted corn germ flour. J. Food Sci. 38:602-606.

Cerning, J., and Guilbot, A. 1973. A specific method for the determination of pentosans in cereals and cereal products. Cereal Chem. 50:176-184.

Corn Refiners' Association. 1986. Standard analytical methods of the member companies of Corn Refiners' Assoc., 6th ed. Corn Industries Research Foundation, Corn Refiners' Assoc., Inc., Washington, DC.

Cross, J. W., and Adams, W. R. 1983. Differences in the embryo-specific globulins among maize inbred lines and their hybrids. Crop Science 23:1160-1162.

Foster, J. F., Yang, J. T., and Yui, N. M. 1950. Extraction and electrophoretic analysis of proteins of corn. Cereal Chem. 27:477-487.

Garcia, W. J., Gardner, H. W., Cavins, J. F., Stringfellow, A. C., Blessin, C. W., and Inglett, G. E. 1972. Composition of air-classified defatted corn and wheat-germ flours. Cereal Chem. 49:499-507.

Hach, C. C., Brayton, S. V., and Kopelove, A. B. 1985. A powerful Kjeldahl nitrogen method using peroxy monosulfuric acid. J. Agric. Food Chem. 33:1117-1123.

Hashimoto, S., Shogren, M. D., and Pomeranz, Y. 1987a. Cereal pentosans: Their estimation and significance. I. Pentosans in wheat and milled wheat products. Cereal Chem. 64:30-34.

Hashimoto, S., Shogren, M. D., Bolte, L. C., and Pomeranz, Y. 1987b. Cereal pentosans: Their estimation and significance. III. Pentosans in abraded grains and milling by-products. Cereal Chem. 64:39-41.

Inglett, G. E., and Blessin, C. W. 1979. Food applications of corn germ protein products. J. Am. Oil Chemists' Soc. 56:479-481.

Landry, J., and Moureaux, T. 1980. Distribution and amino acid composition of protein groups located in different histological parts of maize grains. J. Agric. Food Chem. 28:1186-1191.

Lasztity, R. 1984. Maize proteins in The Chemistry of Cereal Proteins. CRC Press, Inc., Boco Raton, FL. 285 pp.

Lin, C. S., and Zayas, J. 1987. Influence of corn germ protein on yield and quality characteristics of comminuted meat products in a model system. J. Food Sci. 52:545-548.

Lin, M. J. Y., and Humbert, E. S. 1974. Certain functional properties of sunflower meal products. J. Food Sci. 39:368-370.

Mittal, G. S., and Usborne, W. R. 1985. Meat emulsion extenders. Food Technol. 39:121-130.

Nielsen, H. C., Inglett, G. E., Wall, J. S., and Donaldson, G. L. 1973. Corn germ protein isolate — Preliminary studies on preparation and properties. Cereal Chem. 50:435-443.

Nielsen, H. C., Wall, J. S., and Inglett, G. E. 1979. Flour containing protein and fiber made from wet-mill corn germ, with potential food use. Cereal Chem. 56:144-146.

Neumann, P. E., and Wall, J. S. 1984. Chemical and physical properties of proteins in wet-milled corn gluten. Cereal Chem. 61:353-356.

Paulis, J. W., Bietz, J. A., and Wall, J. S. 1975. Corn protein subunits: Molecular weights determined by sodium dodecyl sulfate-polyacrylamide gel electrophoresis. J. Agr. Food Chem. 23: 197-201.

Paulis, J. W., and Wall, J. S. 1969. Albumins and globulins in extracts of corn grain parts. Cereal Chem. 46:263-273.

Phillips, R. D., and Sternberg, M. 1979. Corn protein concentrate: Functional and nutritional properties. J. Food Sci. 44:1152-1155.

Pomeranz, Y. 1985. Carbohydrates: Structural polysaccharides, pectins, and gums in Functional Properties of Food Components. Academic Press, Inc., Orlando, FL. 536 pp.

Reitmeier, C. A., and Prusa, K. J. 1988. The addition of corn milling products to ground pork of various fat percentages. Study 1. Dry- and wet-milled corn germ meals. Submitted.

Wall, J. S., James, C., and Cavins, J. F. 1971. Nutritive value of protein in hominy feed fractions. Cereal Chem. 48:456-465.

Wall, J. S., James C., and Donaldson, G. L. 1975. Corn proteins: Chemical and physical changes during drying of grain. Cereal Chem. 52:779-790.

Watson, S. A. 1987. Structure and composition. Pages 53-82 in Watson, S. A., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology, St. Paul, MN.

Wilson, C. M., Shewry, P. R., and Miflin, B. J. 1981. Maize endosperm proteins compared by sodium dodecyl sulfate gel electrophoresis and isoelectric focusing. Cereal Chem. 58:275-281.

Wu, Y. V., and Sexson, K. R. 1976. Protein concentrate from normal and high-lysine corns by alkaline extraction: Composition and properties. J. Food Sci. 41:512-515.

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ACKNOWLEDGMENTS

Table 1. Protein extraction from dry-milled corn germ meal with
water, sodium chloride and sodium hydroxide[a]

Solvent	Protein (%) in solvent	Protein (%) in solvent after pH 4.7
Water	2.7	2.3
Sodium chloride	1.8	1.6
Sodium hydroxide	6.1	1.6

[a]Means of seven replications.

Table 2.   Protein extraction from dry-milled corn germ meal with
sodium hydroxide and various conditions[a]

Variable		Protein (%) in solvent
Concentration:	0.05 N	8.5[b]
	0.1 N	9.4[b]
	0.2 N	6.1[c]
Ratio:	1:10	9.9[b]
	1:20	10.2[b]
	1:30	10.0[b]
Temperature:	4°C	9.2[b]
	21°C	9.5[bc]
	37°C	9.9[c]
Time:	1 hr	9.6[b]
	2 hr	9.8[b]
	3 hr	10.0[b]

[a] Means of three replications.

[b] Means in a column for each variable not followed by a common
superscript are significantly different ($p < 0.001$ for concentration
variable of residue, $p < 0.05$ for concentration variable of extract
and ratio of residue, $p < 0.01$ for temperature of extract).

Table 3. Three protein extractions from dry-milled corn germ meal with sodium hydroxide[a,b]

Extraction	Protein (%) in solvent
1	10.4
2	1.8
3	1.0

[a] Means of five replications.

[b] Extraction conditions were 0.1 N NaOH, 1 hr stirring, 21°C.

Table 4. Water hydration and oil-binding capacities of corn fractions and meat binders[a]

Fraction	Water hydration capacity (ml/g)	Oil-binding capacity (%)
Dry-milled corn germ flour	1.6	21.3
Protein extracted with NaOH	1.3	22.5
Residue	3.6	20.0
Wet-milled corn germ flour[b]: 1	3.2	30.0
2	4.7	35.4
Corn gluten meal	1.5	36.7
Zein	0.6	70.9
Sodium caseinate	3.4	40.8
Soy protein isolate	3.0	30.4
Vital wheat gluten	1.5	23.4

[a]Means of four replications.

[b]1 = A. E. Staley Manufacturing, Inc., Decatur, IL; 2 = Corn Products, CPC International, Argo, IL.

Table 5. Pentosan contents of dry-milled corn germ meal and other cereal fractions[a]

Cereal fraction	Pentosan (%)[b]
Dry-milled corn germ meal	9.1
Residue[c]	9.6
Wet-milled corn germ meal	18.7
Whole wheat flour	6.9
Wheat bran	15.7
Corn bran	29.2

[a]Means of three replications.

[b]Pentosan (%) = xylose (%) x 0.88.

[c]Three extractions with 0.1 N NaOH.

Table 6. Molecular weights of proteins extracted from dry-milled corn germ meal with water, sodium chloride and sodium hydroxide[a]

Band No.	Molecular weight		
	Water	NaCl	NaOH
1	13,425	12,622	15,667
2	15,772	15,775	17,132
3	21,060	21,196	18,732
4	23,355	23,683	21,060
5	24,352	24,659	23,034
6	25,541	25,549	25,367
7	28,320	28,808	27,386
8	29,504	29,204	28,320
9	31,304	31,304	32,914
10	34,107	34,107	35,717
11	36,533	36,784	36,533
12	42,795	42,017	42,218
13	48,442	48,442	48,115
14	53,713	53,713	50,832
15	58,740	57,947	53,351
16	—	—	58,341

[a]Means of calculated molecular weights of three replications SDS-PAGE.

<u>5 g dry-milled corn germ meal</u>
    +100 ml water
    Stir 1 hr, 21°C
    Centrifuge ──────────────────────► Supernatant
                                            │ Adjust to pH 4.7
                                            ▼ Centrifuge

Germ meal precipitate
    + 100 ml NaCl | Protein Precipitate — H_2O |
    Stir 1 hr, 21°C
    Centrifuge ──────────────────────► Supernatant
                                              │ Adjust to pH 4.7
                                            ▼ Centrifuge

Germ meal precipitate | Protein Precipitate — NaCl |
    + 100 ml NaOH ────────────────────► Supernatant
    Stir 1 hr, 21°C
    Centrifuge   │ Adjust to pH 4.7
                                            ▼ Centrifuge

                                            | Protein Precipitate — NaOH |

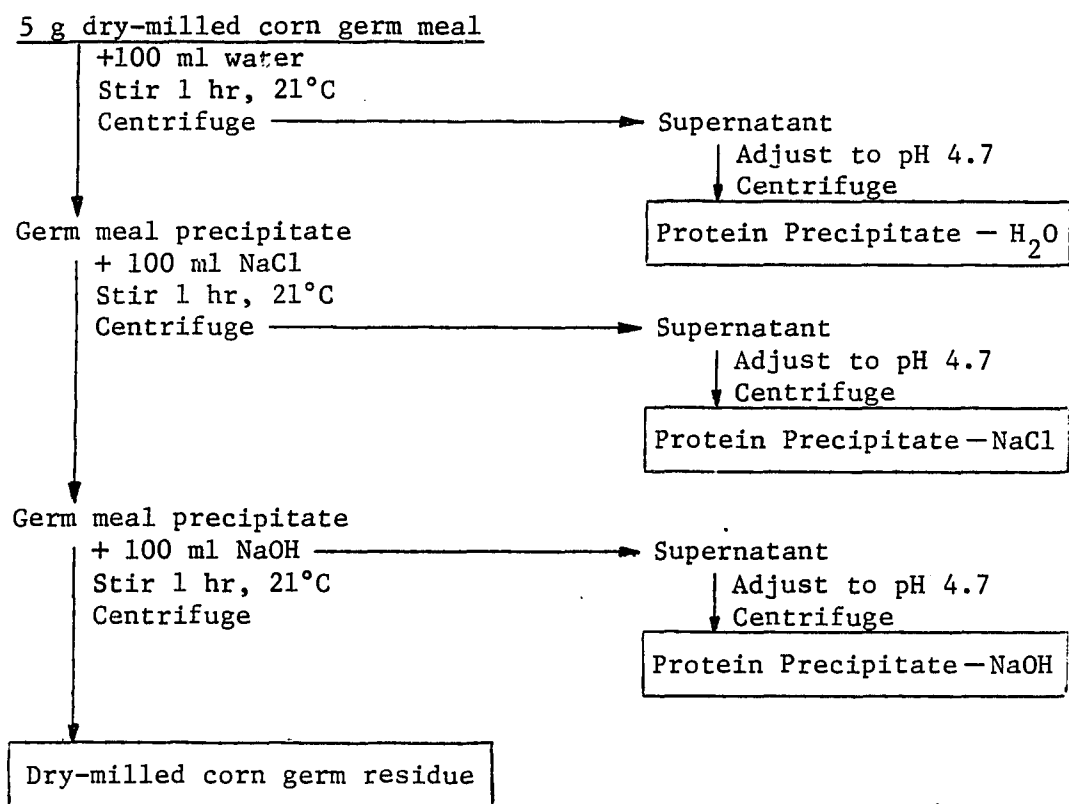| Dry-milled corn germ residue |

Figure 1.   Sequential protein extraction from dry-milled corn germ
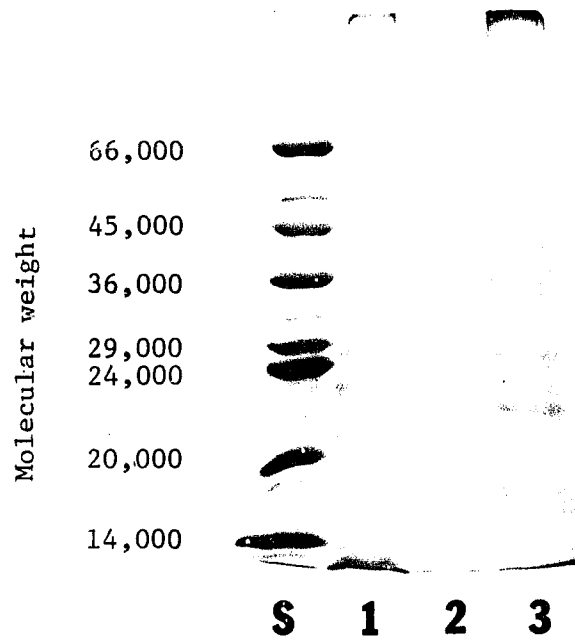   meal

Figure 2. Protein bands from dry-milled corn germ meal. S = standard, 1 = water, 2 = 0.5 N NaCl and 3 = 0.1 N NaOH extractions.

SUMMARY

The fat content of meats consumed by the American public is de-
creasing and probably will continue to decrease as the industry
responds to consumer demands for lower fat and lower cholesterol meats.
Changes in formulations and processing or the addition of ingredients
will be necessary to maintain sensory quality of low-fat meats.
The purpose of this study was to determine the functional charac-
teristics of corn secondary products in ground pork and in pork frank-
furters.

Effects of Fat

Sensory evaluation of ground pork and frankfurters indicated that
tenderness and juiciness increased as fat level increased. Generally,
moisture and protein contents decreased as the fat level of cooked
meat increased. Cooking loss is greater for high fat (30%) products
than for meats with lower fat contents.

Raw ground pork containing 4 or 9% fat contained less cholesterol
than samples containing 18 or 23% fat. The cholesterol content (wet
weight) of cooked pork did not differ among fat levels.

Cooking Loss

Dry- and wet-milled germ flours and zein addition at the 5%
level decreased cooking losses 9, 7.5 and 4.2%, respectively, when
compared to ground pork without corn additions. Corn gluten meal

addition did not influence yield.

Germ flours did not increase the yield of cooked frankfurters. However, the frankfurter emulsion may have been influenced by other factors. The detrimental effect of germ flours may have resulted from competition for available moisture with the meat proteins and water surrounding the fat globules. The method of preparing frankfurters in a model system may have stressed the emulsion. Hydration of the germ meals before addition to meat, more effective comminution and preparation of frankfurters in casings may result in more effective binding by dry- and wet-milled corn germ flours.

Sensory

The color changes that resulted when corn secondary products were added to pork probably are not serious obstacles to usage. Generally, the yellow color of ground pork and pork frankfurters increased with the addition of corn. Addition of wet-milled corn germ flour decreased and zein increased the lightness of the cooked meat.

The addition of corn secondary products to patties and frankfurters decreased pork or cured flavor intensity scores. Zein and wet-milled corn germ flour addition to pork increased the off-flavor intensity scores. Dry-milled corn germ flour did not impart an off-flavor to frankfurters.

Beany, grassy, corny, cereal-like, nutty, stale and musty were flavors noted by the sensory panelists. Reduction of the off-flavors from wet-milled corn germ flour would be necessary before utilization of the flour in meats could be recommended.

The sensory tenderness scores of ground pork patties and pork frankfurters decreased with the addition of germ flours and zein. Generally, the Instron compression values followed the same trend as the sensory scores. In contrast, cooked pork patties with dry-milled germ flour had lower Instron compression values than the control patties. The higher starch content (31%) and lower crude fiber and pentosan contents (5 and 11%, respectively) of the dry-milled germ meal may be responsible for the increased tenderness when compared to wet-milled germ meal (13-18% starch, 11-15% crude fiber and 21% pentosans).

Water Hydration Capacity

The water hydration capacity of dry-milled corn germ residue was greater (3.6 ml/g) than the hydration capacities of protein extracted with 0.1 N sodium hydroxide from dry-milled germ (1.3 ml/g) and the untreated dry-milled germ flour (1.6 ml/g). The alkali treatment may have altered the structure of the residue components and increased their ability to bind water. The functional properties of the proteins were not improved by the extraction conditions of this study. The high water hydration capacity of corn germ meal appears to be due to the hemicellulose fraction. Further research on the utilization of corn milling secondary products in foods should concentrate on the fiber components.

REFERENCES CITED

Alexander, R. J. 1987. Corn dry milling: Processes, products, and
    applications. Pages 351-376 in Watson, S. A., and Ramstad, P. E.
    (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem.,
    St. Paul, MN.

American Heart Association. 1985. An eating plan for healthy
    Americans. American Heart Association, Dallas, TX. 37 pp.

Barbieri, R., and Casiraghi, E. M. 1983. Production of a food grade
    flour from defatted corn germ meal. J. Food Technol. 18:35-41.

Berry, B. W., and Leddy, K. F. 1984. Effects of fat level and cooking
    method on sensory and textural properties of ground beef patties.
    J. Food Sci. 49:870-875.

Blessin, C. W., Garcia, W. J., Deatherage, W. L., Cavins, J. F., and
    Inglett, G. C. 1973. Composition of three food products con-
    taining defatted corn germ flour. J. Food Sci. 38:602-606.

Blessin, C. W., Inglett, G. E., Garcia, W. J., and Deatherage, W. L.
    1972. Defatted germ flour-food ingredient from corn. Food
    Product Devel. 5:34-35.

Buck, J. S., Walker, C. E., and Watson, K. S. 1987. Incorporation of
    corn gluten meal and soy into various cereal-based foods and re-
    sulting functional, sensory, and protein quality. Cereal Chem.
    64:264-269.

Bushway, A. A., Belyea, P. R., True, R. H., Work, T. M., Russell,
    D. O., and McGann, D. F. 1982. Potato starch and flour in frank-
    furters: Effect on chemical and sensory properties, and total
    plate counts. J. Food Sci. 47:402-408.

Canolty, N. L., Schoenborne, B. M., Gregg, V. A., and Haring, R. V.
    1977. Relative protein value of defatted corn germ flour. J.
    Food Sci. 42:269-270.

Cross, H. R., Berry, B. W., and Wells, L. H. 1980. Effects of fat
    level and source on the chemical, sensory and cooking properties
    of ground beef patties. J. Food Sci. 45:791-793.

DePadua, M. R. 1983. Some functional and utilization characteristics
    of sesame flour and proteins. J. Food Sci. 48:1145-1147.

Gardner, H. W., Inglett, G. E., Deatherage, W. L., Kwolek, W. F.,
    and Anderson, R. A. 1971. Food products from corn germ: Evalua-
    tion as a food supplement after roll-cooking. J. Food Sci. 36:
    640-643.

Hermannson, A. M. 1977. Functional properties of proteins for foods-water vapor sorption. J. Food Technol. 12:177-187.

Inglett, G. E., and Blessin, C. W. 1979. Food applications of corn germ protein products. J. Am. Oil Chemists' Soc. 56:479-481.

Kinsella, J. E. 1976. Functional properties of proteins in foods: A survey. C.R.C. Critical Reviews in Food Science and Nutrition 7:219-280.

Kotula, A. W., and Berry, B. W. 1986. Addition of soy proteins to meat products. Pages 75-89 in Ory, R. L. (Ed.), Plant Proteins: Applications, Biological Effects, and Chemistry. American Chemical Society, Washington, DC.

Kregel, K. K., Prusa, K. J., and Hughes, K. V. 1986. Cholesterol content and sensory analysis of ground beef as influenced by fat level, heating and storage. J. Food Sci. 51:1162-1165.

Lauck, R. M. 1975. The functionality of binders in meat emulsions. J. Food Sci. 40:736-740.

Leath, M. N., and Hill, L. D. 1987. Economics of production, marketing and utilization. Pages 201-252 in Watson, S. A., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem., St. Paul, MN.

Lin, C. S., and Zayas, J. 1987. Influence of corn germ protein on yield and quality characteristics of comminuted meat products in a model system. J. Food Sci. 52:545-548.

Lin, M. J. Y., Humbert, E. S., Sosulski, F. W., and Card, J. W. 1975. Quality of weiners supplemented with sunflower and soy products. J. Inst. Can. Sci. Technol. Aliment. 8(2):97-101.

Lucisano, M., Casiraghi, E. M., and Barbieri, R. 1984. Use of defatted corn germ flour in pasta products. J. Food Sci. 49:482-497.

May, J. B. 1987. Wet milling: Process and products. Pages 377-397 in Watson, S. A., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem., St. Paul, MN.

Mittal, G. S., and Usborne, W. R. 1985. Meat emulsion extenders. Food Technol. 39:121-130.

Neumann, P. E., and Wall, J. S. 1984. Chemical and physical properties of proteins in wet-milled corn gluten. Cereal Chem. 61:353-356.

Nielsen, H. C., Wall, J. S., and Inglett, G. E. 1979. Flour containing protein and fiber made from wet-mill corn germ, with potential food use. Cereal Chem. 56:144-146.

Olson, D. G. 1981. Non-meat ingredients. Pages 5-7 in Proceedings Second Annual Sausage and Processed Meats Short Course, Iowa State University Meats Laboratory, Ames, IA.

Patel, K. M., Merkel, R. A., Reynolds, A. E., and Youngs, C. G. 1980. Texturized navy bean protein concentrate as a meat extender in frankfurters. J. Inst. Can. Sci. Technol. Aliment. 13(1):5-9.

Peri, C., Barbieri, R., and Casiraghi, E. M. 1983. Physical, chemical and nutritional quality of extruded corn germ flour and milk protein blends. J. Food Technol. 18:43-52.

Phillips, R. D., and Sternberg, M. 1979. Corn protein concentrate: Functional and nutritional properties. J. Food Sci. 44:1152-1155.

Rakosky, J. 1974. Soy grits, flour, concentrates, and isolates in meat products. J. Am. Oil Chemists' Soc. 51:123-127.

Rakosky, J. 1970. Soy products in the meat industry. J. Agric. Food Chem. 18(6):1005-1009.

Reichert, R. D. 1981. Quantitative isolation and estimation of cell wall material from dehulled pea (Pisum sativum) flours and concentrates. Cereal Chem. 58:266-270.

Reiners, R. A., Wall, J. S., and Inglett, G. E. 1973. Corn proteins: Potential for their use. Pages 285-302 in Symposium Proceedings, 58th Annual Meeting, Am. Assoc. Cereal Chem., St. Paul, MN.

Rhee, K. S., and Smith, G. C. 1983. Effect of cooking on cholesterol content containing different amounts of beef, textured soy protein and fat. J. Food Sci. 48:268-269.

Rooney, L. W., and Serna-Saldivar, S. O. 1987. Food uses of whole corn and dry-milled fractions. Pages 399-429 in Watson, S. A., and Ramstead, P. E. (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem., St. Paul, MN.

Rust, R. E. 1987. Sausage products. Pages 457-485 in Price, J. F., and Schweigert, B. S. (Eds.), The Science of Meat and Meat Products. Food and Nutrition Press, Inc., Westport, CN.

Smith, G. C., Juhn, H., Carpenter, Z. L., Mattil, K. F., and Cates, C. M. 1973. Efficacy of protein additives as emulsion stabilizers in frankfurters. J. Food Sci. 38:849-855.

Sosulski, F. W., and Sosulski, K. 1986. Composition and functionality of protein, starch, and fiber from wet and dry processing of grain legumes. Pages 176-189 in Ory, R. L. (Ed.), Plant Proteins: Applications, Biological Effects, and Chemistry. American Chemical Society, Washington, DC.

Terrell, R. N., Brown, J. A., Carpenter, Z. L., Mattil, K. F., and Monagle, C. W. 1979. Effects of oilseed proteins, at two replacement levels, on chemical, sensory and physical properties of frankfurters. J. Food Sci. 44:865-868.

Tsen, C. C. 1980. Cereal germs used in bakery products: Chemistry and nutrition. Pages 245-253 in Inglett, G. E., and Munck, L. (Eds.), Cereals for Food and Beverages. Academic Press, New York.

Tsen, C. C., Mojibian, C. N., and Inglett, G. E. 1974. Defatted corn-germ flour as a nutrient fortifier in bread. Cereal Chem. 51:262-271.

Tu, C., Powrie, W. D., and Fennema, O. 1967. Free and esterified cholesterol content of animal muscles and meat products. J. Food Sci. 32:30-34.

USDA. 1980. Composition of Foods. U.S. Dept. Agric., Agriculture Handbook 8-7. USDA, Washington, DC. 92 pp.

Wall, J. S., James, C., and Cavins, J. F. 1971. Nutritive value of protein in hominy feed fractions. Cereal Chem. 48:456-465.

Watson, S. A. 1987. Structure and composition. Pages 53-82 in Watson, S. A., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem., St. Paul, MN.

Wills, R. B. H., and Kabirullah, M. 1981. Use of sunflower protein in sausages. J. Food Sci. 46:1657-1658.

Wilson, C. M. 1987. Proteins of the kernel. Pages 273-310 in Watson, S. A., and Ramstad, P. E. (Eds.), Corn: Chemistry and Technology. Am. Assoc. Cereal Chem., St. Paul, MN.

Wolf, W. J. 1970. Soybean proteins: Their functional, chemical, and physical properties. J. Agric. Food Chem. 18:969-976.

Wu, Y. V., and Sexson, K. R. 1976. Protein concentrate from normal and high-lysine corns by alkaline extraction: Composition and properties. J. Food Sci. 41:512-515.

ACKNOWLEDGMENTS

I want to thank Steve Hill, Elaine Fondroy, Michaeleen Lonergan, Barbara Warner, Chris Dinkel, and Susan Krueger, the members of the sensory evaluation panels, the staff of the Food and Nutrition Department, Pearlly Yan and Letha DeMoss for their assistance and good humor.

Chris Fedler deserves a special thanks for her technical expertise, energy and enthusiasm.

I appreciate the assistance of the members of my committee. I especially appreciate the guidance of Ken Prusa.

I am grateful to my friends, especially Judy Brown, Joyce McMurtrey and JoAnn Holland, and to my family for their support and encouragement over the years.

I am most grateful to my husband, Randy Thornhill, for his love, tolerance, patience and understanding throughout the course of this work.

APPENDIX A.

SCORE CARD FOR THE SENSORY

EVALUATION OF GROUND PORK

Name _____ DATE _____

GROUND PORK CHARACTERISTICS

Place a line perpendicular to the score line at the point which best describes your evaluation of the characteristics listed. Label each mark with the sample code number.

Evaluation of the cooked product.

SURFACE COLOR

Very Dark Brown   Very Light Brown

JUICINESS

Extremely	Moderately	Moderately	Extremely
Juicy	Juicy	Dry	Dry

TENDERNESS

Extremely	Moderately	Moderately	Extremely
Tender	Tender	Tough	Tough

PORK FLAVOR INTENSITY

Extremely	Moderately	Slightly	None
Intense	Intense	Intense	

OFF-FLAVOR INTENSITY

Extremely	Moderately	Slightly	None
Intense	Intense	Intense	

MOUTHCOATING

Extremely	Moderately	Slightly	None
Abundant	Abundant	Abundant	

APPENDIX B.

SCORE CARD FOR THE SENSORY

EVALUATION OF FRANKFURTERS

SENSORY CHARACTERISTICS OF FRANKFURTERS EXTENDED WITH CORN GERM FLOUR

Name _____

Date _____

Place a vertical mark across each horizontal line to indicate the intensity of each of the following characteristics of frankfurters. Label each mark with the code number of the sample that it represents.

INITIAL TENDERNESS — the force to bite through the frankfurter skin with molars

```
tough                                            tender
```

CHEWINESS — the resistance to break down on mastication

```
extremely chewy                              not chewy
```

JUICINESS — the progressive increase or decrease in the free fluids in the oral cavity during mastication

```
dry                                              juicy
```

CURED MEAT FLAVOR — characteristic cured sausage-like flavor

```
none                                            intense
```

OFF-FLAVOR — flavors present other than cured meat or spices

```
none                                            intense
```

COMMENTS: