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UNIVERSITY OF ALBERTA

FUNCTIONAL PROPERTIES OF NON-MEAT BINDERS IN COMMINUTED MEAT PRODUCTS

BY

JANET L. STANDISH

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

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The undersigned certify that they have read, and recommend to the the Faculty of Graduate Studies and Research for acceptance, a thesis entitled FUNCTIONAL PROPERTIES OF NON-MEAT BINDERS IN COMMINUTED MEAT PRODUCTS submitted by JANET L. STANDISH in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

Fred H. Wolfe

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L. Jeremiah

January 17, 1992

For Tippy

We shall meet again

ABSTRACT

The effects of several non-meat binders on the functional properties of a wiener type product were investigated. The non-meat proteins used as binders were: soya isolate. wheat flour (WF), wheat rusket (WR), skim milk powder (SMP), oat flour (OF) and deheated mustard flour. Mustard flour was of particular interest because when used in a processed meat product at levels of less than 2%, it is considered to be a spice. Therefore, the term mustard flour need not appear on the ingredient list.

The functional properties investigated included: chilled product yield, water holding capacity (raw batter and cooked product), colour, binding strength and emulsion stability.

In Trial A, products containing 2% soya, 2% WF, and 2% WR, and mustard flour, singly and in combination with soya, WF, SMP and WR were studied. The product with 2% wheat rusket out performed all others. This product exhibited the highest chilled yield, exceptional water holding capacity in the cooked product, and high binding strength. Mustard flour, when used as the sole binder, performed well in the water holding capacity tests and binding strength, but exhibited low emulsion stability. Products with mustard flour in combination with another binder performed erratically.

In Trial B, mustard flour was used singly, but at levels of 0.25%, 0.5% 1.0% and 2.0% in the raw batter. The functional properties of the mustard flour wieners were compared to products containing soya, WF, and OF and an all meat control. No single product scored highest in every functional property test. The 0.25% mustard flour product exhibited high chilled product yield, binding strength, and water holding capacity in the raw batter and cooked product. In addition, mustard flour outperformed wheat flour and soya isolate in these tests, hence mustard flour could replace soya isolate and wheat flour as the binder of choice in comminuted systems.

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The card on his wall read "Keep your promises, Pay your debts". It was a simple statement, but I thought it said a great deal about the person occupying the office. I felt confident that this professor would help make graduate studies a positive experience. I was right. I am deeply grateful and thankful for the assistance and support provided by my supervisor, Dr. Fred Wolfe. I know that this work would have never been completed without his assistance.

I would like to thank the other members of the department who made the hours spent in the lab more enjoyable. They include: Kathie Black, Young Kang, Adam Szpacenko, Len Steele and Gene Arganosa.

Without the constant encouragement (or was it prodding?) of my husband Lyle, this work would have taken much longer to complete. Lyle also spared me many hours of frustration and aggravation by producing all of the tables that appear in this thesis.

I would like to thank the other members of my "family" who made the house a warm and welcome place to come home to: Casa, who is strong and independent; Teaka, who is sensitive and easily hurt, and Kyla, who proves that it possible to survive on looks alone. Lastly I would like to express my gratitude for the special times that Tippy and I shared. Tippy was always there to help make the good times better and the bad times bearable. Rudyard Kipling said

"Brothers and Sisters, I bid you beware,
Of giving your heart, to a dog to tear."

Tippy is deeply missed.

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1.0 INTRODUCTION

Animal slaughter and processing is an important component of the Canadian economy (Table 1). Processed meat products provide the consumer with a wide variety of flavours and textures, and allow the processor to make efficient use of less desirable meat cuts and trim.

The major ingredient in processed products is skeletal muscle. However, other non-meat ingredients have been used as a partial replacement for meat protein since skeletal muscle is relatively expensive. These ingredients are often referred to as binders, fillers or extenders and are usually of plant or dairy origin. The most common plant products are soya isolates or concentrates, starches and modified starches and cereal products such as wheat flour or wheat rusket. Skim milk powder, sodium caseinate, whey protein concentrate and whey powder are the most common dairy derived ingredients. Several other non-meat proteins such as cottonseed protein, fish protein concentrate, egg yolk, autolyzed yeast and corn germ have been studied with regard to their functional properties, but these ingredients are not widely used in processed meats.

As meat processors struggle to reduce input costs, and still maintain quality, they will always be interested in any new binder that can mimic the functional properties of skeletal muscle and thus be used as a replacement for some percentage of the total meat block. It is possible that mustard flour has the requirements of such a binder. If mustard flour could replace other binders at the same or lower cost and still impart the required quality and characteristics to the product, it could become the binder of choice.

Mustard seed is currently grown and processed into mustard flour in Alberta. The crop is well suited for dryland agriculture since it is drought tolerant and requires only 90-100 frost free days to reach maturity. Approximately one acre of mustard was harvested for every one hundred acres of wheat in the 1990-1991 crop year for a total value of $10.3 million (Table 2).

TABLE 1.
Manufacturing in Canada

	Value ($000's)	Value Added ($000's)	Plants	Employees	Wages ($000's)
Total Value (1988)	297 435 900	124 430 100	40 262	1 473 332	38 853 000
Food Manufacturing (1988)	37 159 500	11 997 400	3 313	143 502	3 354 800
Animal Slaughter & Processing (Canada,1988)	8 734 900	1 830 400	536	25 247	662 900
Animal Slaughter & Processing (Alberta,1988)	2 212 300	288 400	73	3 520	94 400
Wieners (Red Meat, Canada, 1988)	178 800		41		

TABLE 2.
Alberta Production Statistics for Wheat, Oats, and Mustard

Year	Crop	Acres Planted	Harvest (tonnes)	Value of Crop ($)
1989-90	Wheat	7.6×10^6	6.45×10^6	835 594 300
	Oats	1.7×10^6	1.62×10^6	135 996 000
	Mustard	8.0×10^5	32 200	9 744 400
1990-91	Wheat	7.7×10^6	6.90×10^6	736 854 000
	Oats	1.5×10^6	1.45×10^6	98 752 500
	Mustard	9.0×10^5	38 900	10 314 000
1991-92	Wheat	7.7×10^6	n/a	n/a
	Oats	1.7×10^6	n/a	n/a
	Mustard	8.0×10^5	n/a	n/a

n/a - not yet available

The mustard flour used in the present study is marketed as AIM deheated mustard, and reportedly imparts the following properties in comminuted meat systems: improved flavour, increased fat and water binding properties, increased ease of peelability, label simplification, decreased oxidation (due to high level of tocopherol in flour) and cost reduction through meat protein substitution.

Native mustard seed and its flour contain a hot principle that results from the breakdown of glucosinolates into p-hydroxybenzyl isothiocynate through the action of the enzyme myrosinase. The presence of this hot principle has limited the amount of mustard flour that can be used as an ingredient. However, AIM has undergone a heat treatment which has reportedly rendered myrosinase inactive, while still maintaining the functional characteristics of the mustard. The recommended usage of AIM in comminuted systems is 2 parts per 100 parts of meat block. At this rate of addition, AIM can replace 3% of the lean meat on a protein for protein basis.

Mustard flour, when used in a processed meat product at levels less than 2% is considered to be a spice. Therefore, the term mustard flour need not appear in the ingredient list but is considered to be part of the spice component. As consumer demand increases for products perceived to be "healthier", consumers may choose products which appear to contain the fewest number of "additives".

However, in order to successfully substitute mustard flour for the more commonly used soy and wheat flour binders, mustard flour must impart similar or superior characteristics in the finished product A comparison of the proximate analysis may yield some insight into the possible functional properties of mustard flour. As depicted in Table 3, soy isolate contains a much higher level of protein and lower fat content than mustard. However, mustard is higher in protein and lower in carbohydrate than wheat flour. Based on these observations, mustard flour may exhibit functional properties that are somewhere between the functional properties produced by these two binders. Since mustard flour has a higher protein level, it may exhibit increased fat and water binding and improved texture

TABLE 3.
Proximate Analysis of the Binders

Binder	Protein (%)	Fat (%)	Water (%)	CHO (%)	Ash + Fibre(%)
Mustard Flour[a]	30.0	30.0	5.0	18.0	17.0
Oat Flour[b]	13.2	7.0	9.6	65.1	5.0
Skim Milk[a] Powder	35.9	0.8	3.0	52.3	8.0
Soya Isolate[a]	91.5	0.8	5.5	0	2.2
Wheat Flour[a]	15.5	1.5	14.0	68.6	0.5
Wheat Rusket[a]	13.0	2.0	5.4	78.1	1.5

a - data supplied by UFL Foods
b - data supplied by ConAgra Ltd.

compared to wheat flour. However, since mustard flour has a higher carbohydrate content than soy isolate, it may exhibit improved water binding properties. The reduced level of protein compared to soy isolate, however, may alter the textural properties resulting in a soft, spongy product.

There is no literature currently available that documents the use of mustard flour in a comminuted product, therefore the purpose of this project was:

1. To examine the effect of different levels of mustard flour on the functional properties of a wiener type product.

2. To examine the effect of mustard flour used singly and in combination with other binders on the functional properties of a wiener type product.

3. To compare the functional properties of mustard flour to some other commonly used binders such as wheat flour, wheat rusket, soya isolate, skim milk powder, and comment on the potential for replacement of these binders with mustard flour.

2.0 LITERATURE REVIEW

2.1 MEAT BATTER MICROSTRUCTURE THEORY

The two basic theories put forth to explain the microstructure of both comminuted meat batters and the subsequent cooked products are the emulsion theory and the nonemulsion or "physical entrapment" theory. While each theory has a group of supporters, it appears that the actual microstructure has yet to be fully elucidated.

2.1.1 Emulsion Theory

An emulsion can be described as a heterogeneous system, consisting of one immiscible liquid intimately dispersed in another one, in the form of droplets with a diameter generally over 0.1 µm (deMan, 1990). Since these systems are thermodynamically unstable, their stability is enhanced by the use of surface active agents (emulsifiers) or other substances. These agents reduce flocculation, coalescence and sedimentation of the dispersed liquid thus increasing the stability of the emulsion. Droplet size of the discontinuous phase, viscosity of the continuous phase, charge on the discontinuous phase, interfacial tension between the two phases and temperature all have specific effects on the stability of emulsions (Zapsalis and Beck, 1986).

Emulsions are referred to as oil-in-water (O/W) emulsions if the continuous phase is water and as a water-in-oil (W/O) if the continuous phase is oil. There are many examples of emulsions in food systems. Margarine and butter are examples of W/O emulsions; milk, mayonnaise and salad dressings are O/W emulsions.

The emulsion theory for comminuted meat products was originally proposed in 1960 by Hansen, who published light micrographs of a wiener batter that clearly showed fat particles surrounded by a film. His theory is based on the principle that the salt soluble proteins in muscle (primarily myosin and actomyosin) will act as emulsifiers in comminuted meats. The proteins surround the fat particles and keep them dispersed in the surrounding water and protein matrix which is stabilized by protein coagulation upon heating. Thus in a meat emulsion, the fat is considered to be the discontinuous phase, the water is the continuous phase, and the protein acts as the emulsifying agent.

This proposed emulsion theory for finely comminuted meat products led to several attempts to model the functional properties of the ingredients that may be used in the system. Swift et al (1961) examined the emulsifying abilities of water soluble proteins and salt soluble proteins from meat. The authors published light micrographs of batters made with both protein types, which clearly showed fat globules surrounded by a film, thus lending support to Hansen's theory. While both protein types were able to emulsify oil in the model system, the salt soluble proteins were found to be the more effective emulsifiers.

In 1963, Swift and Sulzbacher found that the water soluble proteins exhibited increased emulsification properties in increasing concentrations of sodium chloride and their capacity was at a maximum at pH 5.2 and 2M salt. The salt soluble protein also exhibited increased emulsification properties at increased levels of salt attaining a maximum around pH 6.0 and 1.2M salt.

Carpenter and Saffle (1964) developed a simple emulsion capacity test for various types of sausage meats, whereby the fat released from an emulsion upon heating was recorded. They showed a series of photomicrographs which revealed that the fat globule size increased and the protein coat thickness decreased as the amount of oil added to the emulsion increased. When the protein was no longer able to emulsify all of the oil present, the emulsion broke resulting in the coalescence of the fat globules and the association of the protein into strands.

Carpenter and Saffle (1964) also studied the relationship between the content of salt soluble protein and the emulsifying capacity of meat and found that the amount of salt soluble protein could not be used as the sole criterion for predicting the emulsifying capacity. For example, pork stomach which contained 1.73 g of salt soluble protein/100 g meat yielded an emulsification capacity of 28.44 ml oil/100 mg of soluble protein, while pork heart had 6.37 g of salt soluble protein/100 g meat but emulsified only 28.32 ml oil/100 mg of soluble protein.

Subsequent work by Saffle (1966) resulted in a bind value. The bind value, which is now an important component in least cost formulation, reflects the ability of a particular meat trim to emulsify oil. The least cost formulation approach allows the processor to select particular meats and meat trimmings and determine the relative quantity of each required to produce a product with the desired characteristics at the lowest possible price.

However, Parks et al (1985) noted that some of Saffle's bind values were not useful to the processor, since the bind values were given for specific cuts of meat having specific fat, water, and protein contents. Since the processor may not have the same trim as described by Saffle, they will be unsure as to the exact binding value, and will rely on past experience instead. Hence, Parks et al (1985) developed regression equations for striated skeletal muscle enabling the processor to predict bind values if the water and protein contents are known.

While the soluble protein content in meat may not accurately predict emulsification capacity, the NSI was found to be an extremely useful measurement for predicting emulsifying capacities of non-meat protein binders. Inklaar and Fortuin (1969) investigated a case where a processed meat product exhibited substantial and unexpected fat separation. Analysis of the soy isolate used in the product revealed that the NSI and emulsification value were less than one half and approximately 60%, respectively, of the expected values.

The first group to study raw batter and cooked wieners using transmission electron microscopy (TEM) was Borchert et al (1967). The use of this technology resulted in the resolution of fat particles as small as 0.1 µm, and revealed fat particles in the raw batter enclosed in a thin membrane. After cooking, the membrane was no longer intact, exhibiting several small breaks.

Theno and Schmidt (1978) examined the microstructure of three commercially available frankfurter brands using light and scanning electromicroscopy. Brand A was observed to be a coarse protein matrix containing large fat particles and intact muscle pieces. Brand B had a more uniform distribution of fat and protein, however large fat particles and muscle fragments were still visible. Brand C contained small fat particles that appeared to be covered by a protein coat and also exhibited a finely structured protein matrix, indicative of a true meat emulsion. The Brand C matrix was described as lace-like and showed a great deal of uniformity, in sharp contrast to the other two brands.

Apparently Brand A was not comminuted to the same extent as Brand C, since Brand A wieners contained large intact muscle pieces while Brand C showed only fine protein strands. In addition, the fat particles were much larger in Brand A than in Brand C, thus indicating that Brand C was chopped for a longer period of time. The longer chopping time apparently resulted in a larger number of free myofibrils which formed the lace-like protein structure observed in the Brand C wiener.

In a model system, Galluzzo and Regenstein (1978 a,b,c) demonstrated that myosin formed an interfacial film during emulsification. Actomyosin exhibited the same properties as myosin, however, actin formed thin coarse emulsions.

Jones and Mandigo (1982) examined scanning electron micrographs of meat batters that were chopped to different final temperatures to observe microstructural changes that occurred within the batter from initial formation to breakdown. The fat particles did indeed appear to be surrounded by a protein coat, however, several small pores in the coat were visible. The authors theorized that since myosin undergoes heat gelation well below the final processing temperature of the product, the pores may serve as release valves. That is, the protein surrounding the fat particle was heat denatured and stabilized but the fat melted and then continued to expand. As an alternative to complete rupture due to excess pressure, small pores form in the coat, thus allowing small amounts of lipid to escape. Scanning electron micrographs showed tiny particles of exuded fat located next to these small pores. These exuded droplets did not appear to coalesce but instead remained trapped in the surrounding matrix.

As the final chopping temperature increased, the amount of fat and water loss also increased. The micrographs indicated that at lower chopping temperatures, the protein coat surrounding the particle was thinner and the thickness gradually increased with increased temperature. As the thickness increased, the flexibility that allowed for thermal expansion of the fat was lost. The pores were unable to provide enough pressure release and the coat eventually ruptured, releasing the fat which coalesced with other released droplets.

In addition, apparently the protein coat consisted of an outer and an inner membrane or layer. This is logical since emulsifiers contain hydrophyllic and lipophyllic portions. In this case, the lipophyllic portion of the protein would be oriented in towards the fat globule and the hydrophyllic portion would be oriented away from the globule and towards the surrounding matrix.

2.1.2 Physical Entrapment Theory

The physical entrapment theory (PET) was put forth as an alternative explanation for meat batter microstructure (Comer, 1979; Lee et al, 1981; Foegeding, 1988; Regenstein, 1988). Like the emulsion theory, this theory also focuses on the key role the salt soluble proteins play in forming a stabilized comminuted product. However, the theory does not emphasize their role as emulsifiers, but rather emphasizes their role in the formation of a matrix. The salt soluble proteins are believed to form a three dimensional lattice in which the fat and water are imbedded in the interstices. Fat stabilization is not a result of entrapment by a denatured protein coat but is due instead to the fat particles being trapped within the walls of the matrix. Both photomicrographic and physical data lend support to this theory.

Photomicrographs have shown a wide range of fat particle sizes (0.1-100 µm) exist in comminuted meat products. However, only very small particles have been found to be spherical. Particles greater than 20 µm in diameter are usually irregularly shaped and often angular. Lee (1985) proposed that these larger particles are fat cells with intact membranes and/or crystalline fat freed from fat cells during comminution. However, since most fat cells are only 70-80 µm, particles larger than this are probably coalesced fat cells. Published photomicrographs definitely show fat globules surrounded by a protein layer (Gordon and Barbut 1989, 1990a, 1990b, 1991). However, most of the particles shown are 1-5 µm in diameter.

Other physical evidence also exists to support the PET theory. Ackerman et al (1971) found that once fat melted during comminution, emulsion stability was lost, but the liquid fat would produce a stable emulsion when emulsified in an actomyosin solution. Helmer and Saffle (1963) also reported that after prolonged chopping at temperatures near the fat melting point, an unstable batter was produced, but a stable batter could be obtained if the batter temperature was reduced to solidify the fat. If fat was comminuted with the meat, a stable batter was obtained, but if the fat was replaced with oil the emulsion was not stabilized unless an extremely high shear rate was applied (Ackerman et al., 1971). Some proteins which exhibited a high emulsion capacity failed to form stable batters (Saffle, 1973) and the addition of synthetic emulsifiers to batters resulted in a decrease in emulsion stability below the levels achieved without the emulsifiers (Meyer et al., 1964) . Finally, photomicrographs published by Gordon and Barbut (1990a, b, 1991) and Comer and Allan-Wotjas (1988) revealed a finely interwoven protein matrix with fat particles as well as starch granules trapped within the matrix; and Comer and Allan-Wotjas (1988) state unequivocally that the role of the myofibrillar proteins as emulsifiers is "clearly secondary to the functionality of the proteins in forming gels."

However, it is difficult to completely explain fat stabilization in comminuted products by the physical entrapment theory alone. In a raw batter, movement of fat granules is restricted by the protein matrix; but it is difficult to understand how the fat could remain stabilized during heating. Between 35-50 °C the fat undergoes thermal transition (Townsend et al, 1968), but most of the matrix proteins would not gel. As the temperature is increased to 50-70 °C, these proteins become denatured and form a rigid matrix (Acton and Dick, 1984), but the fat would still be free to move. Thus large pools of coalesced fat would be expected throughout the matrix.

Probably the microstructure of the comminuted meat system is a combination of the emulsion theory and the physical entrapment theory. The emulsion theory is supported by the emulsifying capabilities of the salt soluble meat proteins and the existence of the protein coat observed surrounding small particles. This theory accounts for the stabilization of fat particles <1-10 µm in diameter. The physical entrapment theory is supported by photomicrographs of fat particles trapped within the interwoven protein matrix and accounts for the stabilization of the larger (>10 µm) particles.

2.1.3 Role of the Interfacial Protein Film

Since the emulsion theory is based on fat particles surrounded by a protein layer, characteristics of this layer must be elucidated to lend support to the theory. Gordon and Barbut (1990b) published scanning electron micrographs clearly showing a protein coat around the fat particle and particles attached via a protein filament to the surrounding matrix.

The undenatured myosin molecule forms a monomolecular layer around the globule and is bound to other protein in the matrix by protein-protein interactions (Jones, 1984). Myosin is thought to be oriented with the heavy meromyosin located next to globules and the light meromyosin oriented away from globules, providing sites for protein interactions to occur. This theory was based on results published by Borejdo (1983), who determined that 1.30 of the 1.34 hydrophobic sites per mole of myosin were located in the heavy meromyosin fragment.

It should be noted the myosin and not the actomyosin was located at the interface (Jones, 1984). In post rigor muscle, the highest percentage of myofibrillar protein should be actomyosin. However, since a very large amount of protein is required to emulsify all of the fat particles, one might expect actomyosin to be the protein most commonly found at the interface. However, the hydrophobic pocket in myosin has been found to be some distance away from the actin and ATP binding sites (Borejdo, 1983), thus suggesting actomyosin may also participate in the interfacial protein film (IPF) formation. Gordon and Barbut (1990b) used gel electrophoresis to show actomyosin as well as other myofibrillar proteins were indeed involved at the interface.

Possibly the structure around each particle may differ slightly depending upon which proteins are involved in the IPF. Transmission electron micrographs have indicated the IPF itself is composed of several different layers, and each layer may be composed of different proteins (Gordon and Barbut, 1991).

To study differences in the protein coats, Gordon and Barbut (1989, 1990b, 1991) produced several batters containing different chloride salts. Batters made using LiCl (at the same ionic strength as NaCl) contained globules whose IPF was composed of 3 distinct layers, described as inner dense, middle diffuse and external dense. Batters made with $MgCl_2$ however, contained globules whose protein coat was distinctly bi-layer. Although the authors did not describe the layers, they appeared to be external dense and internal dense. Regardless of the salt used in the batter formation, the outer most layer of the coat was attached directly to the surrounding matrix. Thus, apparently once encased in the protein coat, the globule is further immobilized by being bound to the matrix.

Gordon and Barbut, 1990b reported batters containing $CaCl_2$ were more stable than those made with $MgCl_2$ (6.0 vs 7.9 mg fat released /100 g batter, respectively), even though the $MgCl_2$ treatment extracted more salt soluble proteins than the $CaCl_2$ (10.3 mg/ml vs 4.5 mg/ml, respectively); and they concluded there must have been other insoluble proteins responsible for the increased stability of the $CaCl_2$ batter.

Hermansson (1986) suggested the proteins involved in the IPF were an integral part of the protein matrix. This suggestion may help to explain the higher stability of $CaCl_2$ batter in light of the reduced amount of salt soluble proteins obtained. However, Gerwig Huber and Regenstein (1988) reported in most commercial meat emulsions, an insufficient amount of protein was extracted to coat all fat particles. This finding was substantiated when SEM revealed there were both partially coated globules and globules exhibiting pores in the protein coat in commercial meat emulsions (Gordon and Barbut, 1991). However, the distribution of both types of globules was dependent on the type of chloride salt used in the batter.

Globules in stable NaCl raw batters had thick (0.07 µm) coats with few pores, but no fat exudation from these pores was evident. The unstable $MgCl_2$ batter had fat globules with large ruptures in the IFP and pools of coated fat were also observed. SEM also revealed that some particles did have small droplets of fat exiting the particles through pores in the protein coat.

SEM of the cooked product from unstable batters (Gordon and Barbut, 1990) showed an increase in the number of fat particles with rough surfaces and many pores, but these types of particles were found in all products and the pores appeared to be concentrated in the roughest area of the globule. The rough coat is thought to be due to thick dense protein unevenly distributed around the globule, but continuous with the matrix.

SEM also supported the assertion (Jones and Mandigo, 1982) that pores allowed for a release of internal pressure by allowing some lipid to escape. It should be noted however, that the exuded fat was still surrounded by an extension of the parent particle's protein coat.

Gordon and Barbut (1990b) proposed the following mechanism for pore formation and subsequent fat exudation. An increase in temperature of the product occurs during cooking, thus resulting in an increase in the volume of the fat held in the globule. There is a build-up of pressure within the globule which exerts a force on the protein coat. The coat yields to this pressure at its weakest point, resulting in the formation of round, stable appendages covered by the same protein coat that surrounds the original particle. The daughter globule then breaks away leaving insufficient protein to close the gap, thus resulting in pores.

While this explanation seems satisfactory for the cooked product, it does not explain the existence of pores, observed in fat globules in raw batters. Possibly, if there were significantly more pores present in the cooked product than the raw batter, this explanation may have some validity. However, a search of the published literature failed to uncover any reports in which enumeration of these pores was attempted.

In addition, small globules appear to contain only fat, while larger globules appear to contain some sort of internal structure. TEM has revealed a network of very fine strands exist in the globules; presumably protein. Gordon and Barbut (1990b) theorized these strands may be myofibrillar proteins and may even be an integral part of the interfacial protein film and the surrounding matrix. It is also possible these strands may be remnants of the fat cell membranes.

It has been 24 years since Borchert et al (1967) initiated research into the microstructure of comminuted meat systems using TEM, yet the microstructure has not yet been fully elucidated. Swasdee et al (1982) concluded that frankfurters prepared by commercial chopping methods were a heterogeneous, multiphase system in which not all fat droplets were uniformly surrounded by a protein-salt-water interface or a lattice.

2.2 ROLE OF INGREDIENTS

2.2.1 Proteins

The most important ingredients in a comminuted meat product are the myofibrillar proteins. Proteins comprise about 20% of muscle (Table 4) and are generally grouped into three classes: myofibrillar, sarcoplasmic and stromal. In skeletal tissue, the myofibrillar proteins constitute 50-55% of the total protein content. The sarcoplasmic proteins contribute 30-34%, and the remaining 10-15% are the stromal or connective tissue proteins. (Acton et al, 1983)

TABLE 4.
Proximate Analysis of Mammalian Muscle Post-Rigor

Component	% by Weight	
Water		75.0%
Protein		19.0%
Myofibrillar	11.0%	
Sarcoplasmic	5.5%	
Connective Tissue	2.0%	
Lipid		2.5%
Carbohydrate		1.2%
Miscellaneous Edible Non-Protein Substances		2.3%

adapted from Lawrie, 1985

The myofibrillar proteins are the salt-soluble, high molecular weight proteins largely responsible for the functional responses within a comminuted meat batter. Myosin in prerigor and actomyosin (a high molecular weight polymer of F-actin and myosin) in post rigor muscle are the two myofibrillar proteins which play the largest role. Tsai et al (1972) found no emulsion stability upon heating in emulsions made with a tropomyosin-troponin mixture or with actin-tropomyosin-troponin. However, the addition of myosin to both systems resulted in emulsions with stabilities similar to myosin or myosin-actin.

The major connective tissue proteins are collagen and elastin. Collagen is the most abundant, constituting up to one-third of the total body protein in a mature animal. Collagen is divided into four groups, with groups I-III forming the typical collagen fibrils, and group IV collagen forming fine networks in the basement membrane surrounding the muscle cells.

While collagen adds to the overall protein content of the comminuted product, it adds very little functionality. Collagen will bind water at low temperatures but this water is released upon cooking. Sadowska et al (1980) reported an increase in collagen content resulted in decreased product firmness and increased cooking loss. Collagen is not readily soluble and collagen fibres shrink up to one third of their length when heated to 60-65 °C. At temperatures above 65 °C, the collagen is transformed to gelatin which may coalesce into large pools. This is extremely undesirable; therefore collagen should not represent more than 25% of the total protein content (Rust, 1987).

The sarcoplasmic proteins include soluble enzymes, mitochondrial proteins and enzymes, and the muscle pigment proteins. When the ionic strength of the solution is low, the sarcoplasmic proteins make significant contributions to the binding ability of the system. However, when the ionic strength is high, they exhibit little binding ability. Therefore, in most comminuted meat systems these proteins are thought to add very little functionality.

2.2.2 Water

Water comprises about 75% of skeletal muscle. It constitutes about 50-60% of the comminuted meat product, with some arising from the meat block and the remainder added as ice. Water plays an extremely important role in the meat system by providing a medium for solubilization of the myofibrillar proteins, and other materials such as salt and phosphates. Water acts as a lubricant, aids in processing and adds weight to the product at a very low cost. The addition of ice also helps to keep the batter temperature low during chopping.

2.2.3 Lipids

The lipid component of lean skeletal muscle is approximately 3%. Most of these lipids are found as triacylglycerols, with oleic (34-50%), palmitic (24-33%) and stearic (14-29%) acids found in the highest concentrations. Under the current Canadian regulations, comminuted products such as wieners may contain up to 30% fat. The producer may fabricate the product with a high fat meat trim or may add fat previously trimmed from the carcass.

The fat component of the comminuted meat system contributes to the palatability, tenderness and juiciness of the product. Products containing reduced fat levels are often perceived to be dry and chewy. This presents a problem for the processor since the consumer is now demanding a leaner product, but expects the same palatibility characteristics as in products with higher fat contents. In an attempt to develop a leaner "healthier" wiener, Park et al (1989) added high oleic sunflower oil directly to meat batters; and produced products found to be lower in juiciness and with increased firmness and springiness. Park et al (1990) formulated four batches of wieners in which the pork fat component was entirely replaced by high oleic acid sunflower oil at four fat levels (10%, 13%, 15%, 27%). The high oleic acid sunflower oil wieners containing the lowest fat were found to be as acceptable as the high pork fat control, whereas the oleic acid sunflower oil wieners at the highest fat level were less desirable than the pork fat control.

Therefore, the authors concluded that it was possible to formulate a low fat wiener that would be acceptable to the consumer.

2.2.4 Salt

The stability of the comminuted meat batter is directly related to the amount of salt soluble proteins. (Swift et al, 1961, Swift and Sulzbacher, 1963, Smith et al, 1973, Hand et al 1983). Comminution of lean meat must be sufficiently thorough so as to free the myofibrils from the surrounding membranes and sarcolemma. As the degree of comminution increases, the concentration of free myofibrils also increased.

The addition of salt further increases the extraction of these proteins through the "salting-in" phenomena. Sodium chloride produces a shift in the isoelectric point of the proteins to a lower pH thus creating a large net negative charge. Repulsion between the negative groups of the protein causes the protein to open up its spatial arrangement, thereby allowing for increased hydration. Thus, the proteins appear to bind water and swell. The unfolding of the protein due to these steric or conformational effects is very important to the microstructure of the batter (Whiting, 1988; Harding Thomsen and Zeuthen, 1988).

Products with less than 2.5% salt tend to be softer in texture, have a in lower chilled yield and exhibit poor emulsion stability (Barbut et al, 1988). Girard et al (1990) found batter containing 2% salt exhibited a 60% increase in chilled product yield over a salt free batter. When the salt concentration was increased to 3%, a small but not significant increase in yield was observed.

Hand et al (1987) reported no difference in the texture of wieners made with 2.5% or 2.0% salt. However, those made with 1.5% salt were significantly softer. There was a significant difference in the cookout losses among the three salt levels, with the 2.5% product exhibiting the smallest loss. Ockerman and Wu (1990) found the percentage of free water and moisture loss in pork emulsion-type sausage decreased from 24.36% to 20.66% when the salt concentration was increased from 2% to 3%.

Trout and Schmidt (1986) noted as the temperature of the emulsion increased during cooking, the overall water binding ability of the emulsion decreased. In addition, as the concentration of salt decreased from 3.73% to 1.33%, the loss of water binding ability also increased. Consequently, they concluded that increased levels of salt increased the temperature at which the meat proteins aggregated. As aggregation proceeded, the protein matrix shrunk, thus limiting the amount of bound water.

2.2.5 Phosphates

The purpose of the addition of phosphates is to increase the water holding capacity and reduce the cookout loss of the product. Phosphates accomplish this by reducing the pH of the system and by increasing the amount of solubilized protein. However, current Canadian regulations permit the use of phosphates in whole muscle products only. The use of phosphates will become more important, however, in meat batters, due to the consumer demand for leaner "healthier" products. Sodium and fat reduced products are becoming more desirable but present a problem in the processing of comminuted meats. While deleterious effects of fat reduction (excessively dry and chewy products) can be partially overcome with increased water levels, the important role of salt in the system is difficult to duplicate. In addition, the extra binding of water required in the low fat system becomes even more difficult in low fat-low salt systems.

Several researchers have examined meat products containing various levels of salt and phosphates. Knipe et al (1990) found sodium tripolyphosphate in combination with a reduced salt level (0.75%) significantly reduced the cookout loss compared to salt alone. Tetrasodium pyrophosphate reduced total and gel cookout loss beyond that of sodium tripolyphosphate, but no significant differences between the two phosphates with regards to fat binding were observed. When used in combination with 1.5% salt, tetrasodium pyrophosphate, sodium tripolyphosphate, hexametapolyphosphate, and sodium acid pyrophosphate, all improved smokehouse yield compared to 1.5% salt alone. Whiting (1984) stated that sodium acid pyrophosphate (0.25%) in combination with 1.5% salt, reduced water exudate to lower levels than the control (2.5% salt). While a 1.5% salt batter released more fat than a 2.5% batter, the addition of either sodium acid pyrophosphate (SAPP) or sodium tripolyphosphate to the 1.5% batter eliminated fat losses. In addition, the 1.5% salt/0.25% SAPP treatment produced the highest product strength followed by the 2.5% salt/0.25% SAPP treatment.

Knipe et al (1985a) reported sodium pyrophosphate and potassium pyrophosphate produced more stable emulsions than sodium tripolyphosphate or potassium tripolyphosphate. Doubling the phosphate concentration from 0.15% to 0.3% also significantly increased the amount of soluble protein and significantly decreased the total cookout loss, probably due to an increase in pH and some dissociation of the actomyosin.

Comparison of the effect of sodium hydroxide and phosphate addition on emulsion stability in batters with 0.75% salt revealed water retention and emulsion stability improved, while both compounds caused a decrease in the hardness and cohesiveness of the product (Knipe et al, 1985b) . The authors theorized the undesirable texture was a result of increased water retention. Tetrasodium pyrophosphate produced a more stable emulsion alone than did sodium hydroxide, even though sodium hydroxide produced a greater increase in the batter pH. This suggests the tetrasodium pyrophosphate had a functional property in addition to causing an increase in pH.

Barbut et al (1988) examined the effect of added phosphate on turkey wieners containing reduced levels of salt, and again, an increase in pH in the phosphate treated batters was observed. Sensory scores revealed no significant difference among products containing 1.5% salt in combination with hexametaphosphate, tripolyphosphate or SAPP. Overall, the SAPP treatment appeared to provide greater benefits than the other polyphosphates. In a separate study, Barbut (1988) reported products containing 1.5% salt and hexametaphosphate exhibited higher yields than SAPP, tripolyphosphate or the 2.5% salt control. However, a sensory evaluation study was not completed so overall acceptability is unknown.

The use of phosphates enables the processor to reduce the salt content from the traditional 2.5% to 1.5%. The reduced salt product exhibits the characteristics of the higher salt product, but provides the consumer with a alternative that may be perceived as a "healthier" product .

2.2.6 Binders

Non-meat proteins, often referred to as binders, fillers or extenders are added to comminuted meat systems. They perform the following functions: improve emulsion stability, increase chilled yield, improve slicing characteristics, improve flavour and reduce formulation costs. Their use in meat products in Canada is not limited, provided that the product meets the government regulation for minimum total protein (9.0%) and minimum meat protein content (7.5%).

Skim milk powder, wheat flour, and potato starch are the three major binders used in Canadian comminuted meat systems (Comer, 1979). Milk products are well accepted by the consumer. Cereal flours are often high in starch, and as such, are good water binders. However, they tend to impart a bland but starchy flavor. Soy proteins, also frequently used as a concentrated protein source, exhibit good binding abilities, functioning similar to meat proteins. Kinsella (1979) observed soy products to bind water, increase yield, stabilize emulsions and impart texture. Wieners formulated with vegetable protein flour (50% protein) had significantly less cookout loss, and released less fat and water than products formulated with soy flour concentrate (70% protein) or soy isolate flour (90% protein) (Thompson et al, 1984). Gel strength decreased with increased amounts of binder added, but no significant difference among the different binders was detected. Wieners containing 10% texturized soy flour or soy concentrate had texture desirability and overall satisfaction ratings that were not significantly different from the all meat control (Terrell et al, 1979). However, frankfurter-like products that had 10% or 30% of the meat block replaced with cottonseed protein scored lower in texture and overall satisfaction than the all meat control.

Smith et al (1973) compared functional and sensory properties of six soy proteins, three cottonseed proteins, non fat dry milk and fish protein concentrate. While none of these binders scored as highly in any category as the control, the cottonseed proteins came very close in overall acceptability (numerical scores of 32.1 and 32.6) to the control (33.4). This is especially interesting since soy protein isolate (low nitrogen solubility) received a score of 20.6.

Randall et al (1976) observed decreased yield, firmness and rupture force and increased drip loss in wieners made with tripe, cooked beef and textured soy protein. At low levels of substitution, egg white was found to increase yield and decrease drip loss of the product.

The functional properties of defatted corn germ protein have been investigated (Zayas and Lin, 1989a,b). Corn germ protein was added as a powder or preswelled at 2% or 3% and found to increase water holding capacity during comminution and cooking and to increase overall yield. The sensory properties (meaty aroma, off aroma, meaty flavour, off flavour, juiciness, and colour) and textural characteristics (firmness and shear force) were not affected by defatted corn germ protein addition.

Comer and Dempster (1981) studied the functional properties of six non-meat proteins. For total stability, the ingredients were ranked in the following order: sodium caseinate > soy concentrate > textured vegetable protein > potato starch > wheat flour > skim milk powder. However, the values for textured vegetable protein, potato starch, and wheat flour were very similar. The product textures were ranked as follows: potato starch > skim milk powder > soy concentrate > textured vegetable protein > sodium caseinate and wheat flour, which were approximately equal. Similar work (Comer, 1979) showed that Promate 280, a textured plant protein yielded the strongest gel followed by sodium caseinate and potato starch in both low collagen-low extension batters as well as high collagen-high extension batters. There was, however, a 60% decrease in the gel strength between these two batters. Lean beef was the only ingredient that maintained the gel strength in all collagen-extension treatments, thus illustrating once again, the importance of skeletal tissue to comminuted meat systems.

Both Patana-Anake and Foegeding (1985) and Ma et al (1991) studied the functional properties of vital wheat gluten in meat batters and wiener type products. Wheat gluten did not significantly affect chilled product yield, emulsion stability or wiener texture.

Parks and Carpenter (1987) examined the functionality of six non-meat proteins at three meat protein replacement levels (20, 40, and 60%) in meat batters. Autolyzed yeast at all replacement levels and 60% soy flour significantly reduced the chill yield. Batters containing, 60% soy flour, and either 20% or 60% autolyzed yeast exhibited significant fat release. Product texture was negatively affected in batters containing 40% soy protein isolate, 40 or 60% soy protein concentrate, 60% soy flour, or 60% hydrolyzed milk protein, and in all batters containing autolyzed yeast.

The functional properties of five types of starch were examined (Skrede, 1989). The starches were incorporated into sausage batters at a rate of 4%. Potato flour products had the highest yield (92.9%), followed by corn starch (92.2%), wheat starch (91.9%), tapioca (91.7%) and modified potato starch (90.5%). Sensory analysis revealed differences in consistency but not in taste or aroma, with potato starch exhibiting the best overall acceptability.

Foegeding and Ramsey (1987) investigated the effect of iota carrageenan, kappa carrageenan and xanthan gum on the water binding ability and texture of wieners. The force required to fracture the product revealed that iota carrageenan (56.7N) and kappa carrageenan (60.7N) resulted in a softer product than the control (85.8N). Products containing these gums (at the 0.5% or 1.0% level) exhibited higher final moisture contents than the control. Overall, the kappa carrageenan was found to have the highest water binding ability. Similar work by Wallingford and Labuza (1983) showed that products containing xanthan gum had a lower expressible moisture content (49.8%) than products containing carrageenan (51.0%), locust bean gum (53.3%) or low methoxy pectin (55.8%).

The functional properties of many non-meat binders (soy products, milk products, cereal flours, potato starch, hydrocolloids, etc.) in wiener-type products have been well documented. However, no information is available on the use of mustard flour in comminuted systems.

2.3 USE OF MODEL SYSTEMS

Subsequent to Hansen's (1960) assertion that comminuted products were emulsions, other researchers realized that the functional properties of the meat and non-meat ingredients could be studied using model systems (Swift et al, 1961; Hegarty et al, 1963; Carpenter and Saffle, 1964; Borton et al, 1968; Smith et al, 1973).

Model systems have several advantages: experiments cost less due to the decreased amount of materials required, they usually require fewer and less complex pieces of equipment, and they provide reproducible results since a high degree of control can be maintained over all the variables.

Recently though, it has been reported that model systems do not truly reflect functionality in complex comminuted meat systems. Comer (1979) found low correlations between the functional properties of ingredients and their subsequent functional performance in batters and the finished product. Comer and Dempster (1981) reported ingredients do not have unique bind values which relate to stability or texture effects in the final product, despite the existance of patterns of performance which can be used (and probably have been used) by the industry to refine bind values for least cost formulations. For example, a bind value based on emulsification capacity, accounts only for the effect of salt soluble proteins. In such a complex system, however, insoluble protein and carbohydrates may also play a large role in gel and texture development. Thus, Comer and Dempster (1981) concluded it is more productive to examine the system as a whole, despite the increased costs and inconvenience, particularly when combinations of binders are used. Therefore, all batches of wieners created for this project were processed using pilot scale equipment and suitable batch sizes (13.5 - 15 kg).

Obviously from the information presented thus far, comminuted meat products are extremely complex systems. While the function of the myofibrillar proteins in model systems is well understood, the exact function in the comminuted system has not been fully elucidated. The emulsion theory and the physical entrapment theory have been proposed in an attempt to explain the microstructure of the raw batters and cooked products. However, since no consensus among scientists has been reached, the microstructure of comminuted meat systems is still under investigation.

Binders are commonly used in comminuted meat systems, because they increase yield and decrease formulation costs. However, the effect of these binders on the microstructure of the product is not known. Presumably, proteins in these binders contribute to the emulsion stability of the product, but the exact role these proteins play is unclear. Possibly they form part of the matrix, thus helping to trap fat particles. They may also form one or more of the layers in the interfacial protein film, thus coating particles and stabilizing them, or the proteins may simply exist in the interstices of the matrix, thereby increasing the viscosity of the batter.

Salt, water, and fat also play extremely important roles in the comminuted system. Salt facilitates the extraction of the salt soluble proteins, thus increasing the emulsification capacity of the batter. Water is required as a medium for the solubilization of the salt soluble proteins. Fat contributes to the palatability, tenderness and juiciness of the product.

The interactions of these ingredients have been studied for many years, and still there are many questions to be answered. However, each new piece of information aids in the conversion of sausage making from an art to a science.

3.0 MATERIALS AND METHODS

3.1 PRODUCTION OF WIENERS

3.1.1 Raw Ingredients

All meat products were obtained in the fresh state from Gainers, Inc., Edmonton, Alta. The meat ingredients for Trial A consisted of 75%/25% (lean/fat) beef trim, 80%/20% beef trim, 45%/55% pork trim, and beef liver. The meat used in Trial B was 90%/10% beef trim and beef fat. The non-meat proteins (mustard flour, wheat flour, wheat rusket, skim milk powder, soya isolate (PP500E), potato starch, cures, and seasonings were supplied by UFL Foods, Edmonton, Alta. The oat flour and oat bran were supplied by ConAgra, South Sioux City, Nebraska, U.S.A. Cellulose casings with an internal diameter of 22 mm were provided by the Alberta Agriculture Food Processing Development Centre (FPDC), Leduc, Alta.

3.1.2 Wiener Formulation

In order to ascertain the effect of different non-meat proteins on functional properties, it was necessary to develop a formulation which held as many parameters as possible constant. The standard formulation used for all the batches in Trial A is given in Table 5. Since the protein to fat ratio is critical to the functional properties of the product, it is necessary to ensure that this ratio remained constant from batch to batch. Regulations B.14.030 and B.14.035 of the Food and Drugs Act (1988) state that processed meat products such as wieners must contain a minimum of 9.0% total protein and a minimum of 7.5% meat protein.

In Trial A, raw wiener batters were formulated to contain a meat protein level of 8.0% and a total protein level of 10.0%. Since evaporation of moisture in the batter occurs during the cooking/smoking process, it was expected that the protein content in the finished product would be slightly higher than the raw batter.

TABLE 5. Trial A: Basic Batter Formulation

Component	% by Weight
Protein	10.0%
Meat Block	8.0%
Binder	2.0%
Moisture	53.0%
Fat	22.0%
Binder/Starch	11.8%
Salt	1.5%
Spice	0.77%
Sodium Nitrite	120 ppm
Sodium Erythorbate	312.5 ppm

The only parameters held constant in Trial A were protein, cure, salt and seasoning levels. Small variations in the fat and moisture content were expected since the added non-meat protein sources contribute some fat and moisture, but not on the same weight percentage basis as the meat block. Potato starch, which contains no significant amount of protein or fat, was used as a filler, to ensure that the final formulation was correctly balanced.

Formulations for the wiener batches of Trial B are given in Table 6. In this trial, all parameters were held constant. Each batch contained exactly the same percentage of protein, fat, moisture, carbohydrate, and fibre. A protein level of 11.0% for the raw batter was chosen as the standard for the batches examined in Trial B, to ensure that the wieners produced would meet federal regulations and to ensure the level of protein was adequate for the formation of a stable emulsion. The contribution of protein by the binder was considered when the size of the meat block was calculated. Therefore, as the level of protein from the binder increased, the contribution of protein from the meat block was decreased, thus ensuring a constant protein level. Note this difference from Trial A, where non-meat and meat protein levels were held constant for all batches. Here, the protein total was held constant but the portions contributed by meat and non-meat sources were allowed to vary from batch to batch.

Since the reduction of the meat block also results in smaller contributions of fat and moisture, these two components were added as beef fat and ice, respectively. Since batches of wieners containing high levels of binder had more carbohydrate and fibre than the all-meat batch, potato starch was added as the carbohydrate source and oat bran (35 mesh) was added as the fibre source, to ensure all batches had the same amount of carbohydrate and fibre.

3.1.3 Fabrication of Wieners

Wiener fabrication was carried out at FPDC. Grinding, mixing, chopping and stuffing of the meat ingredients were done at 4 °C. Meat and fat was ground once

TABLE 6. Trial B:
Basic Batter Formulation

Component	% by Weight
Protein	11.0%
Moisture	57.0%
Fat	23.0%
Carbohydrate	4.25%
Fibre	0.31%
Salt	2.16%
Sucrose	1.0%
Spice	0.77%
Sodium Nitrite	500 ppm
Sodium Erythorbate	312.5 ppm

through a 20 mm plate. Appropriate amounts of meat, fat and ice were placed in the silentcutter (Sydelman K-64 Vacuum/Cooking cutter) and chopped for about 10 bowl revolutions before the remaining dry ingredients were added. Soya isolate was not added in the powdered form but was rehydrated at a ratio of 5:1 (water:soya) and left overnight before being incorporated into the batter. The batter was chopped until the emulsion temperature reached 14 °C. In Trial A, the batter was then transferred to an emulsion mill (Stephan Microcut 15) where the plates were set 13 mm apart. However, the emulsion mill was not used during processing of the batter in Trial B. Batter was then stuffed using a vacuum stuffer (Vemag 1000-S with built-in linker), mechanically linked into 15 cm links and placed on the smokehouse tree. Wieners were placed in the smokehouse (RONDAIR, model #ASR3615) and cooked and smoked as described in Appendix A. After chilling, the wieners in Trial A were vacuum packaged on a Snorkelvac, and the wieners in Trial B were packaged on a Multivac.

3.2 ANALYSIS OF WIENERS

3.2.1 Proximate Analysis

All cooked wieners were ground three times through a 3 mm plate before analysis was undertaken. Protein, fat and moisture contents of both the raw batters and cooked wieners were measured using AOAC (1984) methods.

For protein determination, a sample (0.7 g) of the wiener was digested with 13 ml of concentrated sulphuric acid for 2 hours, using a Buchi 425 digestor (temperature setting #7) . After cooling, 50 ml of water and 100 ml of the sodium hydroxide solution (30% w/v and 2% w/v sodium thiosulfate) were added. This mixture was distilled using a Buchi 320 N_2 Distillation unit and the distillate was collected in an erlenmeyer flask containing 50 ml of boric acid (4% w/v) and 5 drops of the indicator solution (100 mg bromcresol green and 40 mg methyl red in 100 ml of methanol). Distillation was considered complete when

100 ml of distillate had been collected. The distillate was titrated with a standardized sulphuric acid (ca 0.1N) solution. Protein is considered to be N x 6.25 (AOAC, 1984)

For moisture determination, a 4 g sample was weighed into a predried and weighed aluminum dish and dried overnight (18 hrs) in a forced air oven at 105 °C. The moisture content was calculated as follows:

$$\% \text{ moisture} = \frac{\text{initial weight (g) - final weight (g)}}{\text{initial weight (g)}} \times 100\%$$

Fat analysis was performed using the Goldfish extraction unit. A 3 g sample was mixed with ca 3 grams of sand and was dried overnight in a forced air oven at 105 °C. The dried sample was extracted with petroleum ether (b.p. 30-60 °C) for 6.5 hours. Fat content is considered to be the weight gain of the beaker divided by the sample weight times 100%.

3.2.2. Functional Properties

Most of the methods used to measure the functional properties of the wieners were methods that had been suggested by others and then adapted to suit this project.

3.2.2.1 Yield

The yield is determined by weighing the stuffed raw batters prior to cooking, and once again after chilling. The calculation is as follows:

$$\text{Yield} = \frac{\text{chilled weight (g)}}{\text{pre-cooked weight (g)}} \times 100\%$$

3.2.2.2 Water Holding Capacity - Raw Batter

The water holding capacity of the raw batters in Trial A was measured using the method proposed by Knipe et al (1985a). A 20 g sample of batter was placed in a 50 ml polycarbonate centrifuge tube, a 6 ml aliquot of 0.85% NaCl solution was added and the contents were thoroughly mixed. The tubes were then centrifuged for 15 minutes at 10 000 x g at 4°C in a Beckman J2-21 refrigerated centrifuge. The supernatant was removed from the tube and its volume measured using a graduated cylinder. Batters that exhibit high water holding capacity should produce a supernatant of 6 ml or less.

The water holding capacity of the raw batters in Trial B was measured using the an adaptation of the method suggested by Knipe et al (1985a). Salt concentration of the solution was changed to reflect the salt concentration of the batter and the sample size was changed because placing 20 g of batter in a 50 ml tube was found to be very difficult. The amount of solution added was increased to ensure an excess amount present.

A sample (3.00 g) of raw batter was placed in a 50 ml polycarbonate centrifuge tube and 15 ml of a NaCl solution (2.5% w/v) was added. The tube contents were thoroughly mixed and then centrifuged at 12 000 rpm (17 418 x g) for 15 minutes at 22 °C in a Beckman J2-21 centrifuge. After centrifugation, the supernatant was removed with a pasteur pipette and weighed. Water holding capacity for the raw batters is expressed as the number of grams of expressed fluid per gram of sample.

3.2.2.3 Water Holding Capacity - Cooked Product

The water holding capacity measurement for the wieners is an adaptation of the method suggested by Ritchey and Hostetler (1964). A 0.75 g sample of wiener is placed between two sheets of aluminium foil (5.0 cm x 5.0 cm), and then between two sheets of Whatman #4 filter paper (12.5 cm). This assembly was then placed between two sheets of plexiglass(12 cm by 12 cm), and squeezed in a Carver Laboratory Press at 1000 psi for 30 seconds. The meat is removed from the inside of the foil and the moisture content of the pressed sample is determined. Water holding capacity (WHC) is expressed as:

$$\text{WHC} = 100 - \frac{\text{initial wt pressed sample (g) - final wt pressed sample (g)}}{\text{Moisture pre-pressed sample (g)}} \times 100\%$$

3.2.2.4 Colour

The colour of the cooked wiener was analyzed using a Hunterlab colorimeter model D25-2, calibrated with standard plate #C2-7991. Eight wieners were ground in a Cuisinart food processor (model DLC-8 plus) for one minute. The chopped material was then placed in the bottom half of a petri dish, filled to the rim, and the surface was smoothed. The L, a and b values were immediately recorded.

3.2.2.5 Binding Strength

Binding strength of the wieners was analyzed using an Instron Universal Testing Machine model #1130 and a Kramer shear cell. Wieners were cut in half longitudinally and then 35 mm sections, taken at least 10mm from the end of the wiener, were placed in the centre of the shear cell, skin side up. The full scale load was 50 kg while the cross head and chart speeds were set at 5 cm/minute as suggested by Huang and Robertson (1977). The binding strength is expressed as kg of force necessary to shear the wiener and is considered to be the maximum height of the peak.

3.2.2.6 Emulsion Stability

Emulsion stability of the wieners was measured using adapted versions of Folch et al (1957) and Carpenter and Saffle (1964). A sample of wiener (10.00 g) was placed in a 50 ml polycarbonate centrifuge tube. Twenty ml of water at 70 °C was added, the contents were thoroughly mixed and the tubes were placed in a 70 °C water bath for exactly 5 minutes. The tubes were then centrifuged at 18 000 rpm (39 191 x g) for 30 minutes at 2 °C in a Beckman J2-21 refrigerated centrifuge.

Fat released from the emulsion rises to the surface of the water and solidifies as a plaque. Unfortunately this plaque could not be simply removed and weighed because some wiener material remained attached to its underside. Therefore, the plaque was removed with a small spatula, placed in a glass centrifuge bottle, and 100 ml of chloroform:methanol (2:1) was added. The contents were swirled and then allowed to stand until the plaque dissolved. A 20 ml aliquot of Folch upper phase solution, chloroform:methanol:water

(3:48:47) was added and the flask contents swirled. Finally 3.0 ml of water was added, the contents were swirled once again and then centrifuged at 2000 rpm for 20 minutes in a IEC centrifuge model S2K at room temperature. The top layer and the interfacial solid material were aspirated and the remaining liquid was placed into a preweighed 250 ml round bottomed flask. The flask contents were evaporated on a Buchi Rotavaporator set at #7, while the flask was held in a water bath at 45 °C. When most of the liquid was removed, 25 ml of 98% ethanol was added to the flask and the mixture was evaporated until the remaining fat bubbled. The flasks were then stored overnight in a desiccator and reweighed.

Total weight of fat removed was divided by the sample size, and then this number was divided by the total amount of fat in the original sample to yield the emulsion stability number. Therefore, smaller numbers indicate higher emulsion stability and represent the ability of the cooked product to retain fat during the particular conditions of heating employed.

3.2.2.7 Cold Water Absorption

Cold water absorption of mustard flour, wheat flour, wheat rusket, skim milk powder, soya isolate PP500E, potato starch, oat flour, oat bran, and skim milk powder were measured using an adaptation of the method of Comer (1979). A sample of the flour (1.00 g) was placed in a 50 ml polycarbonate centrifuge tube, 20 ml of water (room temperature) was added and the contents were thoroughly mixed and left to stand for 10 minutes, stirring occasionally. The tubes were centrifuged at 18 000 rpm (39 191 x g) for 20 minutes at 4 °C in a Beckman J2-21 refrigerated centrifuge. After centrifugation, the supernatant was removed with a pasteur pipette and weighed. Cold water absorption was expressed as the number of grams of water retained by one gram of sample.

3.3 STATISTICAL ANALYSIS

Data were analyzed using the StatView 512+ statistical package from BrainPower Inc. One way analysis of variance was performed on experimental data and the Scheffe F test was utilized for multiple comparisons of means at the $P < 0.05$ level.

4.0 RESULTS AND DISCUSSION

4.1 FUNCTIONAL PROPERTIES OF THE BINDERS

4.1.1 Cold Water Absorption

The cold water absorption capacity of all the binders is presented in Table 7. Soya isolate exhibited the highest cold water absorption capacity at 7.73 g water/g soya, followed by wheat rusket (4.87 g water/g wheat rusket) and potato starch (2.50 g water/g starch). Oat flour exhibited the lowest cold water absorption capacity at only 0.80 g water/g oat flour. Theoretically, if each binder was able to stabilize added water to the same extent during cooking, then those batches containing significant amounts of soya, wheat rusket or starch would also exhibit high moisture levels in the cooked product and provide high chilled yields.

The ranking of the binders is quite different when the cold water absorption capacity is calculated on a protein basis. Wheat rusket absorbed 37.46 g water/g protein, more water than was absorbed by soya isolate (8.44 g water/g protein) or oat flour (6.08 g water/g protein). If calculated on a carbohydrate basis, mustard flour exhibited the highest cold water absorption capacity (6.94 g water/g carbohydrate), followed by wheat rusket (6.24 g water/g carbohydrate) and skim milk powder (2.93 g water/g carbohydrate).

4.1.2 Colour

The *L*, *a* and *b* values for each binder are presented in Table 8. Each *L*, *a* and *b* value is significantly different for each binder. Potato starch gave the highest *L* value at 96.9, followed by skim milk powder at 95.3. The range in *a* values was from -3.9 for skim milk powder to 1.6 for wheat rusket. The range in *b* values was from 2.8 for starch to 25.2 for mustard flour.

The extent to which the color of the binder affects the colour of the cooked product is a function of the concentration of the binder in the batch and the extent of colour change that may occur in the binder during processing.

TABLE 7.
Cold Water Absorption

Binder	g water/ g binder	g water/ g protein	g water/ g CHO
Mustard Flour	1.25 ^{d} (0.02)	4.17	6.94
Oat Flour	0.80 ^{e} (0.01)	6.08	1.23
Potato Starch	2.50 ^{c} (0.09)	--	2.50
Skim Milk Powder	1.52 ^{d} (0.10)	4.26	2.93
Soya Isolate	7.73 ^{a} (0.09)	8.44	--
Wheat Flour	0.87 ^{d,e} (0.01)	5.61	1.26
Wheat Rusket	4.87 ^{b} (0.08)	37.46	6.24

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

TABLE 8.
Colour of Binders

Batch	L	a	b
Mustard Flour	77.9^{a} (0.1)	-3.3^{a} (0.0)	25.2^{a} (0.1)
Oat Bran (35 mesh)	73.6^{b} (0.0)	1.5^{b} (0.0)	13.6^{b} (0.1)
Oat Flour	84.7^{c} (0.1)	0.6^{c} (0.1)	9.0^{c} (0.0)
Skim Milk Powder	95.3^{d} (0.1)	-3.9^{d} (0.0)	12.8^{d} (0.0)
Soya Isolate	86.6^{e} (0.1)	-2.4^{e} (0.0)	16.0^{e} (0.0)
Starch	96.9^{f} (0.1)	-1.2^{f} (0.0)	2.8^{f} (0.0)
Wheat Flour	87.3^{g} (0.1)	-0.3^{g} (0.0)	10.5^{g} (0.0)
Wheat Rusket	69.7^{h} (0.1)	1.6^{h} (0.1)	14.3^{h} (0.0)

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

4.2 TRIAL A

This trial was designed to examine the effects of incorporating several non-meat binders, particularly mustard flour, singly and in combination into wiener batters on the functional properties of raw batters and cooked products. With the exception of batch #10, all of the batters were formulated so as to contain 8% meat protein, 2% non-meat protein, 53% moisture and 22% fat in the raw state. When two binders were used in combination, the recipes were formulated such that each binder contributed one-half of the protein to the overall non-meat protein content of the batch.

The proximate analysis values for the raw batters were not expected to exactly match the formulated values because the actual fat, moisture and protein contents of the raw meat ingredients were not known. When ordering meat ingredients, it is possible to specify the amount of lean content required. However, the amount specified is only an approximation of the true lean content, since this determination is made by visual inspection and estimation of the apparent content of lean and fat.

The final batch weight was 13.5 kg of which 1.60 kg was available for addition of non-meat protein. Both wheat flour and wheat rusket have a low protein content (15.5% and 13.0%, respectively), thus in order to obtain 2% non-meat protein it was necessary to add 1671 g of wheat flour and 1838 g of wheat rusket. This extra weight exceeded the 1.60 kg allotted for binder addition, and therefore resulted in a small reduction of formulated values for fat, protein and moisture contents. This was deemed more desirable than adding an insufficient amount of the binder which would have resulted in a lower protein contribution by the binder.

For binders containing very high levels of protein (eg. soya), only a small portion of the 1.60 kg available was required for the addition of binder. In order to maintain the correct formulation weight, potato starch was added as an additional filler and since a different weight of binder was added to each batch, a different weight of starch was also added to each batch. Different amounts of starch may alter the functional properties of the finished products, thus obscuring the effects of the binders. Obviously this is undesirable and this problem was corrected when calculations were completed for Trial B.

4.2.1 Proximate Analysis

The average protein, moisture and fat contents for the raw batters were 11.73%, 54.46% and 21.47%, respectively. The fat content was the closest to the formulated value of 22% , followed by the protein (10%) and the moisture content (53%). Overall, the values were very close to the formulated values especially since the contribution of moisture and fat by the non-meat proteins was not taken into consideration when the recipes were formulated.

The proximate analysis of the raw batters and cooked products is presented in Tables 9-11. There were statistically significant differences in the moisture contents of raw batters #1-9. However, from a practical standpoint, these differences were not important. The moisture content of batch #10 (1% AIM-30% water) was statistically different from all other batters. This was expected because this batch was formulated to contain 1.5 times as much added water as the other batches. The small variations which occur among batches #1-9 were probably due to the absorption of some of the water used to lubricate the material holding bins and processing equipment.

There were statistically significant differences in the moisture contents of the cooked product batches #1-9. The differences found among these products are due to the variability in water binding ability of the binder, shrinkage during processing, and initial water content of the raw batter. The moisture content of batch #10 was significantly lower than all other batches, which indicated that this batter was unable to bind water during cooking. Therefore, this product would also be expected to have a low chilled yield.

There were no statistically significant differences in fat contents among the batches for both the raw and cooked products. The small variations in fat content observed, probably resulted from differing abilities of each non-meat protein to bind and/or stabilize

TABLE 9. Trial A: Raw Batter & Cooked Product Moisture Content

Batch	Raw(%)	Cooked(%)
2% AIM	54.07^{e} (0.27)	$52.44^{e,f}$ (0.01)
1% AIM-1% WR	56.25^{c} (0.03)	$51.62^{c,d}$ (0.13)
1% AIM-1% WF	53.64^{e} (0.18)	$51.85^{c,d,e}$ (0.11)
1% AIM-1% Soya	54.69^{d} (0.02)	$51.99^{d,e}$ (0.02)
1% AIM-1% SMP	54.93^{d} (0.02)	50.78^{b} (0.07)
3% AIM	53.87^{e} (0.05)	52.99^{f} (0.03)
2% WF	54.84^{d} (0.06)	52.82^{f} (0.05)
2% WR	53.16^{b} (0.04)	52.77^{f} (0.11)
2% Soya	55.07^{d} (0.04)	$51.20^{b,c}$ (0.20)
1% AIM-30% Water	61.64^{a} (0.02)	47.80^{a} (0.11)

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

TABLE 10. Trial A: Raw Batter & Cooked Product Fat Content

Batch	Raw(%)	Cooked(%)
2% AIM	21.56^{a} (1.98)	25.38^{a} (1.89)
1% AIM-1% WR	21.37^{a} (1.66)	25.55^{a} (0.73)
1% AIM-1% WF	23.02^{a} (0.80)	26.62^{a} (0.45)
1% AIM-1% Soya	22.06^{a} (0.65)	25.89^{a} (0.87)
1% AIM-1% SMP	19.11^{a} (1.69)	26.28^{a} (0.17)
3% AIM	20.47^{a} (2.74)	26.43^{a} (1.55)
2% WF	22.84^{a} (0.08)	26.47^{a} (1.93)
2% WR	20.84^{a} (1.13)	24.75^{a} (1.23)
2% Soya	21.90^{a} (0.16)	25.20^{a} (0.50)
1% AIM-30% Water	23.39^{a} (0.08)	26.50^{a} (1.03)

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

TABLE 11. Trial A:
Raw Batter & Cooked Product Protein Content

Batch	Raw(%)	Cooked(%)
2% AIM	$11.54^{d,e}$ (0.02)	$13.46^{c,d}$ (0.01)
1% AIM-1% WR	11.44^{d} (0.01)	13.75^{d} (0.06)
1% AIM-1% WF	11.78^{c} (0.01)	$13.24^{c,d}$ (0.04)
1% AIM-1% Soya	11.79^{e} (0.05)	$13.38^{c,d}$ (0.11)
1% AIM-1% SMP	$11.55^{d,e}$ (0.08)	13.17^{c} (0.06)
3% AIM	12.82^{a} (0.04)	14.22^{a} (0.08)
2% WF	11.74^{e} (0.05)	$13.52^{c,d}$ (0.04)
2% WR	11.17^{c} (0.01)	12.64^{b} (0.02)
2% Soya	11.73^{e} (0.01)	$13.49^{c,d}$ (0.01)
1% AIM-30% Water	10.62^{b} (0.01)	13.12^{c} (0.01)

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

fat during comminution and cooking. Small variations due to differences in lipid content of each non-meat binder may also exist.

There were statistically significant differences in the protein content of the raw batters. Batch #10 was statistically different from all other batters, because this batch was formulated with 1% binder protein and additional water. Batch #6 was also statistically different from all other batters because it was formulated with 3% binder protein.

The protein content of the cooked products was also statistically different. This is a result of differences in the raw protein contents as well as the difference in moisture loss in each batch. As the moisture loss during cooking increased, the relative protein content also increased. In the cooked product, batch #10 was not different from all other products. This product lost a relatively large proportion of its of water during cooking causing the net protein content to be similar to other batters.

4.2.2 Functional Properties

4.2.2.1 Yield

The yield of the chilled product (Table 12) reflects the [illegible] weight due to shrinkage during cooking. The 2% WR, 2% AIM, and 1% AIM-[illegible] products all showed very similar yields with the 2% WR the highest at 89.0%. The batch exhibiting the lowest yield was batch #10, the 1% AIM-30% water formulation (83.0%), indicating the protein and/or the subsequent matrix formed in this batter was unable to bind or stabilize the incorporated level of moisture during the cooking process.

Variation among the other batches was mainly due to the different water binding abilities of the respective non-meat binders. Although soya binder was found to have the largest cold water absorption capacity, the 2% soya product exhibited only the sixth highest yield. Since the soya isolate was very protein dense, only a small amount of soya was actually used in the formulation. Therefore, a much larger portion of the total binder was contributed by potato starch which was observed to have the third highest cold water

TABLE 12. Trial A:
Yield of Chilled Product

Batch	Yield (%)	Rank
2% AIM	88.6	3
1% AIM-1% WR	87.4	7
1% AIM-1% WF	88.3	4
1% AIM-1% Soya	88.8	2
1% AIM-1% SMP	87.6	6
3% AIM	8[illegible]	8
2% WF	87.8	5
2% WR	89.0	1
2% Soya	87.6	6
1% AIM-30% Water	83.0	9

absorption ability. However, apparently this combination of starch and soya was apparently unable to bind as much water during cooking since this batch showed a larger than average decrease in moisture content from the raw batter to the cooked product. Based on this observation, decreased chilled yield would be expected.

The 2% wheat rusket batch contained 1838 g of wheat rusket which was ranked second in the cold water absorption test, with almost twice as much water binding ability as potato starch. The 2% wheat rusket product had the highest chilled yield due to the large amount of rusket used and its ability to bind water. The mustard flour had low water binding ability in the cold water absorption test but resulted in high chilled yield when used at the 2% level or in combination with soya or wheat flour.

4.2.2.2 Water holding Capacity - Raw Batters

Water holding capacity of the raw batters is presented in Table 13. Results indicated, in the raw batter, the 1% AIM-1% WR, 2% WR, 2% WF and the 2% AIM absorbed some water from the added saline solution. Wheat rusket exhibited a high cold water absorption capacity, therefore it may not have been fully rehydrated during the comminution process, resulting in additional water absorption during the water holding capacity test. Thus, these batters could possibly have been formulated with more added water, thereby decreasing the production cost of the final product. The usefulness of rehydration of this binder prior to batter incorporation should be examined.

At the other end of the spectrum, the 1% AIM-30% water batter lost a relatively large amount of water to the saline solution, indicating poor water holding capacity. This is not surprising in view of the low chilled yield and large decrease in moisture content during cooking. Statistical analysis was not performed because of the small number of repetitive measures.

4.2.2.3 Water holding Capacity - Cooked Products

The cooked products exhibited a slightly different water holding capacity pattern than the raw products (Table 14). The 1% AIM-1% WR and

TABLE 13. Trial A:
Water Holding Capacity of Raw Batter

Batch	mls released	Rank
2% AIM	5.9	3
1% AIM-1% WR	5.7	1
1% AIM-1% WF	6.1	5
1% AIM-1% Soya	6.0	4
1% AIM-1% SMP	6.1	5
3% AIM	6.0	4
2% WF	5.9	3
2% WR	5.8	2
2% Soya	6.0	4
1% AIM-30% Water	6.4	6

TABLE 14. Trial A:
Water Holding Capacity of Cooked Product

Batch	WHC(%)	Rank
2% AIM	99.13 ^{a} (0.16)	3
1% AIM-1% WR	95.60 ^{b} (0.13)	10
1% AIM-1% WF	95.68 ^{b} (0.81)	9
1% AIM-1% Soya	99.07 ^{a} (0.18)	4
1% AIM-1% SMP	98.39 ^{a} (0.32)	8
3% AIM	98.55 ^{a} (0.05)	6
2% WF	99.04 ^{a} (0.17)	5
2% WR	99.29 ^{a} (0.24)	2
2% Soya	100.27 ^{a} (0.11)	1
1% AIM-30% Water	98.44 ^{a} (0.18)	7

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

1% AIM-1% WF were statistically different than all other batters, but not from each other. All other batters were not statistically different. However, there were differences that are of practical importance. The 2% WR product exhibited exceptionally high water holding capacity at 99.29%, closely followed by 2% AIM (99.13%).

The batch containing 2% soya is an anomaly in that repeated analysis of the product showed a water holding capacity of greater than 100%. Since 100% should have been the maximum value, the value obtained was most likely a result of cumulative errors in weighing, drying etc. It is possible that data obtained for other batches also contained some level of cumulative error, but the error is particularly obvious in this case since the final value obtained exceeded 100%.

It is important to note that this batch also contained the highest amount of starch, which is known for its ability to bind water. Therefore, these results may indicate the importance of complex carbohydrates in a comminuted meat system.

4.2.2.4 Colour

The Hunterlab Colorimeter *L* value measures the lightness-darkness of the product. A numerical value of 100 is given to pure white. The *a* value represents the red-green portion where positive values are the red portion and negative values are the green portion. The *b* value represents the blue-yellow portion where positive values are the yellow portion and negative values are the blue portion.

There were statistical differences in the *L*,*a* and *b* values for each product. These differences are not important from a practical standpoint because of the wide range in colour of commercially available products. All of the cooked products had an *L* value of between 53.3 (2% WR) and 55.7 (2% WF). The *a* values ranged from 11.9 (3% AIM) to 15.0 (1% AIM-30% water) and the *b* values were between 13.9 (1% AIM-30% water) and 16.0 (3% AIM) (Table 15).

TABLE 15. Trial A:
Colour of Cooked Product

Batch	L	a	b
2% AIM	$54.0^{a,b}$ (0.07)	$12.3^{f,g}$ (0.10)	16.0^{a} (0.03)
1% AIM-1% WR	$54.9^{a,c}$ (0.09)	$12.8^{d,e,f}$ (0.13)	15.4^{b} (0.03)
1% AIM-1% WF	$53.4^{a,b}$ (0.15)	$13.1^{c,d,e}$ (0.12)	15.4^{b} (0.09)
1% AIM-1% Soya	$55.0^{a,c}$ (0.32)	$13.6^{b,c}$ (0.19)	15.3^{b} (0.10)
1% AIM-1% SMP	$54.2^{a,b}$ (0.42)	$13.8^{b,c}$ (0.20)	$15.5^{a,b}$ (0.08)
3% AIM	$54.1^{a,b}$ (0.04)	11.9^{g} (0.04)	16.0^{a} (0.03)
2% WF	55.7^{c} (0.05)	$12.5^{e,f,g}$ (0.03)	15.1^{b} (0.05)
2% WR	53.3^{b} (0.15)	$13.3^{b,c,d}$ (0.07)	14.3^{c} (0.03)
2% Soya	$54.6^{a,c}$ (0.25)	14.0^{b} (0.09)	14.5^{c} (0.13)
1% AIM-30% Water	$54.7^{a,c}$ 0.04)	15.0^{a} (0.03)	13.9^{c} (0.05)

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

L values are as would be expected since the wheat flour binder had the highest *L* value (87.3), while the wheat rusket exhibited the lowest *L* value (69.7) and a large amount of each of these binders was incorporated into the respective batters.

The AIM flour had the second lowest *a* value (-3.3) of all the binders. Therefore, as the amount of AIM in the batter increased, the *a* value of the product decreased. The 1% AIM-30% water product exhibited the highest *a* value, because it contained only a small amount of AIM and no other binders or starch. Therefore, the red colour of the meat was not masked by non-meat ingredients.

The *b* value for the AIM flour was 40% higher than the next highest binder. Therefore, products containing large amounts of AIM exhibited the highest *b* values. The 1% AIM-30% water batch had the lowest *b* value, once again due to the lack of large quantities of binder and starch.

4.2.2.5 Binding Strength

Binding strength of the cooked product is expressed as kilograms of force necessary to shear the product. The 2% soya product (24.57 kg force) exhibited the firmest texture, followed by the 2% WR (22.82 kg) and 2% AIM (22.68 kg) products (Table 16). Batch # 10 (1% AIM-30% water) exhibited the lowest binding strength of all batches with only 17.82 kg of force required to shear the wiener. If texture was a function of protein content alone, then the 1% AIM-30% water product should exhibit approximately the same textural properties as the other products.

The final water content of all other 1% AIM products was actually higher than the 1% AIM-30% water product. The additional water added to the 1% AIM-30% water batter must have had a negative effect on the ability of the proteins to form a strong matrix, thus producing a softer product, and lower water and fat stability observed for this product.

Statistical analysis of the data revealed that all of the products exhibited the same binding strength with the exception of 2% soya and 1% AIM-30% which were different from each other. The method of analysis resulted in large variability in the repetitive

TABLE 16. Trial A: Binding Strength of Cooked Product

Batch	Shear Force (kg)	Rank
2% AIM	$22.68^{a,b}$ (1.48)	3
1% AIM-1% WR	$21.65^{a,b}$ (0.39)	4
1% AIM-1% WF	$20.94^{a,b}$ (0.92)	6
1% AIM-1% Soya	$20.79^{a,b}$ (0.33)	7
1% AIM-1% SMP	$21.39^{a,b}$ (0.64)	5
3% AIM	$19.54^{a,b}$ (0.30)	9
2% WF	$20.45^{a,b}$ (0.70)	8
2% WR	$22.82^{a,b}$ (1.02)	2
2% Soya	24.57^{a} (1.14)	1
1% AIM-30% Water	17.82^{b} (0.71)	10

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

measures for each batch. Therefore, data analysis was only able to identify statistical differences in the extreme means. However, the differences among these means may be of practical importance.

4.2.2.6 Emulsion Stability

Emulsion stability is extremely important in comminuted meat systems. Low stability results in the coalescence of fat which results in fat pools and caps in the cooked product. For these trials, products exhibiting the lowest emulsion stability number actually have the best emulsion stability in the cooked product. The 2% soya and 1% AIM-1% WF products exhibited significantly higher emulsion stability than all other products (Table 17). The 1% AIM-30% water batch exhibited the lowest emulsion stability, but it was not significantly different from the 2% AIM or 3% AIM products.

TABLE 17. Trial A: Emulsion Stability of Cooked Product

Batch	Emulsion Stability #	Rank
2% AIM	$0.76^{a,b}$ (0.02)	6
1% AIM-1% WR	0.70^{b} (0.00)	4
1% AIM-1% WF	0.51^{c} (0.00)	1
1% AIM-1% Soya	0.69^{b} (0.01)	3
1% AIM-1% SMP	0.17^{b} (0.02)	2
3% AIM	$0.72^{a,b}$ (0.01)	5
2% WF	0.67^{b} (0.02)	2
2% WR	0.69^{b} (0.01)	3
2% Soya	0.51^{c} (0.00)	1
1% AIM-30% Water	0.81^{a} (0.03)	7

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

4.3 TRIAL B

The objective of Trial B was to examine the effect of non-meat binders used singly but at a series of levels, on the functional properties of raw batters and cooked products by eliminating as much variability as possible in the batter formulation. The batches in this trial were formulated so that the levels of all of the components (fat, water, carbohydrate, fibre etc.) were the same in each batter. The protein level was also held constant, but non-meat proteins were substituted for meat proteins. This involved a reduction in the size of the meat block. Therefore, fat and ice were added, as required, to maintain the proper composition of the batter. No binder was added to the all meat control, carbohydrate and fibre levels were maintained by the addition of potato starch and oat bran ([illegible] mesh), respectively. Therefore, any difference in functional properties among the batches should be entirely due to the effect of the binder.

It is important to note that in Trial A the percentage of binder (eg. 2% AIM) referred to the percentage of protein contributed by the binder to the raw batter. In Trial B, the percentage of binder refers to the percentage of binder, not protein contributed by the binder, in the raw batter. Therefore, the amount of protein contributed by the binder and the total percentage of binder incorporated is much less in Trial B than in Trial A.

4.3.1. Proximate Analysis

The proximate analysis of the raw batters and cooked products are presented in Tables 18-20. The average protein and moisture contents of raw batters were slightly higher than the formulated values of 11% and 57% respectively, while the average fat content was much lower than the formulated value of 23%.

The most logical explanation for this finding is the meat block contained more than 90% lean tissue, which resulted in a decreased amount of fat and water and an increased amount of protein contributed by the meat block. Additional error in the expected contribution of fat from the added beef fat was detected, since the calculations were based upon the assumption the tissue contained only fat. Therefore, the water and protein content

TABLE 18. Trial B:
Raw Batter & Cooked Product Moisture Content

Batch	Raw(%)	Cooked(%)
2% Soya	$60.48^{b,c}$ (0.13)	$56.98^{c,d}$ (0.08)
1% Soya	60.25^{b} (0.02)	56.31^{c} (0.06)
0.5% Soya	$60.11^{a,b}$ (0.03)	55.57^{b} (0.09)
2% AIM	60.23^{b} (0.05)	$56.55^{c,d}$ (0.06)
1% AIM	61.08^{d} (0.03)	56.41^{c} (0.05)
0.5% AIM	61.82^{e} (0.11)	57.06^{d} (0.11)
0.25% AIM	61.13^{d} (0.07)	56.39^{c} (0.11)
1% Oat Flour	59.87^{a} (0.18)	$56.49^{c,d}$ (0.06)
1% Wheat Flour	$60.95^{c,d}$ (0.06)	53.88^{a} (0.19)
All Meat Control	62.96^{f} (0.04)	55.27^{b} (0.07)

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

TABLE 19. Trial B:
Raw Batter & Cooked Product Fat Content

Batch	Raw(%)	Cooked(%)
2% [illegible]	$18.69^{b,c,d,e}$ (0.18)	$20.46^{b,c}$ (0.19)
1% Soya	$19.41^{d,e}$ (0.02)	$21.48^{c,e}$ (0.04)
0.5% Soya	19.65^{e} (0.13)	22.11^{e} (0.14)
2% AIM	$18.79^{c,d,e}$ (0.10)	$21.15^{c,e}$ (0.19)
1% AIM	$18.48^{b,c,d}$ (0.14)	20.50^{c} (0.07)
0.5% AIM	17.82^{b} (0.14)	19.14^{b} (0.48)
0.25% AIM	$18.45^{b,c,d}$ (0.08)	$20.21^{b,c}$ (0.20)
1% Oat Flour	$19.14^{d,e}$ (0.15)	20.67^{c} (0.49)
1% Wheat Flour	$17.83^{b,c}$ (0.31)	$21.03^{c,e}$ (0.05)
All Meat Control	16.22^{a} (0.04)	17.63^{a} (0.12)

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

TABLE 20. Trial B:
Raw Batter & Cooked Product Protein Content

Batch	Raw(%)	Cooked(%)
2% Soya	12.16^{a} (0.07)	13.07^{a} (0.05)
1% Soya	12.13^{a} (0.04)	13.24^{a} (0.06)
0.5% Soya	12.24^{a} (0.03)	$13.67^{b,c}$ (0.04)
2% AIM	12.18^{a} (0.03)	$14.04^{c,d}$ (0.10)
1% AIM	12.39^{a} (0.07)	14.15^{d} (0.13)
0.5% AIM	$12.46^{a,b}$ (0.07)	$13.99^{c,d}$ (0.05)
0.25% AIM	12.30^{a} (0.04)	$13.98^{c,d}$ (0.07)
1% Oat Flour	12.26^{a} (0.05)	$13.28^{a,b}$ (0.11)
1% Wheat Flour	12.34^{a} (0.14)	$13.73^{b,c,d}$ (0.04)
All Meat Control	12.84^{b} (0.06)	14.67^{e} (0.07)

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

of the added beef fat was not taken into consideration, resulting in a decrease in the amount of fat and an increase in the amounts of protein and water, not accounted for in the formulation.

There were statistically significant differences in the moisture content of the raw batters. There were also statistically significant differences in the moisture content of the cooked products. Statistical differences in fat content among raw batters and among cooked products were also noted. In the raw batters, the protein content of the batches were very similar. The 0.5% AIM batter was not significantly different from the all meat control or any other batch. The all meat control was observed to be statistically different from all other batters with the above noted exception of of the 0.5% AIM batter. Significant differences in protein content among cooked products were observed. This is not indicative of a formulation error but resulted from differences in moisture loss during cooking.

The all meat control exhibited a significantly higher moisture and protein content and a significantly lower fat content than all other batches. Due to an error in the estimation of required meat block, the all meat control was formulated with tissue that was not part of the meat block used for the other batches. If this error had been noted prior to production of batters #1-9, this tissue would have been mixed with the other meat block. Like the meat block used in batters #1-9, this tissue was also beef trim (house run), but appeared to contain a higher ratio of lean to fat than the original meat block. The extra lean tissue provided more water and protein and less fat than expected from the 90% lean meat block. Thus, the proximate analysis obtained for this batch appears to be reasonable. The all meat control product produced with this tissue should exhibit increased fat stability and binding strength compared to an all meat product which incorporated the tissue used for all other batches.

4.3.2 Functional Properties

4.3.2.1 Yield

Binders exhibiting high fat and water stabilization would be expected to produce batches with increased yield. The batch containing 1% soya exhibited the highest yield (93.4%), followed by the 2% soya batch (93.1%), while the batch containing 0.5% soya had a yield of 91.6% (Table 21). Since soya has been reported to exhibit excellent binding properties (Kinsella, 1979), a pattern of increased addition resulting in increased yield was expected. Although no pattern was observed, a large increase in yield resulted from doubling the soya content from 0.5% to 1.0%. However, doubling the soya content once again (1.0% to 2.0%) did not result in a large increase in yield. Apparently, this additional soya protein had little effect on the matrix, therefore no increase in yield was observed.

Mustard flour, at levels of 0.25% and 1.0%, resulted in the same product yield as the 0.5% soya batter (91.6%). This resulted in a three way tie for the third highest yield. Like the soya batches, there was no apparent correlation between rate of addition and yield produced by mustard flour. Batters containing 2.0% and 0.5% exhibited lower yields (90.8% and 90.5%, respectively) than the other two mustard flour batters.

The batch containing 1% oat flour had a yield (91.2%), which was slightly lower than the wheat flour batch (91.5%), but higher than the 2% and 0.5% mustard flour batches. The all meat control batch exhibited the poorest yield at only 84.7%. This value would be expected in view of the sharp decrease in moisture content (62.96% to 55.27%) that occurred during cooking/chilling.

4.3.2.2 Water Holding Capacity - Raw Batters

Significant differences in the water holding capacity of the raw batters were observed. As in Trial A, some of the raw batters actually absorbed water during the water holding capacity test. The 1% and 0.25% mustard flour batters showed the highest level of water absorption at 0.35 g water/g batter (Table 22). The water holding

TABLE 21. Trial B: Yield of Chilled Product

Batch	Yield (%)	Rank
2% Soya	93.1	2
1% Soya	93.4	1
0.5% Soya	91.6	3
2% AIM	90.8	6
1% AIM	91.6	3
0.5% AIM	90.5	7
0.25% AIM	91.6	3
1% Oat Flour	91.2	5
1% Wheat Flour	91.5	4
All Meat Control	84.7	8

TABLE 22. Trial B:
Water Holding Capacity of Raw Batter

Batch	g water absorbed/g batter	Rank
2% Soya	0.04^{b} (0.01)	7
1% Soya	$0.12^{b,c}$ (0.03)	5
0.5% Soya	-0.20^{a} (0.01)	8
2% AIM	$0.11^{b,c}$ (0.02)	6
1% AIM	$0.35^{d,e}$ (0.02)	1
0.5% AIM	$0.21^{c,d}$ (0.03)	4
0.25% AIM	0.35^{e} (0.03)	1
1% Oat Flour	$0.29^{d,e}$ (0.02)	2
1% Wheat Flour	$0.28^{d,e}$ (0.03)	3
All Meat Control	-0.20^{a} (0.01)	8

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

capacity of the 1% mustard flour batch was significantly different from all other batters except the 1% mustard flour batter. The 0.5% and 2% mustard flour batters also absorbed water but only at the rate of 0.21 and 0.12 g water/g batter, respectively. Since absorption of water by batters containing mustard flour was also observed in Trial A, it would appear that rehydration of the flour before incorporation into the batter should be investigated.

Of the soya batches, the 1% batter absorbed the most water (0.12 g water/g batter), while the 0.5% soya batter actually lost water (0.20 g water/g batter). The water holding capacity of the wheat flour batter (0.28 g water/g batter) and the oat flour batter (0.27 g water/g batter) were not significantly different from the 2% and 0.5% mustard flour batters. The all meat control batter lost the same amount of water during the test (0.20 g water/g batter) as the 0.5 % soya product.

It should be noted that the all meat control batter exhibited a low chilled yield, a sharp decrease in moisture content after cooking/chilling, and low water holding capacity, suggesting these properties may be related. No apparent pattern between rate of addition and water holding capacity was observed for the soya or mustard flour series.

4.3.2.3 Water Holding Capacity - Cooked Product

The water holding capacity of the cooked products (Table 23) did not follow the same pattern as the raw batter water holding capacity. The 2% soya product exhibited the highest water holding capacity (98.98%), followed by the 0.25% mustard flour (98.80%), 1% soya (98.31%) and 1.0% oat flour products. There was no significant difference in water holding capacity among these batters. However, it is possible that the difference observed could be of practical importance, possibly indicating the shelf life of the product.

Water holding capacity decreased as soya content decreased, while an increased content of mustard flour resulted in increased water holding capacity, (with the exception of the 0.25% batter). The all meat control was significantly different from all other batters, and exhibited the lowest cooked water holding capacity at only 90.94%.

TABLE 23. Trial B: Water Holding Capacity of Cooked Product

Batch	WHC(%)	Rank
2% Soya	98.98 ^{d,e} (0.09)	1
1% Soya	98.31 ^{c,d,e} (0.11)	3
0.5% Soya	95.79 ^{b,c} (0.70)	7
2% AIM	96.48 ^{c,d} (0.54)	5
1% AIM	95.87 ^{c,d} (0.53)	6
0.5% AIM	93.24 ^{a,b} (0.49)	8
0.25% AIM	98.80 ^{d,e} (0.21)	2
1% Oat Flour	96.82 ^{c,d,e} (0.43)	4
1% Wheat Flour	92.98 ^{a,b} (0.26)	9
All Meat Control	90.94 ^{a} (0.71)	10

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

A comparison between the rankings of the batches in the raw and cooked water holding capacity tests revealed the water holding capacity of the raw batter can not be used to predict the water holding capacity of the cooked product. For example, the 2% soya product was first in the cooked water holding capacity test yet ranked seventh in the raw batter test. Possibly the water in the raw batter is not tightly bound and is released during the water holding capacity test. During cooking, this loosely bound water evaporates, leaving only the more tightly bound water. Therefore, the cooked product exhibits exceptionally high water holding capacity, while the raw batter exhibits relatively low water holding capacity. Thus, possibly the chilled yield, raw batter water binding capacity, and difference in moisture contents before and after cooking are more useful indicators of batter stability than the cooked product water holding capacity test.

4.3.2.4 Colour

There were statistical differences in the *L*,*a* and *b* values for each product (Table 24). These differences are not important from a practical standpoint because of the wide range in colour of commercially available products. The *L* values ranged from 46.6 (all meat control) to 49.7 (2% mustard flour). The all meat control had the lowest *L* value as expected, since this batch also had the highest content of lean meat and no added binder. The *L* value for the 2%, 1% and 0.5% mustard flour products were significantly different, indicating that a decrease in amount of mustard flour added caused a decrease in the *L* value. The *L* value of the soya products were not significantly different, indicating that rate of addition of soya isolate did not affect the colour of the product.

The *a* values ranged from a high of 18.7 (0.5% mustard flour) to a low of 16.7 (0.5% soya) which was also statistically different from all other products. The *a* value for the 2% mustard flour product was statistically different from all other mustard flour products. Mustard flour binder was previously found to have the lowest *a* value (-3.3), so it was expected to cause a decrease in *a* value relative to the control. The *a* values for the

TABLE 24. Trial B:
Colour of Cooked Product

Batch	L	a	b
2% Soya	$48.7^{b,c}$ (0.15)	18.6^{c} (0.14)	$12.6^{b,c}$ (0.07)
1% Soya	49.1^{b} (0.53)	$18.2^{b,d}$ (0.18)	$12.4^{b,c}$ (0.10)
0.5% Soya	$48.7^{b,c}$ (0.08)	16.7^{a} (0.10)	12.9^{b} (0.05)
2% AIM	49.7^{b} (0.07)	17.6^{b} (0.10)	12.8^{b} (0.04)
1% AIM	48.1^{c} (0.05)	$18.6^{c,d}$ (0.08)	$12.2^{a,c}$ (0.05)
0.5% AIM	47.1^{a} (0.30)	18.7^{c} (0.13)	$12.3^{a,c}$ (0.10)
0.25% AIM	47.1^{a} (0.21)	$18.6^{c,d}$ (0.21)	$12.3^{a,c}$ (.10)
1% Oat Flour	46.7^{a} (0.12)	$18.2^{b,d}$ (0.17)	$12.1^{a,c}$ (0.06)
1% Wheat Flour	$47.6^{a,c}$ (0.52)	17.9^{b} (0.14)	11.9^{a} (0.11)
All Meat Control	46.6^{a} (0.10)	$18.1^{b,d}$ (0.16)	11.9^{a} (0.08)

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

soya products were statistically different from each other, thus indicating that the rate of addition of soya isolate affected the colour of the product.

The *b* values ranged from a high of 12.9 (0.5% soya) to 11.9 for the all meat control and wheat flour. The 2% mustard flour product *b* value (12.8) was significantly different from the other mustard flour products. Based upon the results obtained in Trial A, all the AIM products would have been expected to have higher *b* values. However, it now appears that at least 2% AIM flour (rate of addition) is required to produce a difference in the colour of the product. There was no significant difference in the *a* values of the soya products.

4.3.2.5 Binding Strength

Binding strength of the soya products showed a definite pattern with increased soya content resulting in decreased binding strength (Table 25). The 2% soya product was the least firm, with 14.50 kg of force required to shear the wiener. None of the soya containing products were as firm as all the meat control (21.05 kg). The 2% mustard flour product was the softest of the mustard flour series (17.38 kg), while the 0.5% mustard flour (23.46 kg) was the firmest product of all of the mustard flour batches. The oat flour (23.46 kg), wheat flour (21.16 kg) and 0.25%, 0.5%, 1% mustard flour products were firmer than the control.

There was no significant difference in binding strength among the 2% soya, 1% soya and 2% mustard flour products. While different from the previously noted products, there was no significant difference in binding strength among the remaining seven products. The method of analysis resulted in large variability in the repetitive measures for each batch. Therefore, data analysis was unable to identify statistical differences among most means. However, the differences among these means may be of practical importance.

4.3.2.6 Emulsion Stability

The 2% soya product had a significantly lower emulsion stability number, therefore higher emulsion stability, than all other products (Table 26). The 1%

TABLE 25. Trial B:
Binding Strength of Cooked Product

Batch	Shear Force (kg)	Rank
2% Soya	14.50^{a} (0.50)	9
1% Soya	15.38^{a} (0.64)	8
0.5% Soya	20.60^{b} (0.29)	6
2% AIM	17.38^{a} (0.59)	7
1% AIM	21.16^{b} (0.51)	4
0.5% AIM	23.46^{b} (0.57)	2
0.25% AIM	22.82^{b} (0.49)	3
1% Oat Flour	23.47^{b} (0.43)	1
1% Wheat Flour	21.16^{b} (0.49)	4
All Meat Control	21.05^{b} (0.68)	5

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

TABLE 26. Trial B:
Emulsion Stability of Cooked Product

Batch	Emulsion Stability #	Rank
2% Soya	0.53^{a} (0.01)	1
1% Soya	0.69^{b} (0.00)	3
0.5% Soya	$0.75^{b,d}$ (0.02)	7
2% AIM	0.66^{b} (0.02)	2
1% AIM	$0.76^{b,d}$ (0.00)	8
0.5% AIM	0.72^{b} (0.02)	6
0.25% AIM	$0.84^{c,d}$ (0.04)	9
1% Oat Flour	0.89^{c} (0.01)	10
1% Wheat Flour	0.70^{b} (0.01)	4
All Meat Control	0.71^{b} (0.02)	5

Means in the same column with different superscripts are significantly different ($P < 0.05$)

Values in parentheses represent standard error

and 0.5% soya products had emulsion stability numbers of 0.69 and 0.75 respectively, thus exhibiting a pattern of decreased emulsion stability with decreased amounts of soya. However, these values were not statistically different.

The 2% AIM wieners had the highest emulsion stability number (0.69) of the mustard flour series. A pattern of decreased amounts of mustard flour resulting in decreased emulsion stability was observed. However, there was no significant difference among the emulsion stability numbers of these products. With the exception of the 2% AIM product, all other AIM products exhibited lower emulsion stability than the all meat control (0.71). The 2% oat flour product exhibited the lowest stability at 0.8940. This value was not significantly different from the value obtained for 0.25% AIM (0.84), however, the emulsion stability of these products was significantly lower than all other products.

5.0 CONCLUSION

5.1 TRIAL A

Experiments performed in Trial A were designed to identify which binders when used singly or in combination with mustard flour, produced a wiener which exhibited the most advantageous functional properties.

The batch containing 2% wheat rusket protein had the highest yield, the second highest water holding capacity in the raw batter, the second highest water holding capacity in the cooked product, the second highest binding strength, and tied for the third highest emulsion stability. None of the other binders scored as highly in as many tests as the wheat rusket. The exceptional functional properties produced by wheat rusket may be due to the high levels of carbohydrate contained in the flour.

Soya isolate when used at the 2% protein level the highest water holding capacity in the cooked product, the firmest texture, and exhibited the highest emulsion stability. Mustard flour, used at the 2% protein level exhibited the third highest yield, third highest water holding capacity in the raw batter, third highest water holding capacity in the cooked product, and the third highest binding strength. However, this product exhibited low emulsion stability. Mustard flour, used at 1% protein level, produced products with functional properties lower than those obtained with mustard flour used at the 2% protein level.

Batches containing mustard flour in combination with other binders performed erratically. The 1% AIM-1% WR product had the fourth highest binding strength but had the lowest water holding capacity in the cooked product. The 1% AIM-1% WF product exhibited the highest (tied with 2% soya) emulsion stability and the fourth highest chilled yield, but also had the second lowest water holding capacity in the cooked product. The 1% AIM-1% SMP product had the third highest emulsion stability (tied with 2% WF), fifth highest water holding capacity in the raw batter and the eighth highest water holding capacity in the cooked product. The 1% AIM-1% soya product exhibited the second highest chilled yield, but was seventh in binding strength. Overall, combinations of mustard flour and other binders did not produce products with superior functional properties.

Overall, the 2% wheat rusket product was the best product, closely followed by the 2% soya isolate and 2% mustard flour products.

5.2 TRIAL B

The purpose of Trial B was to examine the effect of binders on functional properties by substituting binder protein for meat protein. Unlike Trial A, where the meat block and total protein content was constant for each batch, batters in Trial B were formulated with different contents of meat protein. Meat protein was replaced at four different levels by mustard flour protein, three different levels by soya isolate protein and by oat flour and wheat flour proteins. An all meat batch was also formulated to serve as a control.

There was no one product that scored the highest in every functional property category. However, the 0.25% mustard flour product did score well in a number of tests. It exhibited the third highest yield, the highest water holding capacity in the raw batter (tied with 1% mustard flour), the second highest water holding capacity in the cooked product, and third highest binding strength. Unfortunately, it exhibited the second lowest emulsion stability. It is possible that the emulsion stability test is not one of the most important indicators of quality, since none of the batches had obvious fat caps or fat pools after cooking and chilling, thus indicating adequate emulsion stability.

The 1% mustard flour product ranked second in water holding capacity in the raw batter, third in chilled yield, fourth in binding strength, and sixth in water holding capacity in the cooked product. However, it was eighth in emulsion stability. The oat flour product exhibited the highest binding strength, but the lowest emulsion stability. Wheat flour was third in water holding capacity in the raw batter, and fourth in chilled yield, binding strength and emulsion stability, but it was ninth overall in water holding capacity in the cooked product.

The soya isolate products and the other mustard flour products performed erratically. The all meat control product scored almost last in all categories except binding strength and emulsion stability where it was fifth.

It would appear that mustard flour, when used at the 0.25% addition level, produced the most desirable product and performed much better than wheat flour or soya isolate, which are two of the most common binders used in Canadian comminuted meat products.

5.3 SUMMARY AND RECOMMENDATIONS

The products formulated in Trials A and B contained different levels of protein and different levels of binders. Therefore, comparisons can not be made between trials. The most desirable product in Trial A was the 2% wheat rusket product, closely followed by the 2% soya isolate and 2% mustard flour products. The best product in Trial B was the 0.25% mustard flour product, followed by the 1% mustard flour product. Based on the functional properties of the finished product, mustard flour apparently has the potential to become the binder of choice in comminuted meat systems.

However, there is a very large difference in the relative cost of each of the binders studied in this project. The cost of each binder on an "as is" basis and a protein basis is presented in Table 27. The choice of binder for use in a comminuted meat system is based on its functional properties in the system as well as its cost. Mustard flour performed satisfactorily in the comminuted system in Trial B. Therefore, it should be considered as a potential binder used in commercial production of wieners and other comminuted products.

However, mustard flour is the third most expensive binder on an "as is" basis and the second most expensive binder on a protein basis. Mustard flour, however, does have one distinct advantage over all the other binders studied: when incorporated at a level of

TABLE 27.
Price of Binders

Binder	$ per kg	$ per kg protein
Mustard Flour	1.04	3.47
Oat Flour	1.40	10.61
Skim Milk Powder	4.55	12.67
Soya Isolate	4.58	5.01
Wheat Flour	0.35	2.26
Wheat Rusket	0.75	5.77

less than 2%, mustard flour is considered a spice, and therefore, is not required to appear on the label. Thus, a meat product incorporating mustard flour may be perceived by the consumer to contain fewer "additives", which may influence the consumers choice of products, and possibly increase the market share for the processor. Therefore, processors must decide if the benefits of mustard flour usage outweigh the slightly higher costs of this binder.

Wheat rusket produced the best product in Trial A, but on a protein basis, it is 1.7 times more expensive than mustard flour and also more expensive than wheat flour or soya isolate. Therefore, the cost of using this binder singly in a product is probably prohibitive.

Two projects are worthy of investigation to uncover new information on the function of binders in comminuted meat systems:

1. Since wheat rusket absorbed water during the raw batter water holding capacity test, the effects of rehydration of this binder on chilled yield, binding strength, and water holding capacity (cooked product), should be examined. It is possible that rehydration before incorporation into the batter may enable the processor to substitute additional amounts of the binder for meat protein, thus reducing overall production costs.

2. Little information is available detailing how the binders function within the protein matrix/emulsion system. Since different binders contain different types of protein, the proteins will probably interact differently in the matrix. A study could be undertaken to examine how the proteins from different binders exist in the matrix. Possibly some binder proteins form part of the matrix and/or the interfacial protein film, while other proteins may simply exist in the interstices. If how these proteins function at the microstructural level was discovered, then it would be possible to select specific proteins (or specific binders which contained large quantities of these proteins) for use in comminuted meat systems. A

protein found to form the matrix or the interfacial protein film could replace significant quantities of meat protein, thus representing a significant saving for the processor.

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7.0 APPENDIX A. Protocol Used for the Cooking of Wieners

Program 1 Smoke Program Reddening 15 minutes
Predry 10 minutes
Smoke 25 minutes
Temperature 56 °C

Program 2 Dry 1
Temperature 70 °C
Moisture 65 °C
30 min

Program 3 Cook/Scald
Temperature 76 °C
Core temperature 70 °C

Program 4 Shower
Core temperature 8 °C

Hold in cooler 30 minutes at 4 °C