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Meat in emulsion type sausages – An overview

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Abstract

This paper provides a critical overview of the utilisation and use of various types of meat and animal fat in emulsion type sausages. Emphasis has been placed on the functionality of beef, pork, poultry, fish and mutton in the meat emulsions. Meat raw material selection has an important influence on the yield, texture and microstructure of comminuted sausage products. It is difficult to evaluate the large amount of data due to the use of varying techniques in obtaining these data. Hence, standardization of these methods is required. Further research is needed to improve methodology to determine the functional properties of meat systems. Mathematical models are required to describe the behavior of various meat systems in meat emulsions. These models will assist in the optimization of the functionality of final product, and the optimum and proper utilisation of different meat products. Further investigations are required to determine the effects of various ingredients in structure forming properties of the sausages.

Key words: Comminuted meat, meat emulsion, sausage, meat processing, meat type, frankfurter, meat functionality.

Introduction

In meat emulsions, two protein sources are animal products and non-meat proteins. Utilisation of more diversified animal protein sources for the preparation of comminuted meat products requires information on their relevant functional properties or parameters. Functional parameters are closely related to the size, configuration and conformation of protein molecules [1]. Modifications of muscle proteins, with resultant improvements in functional properties, may be one means of increasing efficient utilisation of these protein resources. Better functionality would provide greater flexibility in choice of proteins and ensure reliable ingredient uniformity, both of which should facilitate modern manufacturing processes and aid computer-based formulations designed to optimise several criteria, including functionality, flavour and nutritional balance [2]. Meats in emulsion sausages are various forms of beef, pork, chicken, fish and mutton. These and other meat products have been used in the meat emulsion industry for many years, but little systematic research has been published to document their effectiveness and performance.

Beef and Pork

The muscle type is more important in determining myoglobin concentration than the animal species [3]. Genetic and certain environmental factors, in addition to age, exercise and diet of the animal, affect muscle myoglobin concentration. Post-slaughter treatment of the carcass has a significant effect on the relative concentration of myoglobin and hemoglobin.

The highest yields were obtained with *M. biceps brachii* and the lowest with *M. serraturs* [4]. The muscles were taken from young bulls 5-7 days after slaughter. The *M. biceps femoris*, which has good properties when used as intact muscle, functioned poorly when used in comminuted meat products. Shoulder meat gave the lowest and neck meat the highest yield according to the net and the frying tests. The anterior part of *M. serraturs* and the more undefined shoulder meat gave the lowest yield. The high collagen content and the state of the collagen/gelation was probably the reason for the higher rupture forces of cold sausage samples of foreleg relative to the other samples. Sausages made from shoulder meat had a significantly higher rigidity modulus than the other systems.

The emulsifying capacity (EC) of 13 beef and pork trimmings was evaluated [5] using the Swift et al.[6] method (Table 1). The fatter trimmings indicated a more efficient emulsification by the protein, because these products had higher EC per unit of protein compared to leaner trimmings. Emulsions made from pork hearts and brains were very unstable, whereas the stability was satisfactory for emulsions made from trimmings derived from striated skeleton muscle. Pork hearts formed a very unstable emulsion when compared to pork trim (60 to 75%), beef cheeks and beef cheeks preblend. The results indicated that beef cheeks preblend formed as stable an emulsion as the beef cheeks. Blood plasma had a higher EC and skeletal muscle the lowest[7]. The

Table 1. Emulsifying capacity (EC) of meat trimmings and fats.

Product	EC, mL oil/ g sample [5]	Product	EC, g fat/ g protein [59]
Beef cheek	489	Pork back fat	139.4b*
Beef hearts	460	Pork leaf fat	127.0e
Veal (90-95%)	450	Pork jowl fat	138.4bc
Beef trim (80-85%)	429	Pork ham fat	137.8 bc
Beef cheek, preblend	428	Pork shoulder fat	139.8b
Beef trim (50-55%)	366	Beef loin fat	144.2a
Pork hearts	444	Beef kidney knob fat	136.6c
Pork trim (75-80%)	428	Beef flank & cod fat	142.8a
Pork trim (60-65%)	416	Beef brisket fat	136.4c
Pork trim (38-43%)	351	Beef chuk fat	128.4e
Pork brain	306	Mutton kidney knob fat	127.8e
Skinless jaws	304	Mutton leg fat	131.8d
Mutton (80-85%)	438	Rendered chicken fat	133.4d

*Means within the same column with different letters following them are significantly different.

Table 2. Functional properties of beef and pork meats [50, 51, 66].

Tissue powder	Total protein, %	Soluble protein, % of total protein	EC, mL oil/100 mg total protein	mL fat released from 10 g emulsion	mL water and suspended solid released from 10 g emulsion
Blood	83.9	69.7	43.8	0.03	1.4
Brain	70.5	18.9	19.2	0.08	1.3
Lung	80.0	16.2	12.5	0.02	0.7
Stomach	74.8	16.1	15.8	0.04	1.0
Duodeum	85.6	12.4	17.3	0.12	2.3
Kindney	76.5	8.7	13.2	0.17	2.0
Liver	79.7	8.2	12.8	0.01	1.0
Spleen	84.3	3.2	9.5	0.11	1.7
Heart	85.3	2.9	9.6	0.12	1.5
Beef muscle	21.9	22.7	16.0	0.02	1.1
Beef muscle(fresh)	-	-	23.5	-	-
NFDM*	-	-	12.0	-	
Pepsin	-	-	12.1	-	-
Papain	-	-	8.5	-	-
Pancreatic	-	-	10.6	-	-
Beef trimmings	-	-	21.3	-	-
Pork fat	-	-	15.5	-	-
Chicken backs (Mechanically deboned)	-	-	19.9	-	-

*Non-fat dry milk.

functional properties of various beef and pork meats are given in Table 2.

The amount of fat, which can be emulsified by 1 g of salt soluble protein, is a constant for each type of meat [8]. On the basis of EC and emulsion stability (ES), a bind constant was defined. This was determined for 81 meats cuts. 'High bind' meat included skeletal muscle meats from bulls, cows and mutton carcasses. Examples of 'medium binding' meats included cheek meat, veal and pork trimmings. Examples of 'low binding' or filler meats included ox lips, tripe, pork stomach and partially defatted pork tissue [9]. Regression models to predict the 'bind value constant' of meat emulsion ingredients were developed [10] by dividing these ingredients into four classes: (I) striated skeletal muscles, (II) striated non-skeletal muscles, (III) organ and smooth muscles and (IV) non-meat proteins. The following are the regression models:

Class I: $Y = -1.676 + 1.423\,X$, $r^2 = 0.945$

Class II: $Y = 0.654 + 0.798\,X$, $r^2 = 0.782$

Class III: $Y = 2.54 - 0.491\,X + 0.027\,X^2 - 3.61\,E\text{-}4\,X^3$, $r^2 = 0.975$

Class IV: $Y = -8.977 + 5.550\,X - 0.155\,X^2 + 1.28\,E\text{-}3\,X^3$, $r^2 = 0.94$

Where Y is 'bind value constant', X is percentage protein in the ingredient, and r^2 is the coefficient of determination.

The effects of enzymatic modification on beef heart protein functionality in model system and meat emulsion were examined [11]. The modification of heart myofibrils with ficin (enzyme) was effective in improving protein solubility and EC compared to controls. Normal (2%) and low (0.5%) salt frankfurters made with 30% enzyme modified beef heart had significantly greater smokehouse yields, consumer cooked yields and ES than frankfurters made with 30% unmodified heart.

Increasing the level of pork heart in the meat emulsion increased the shrinkage and decreased the sensory panel scores for firmness and preference of the products. The type of additive had no effect on shrinkage or texture measured mechanically [12]. However, others [13] reported that pork hearts reduced product tensile strength.

Frankfurters were prepared [14] with beef trim, pork fat, and 0 to 50% mechanically processed pork product (MPPP) produced by a hydraulic press deboner. ES tests indicated that formulations with 30% or less MPPP were similar in smokehouse yield, and percentage of water and fat lost during cooking. Water holding capacity (WHC) increased with increasing levels of MPPP, but frankfurters containing >30% MPPP were softer in texture as determined by Warner-Bratzler shear force values. Increased fat and water loss during processing of 40 and 50% MPPP formulations resulted in lower yields and smaller frankfurter diameters. Emulsions with a decreasing stability was obtained with pork fat in the following order: flare fat, back fat, ham fat, belly fat, cheek fat and soft belly fat [15]. Beef fat and mutton fat are not as versatile as pork fat, and therefore only a very limited fat/water ratio is possible (Table 1).

Lean beef chuck, beef tripe, beef plasma, lean pork trim, mechanically deboned (MD) chicken and pork hearts were used [16] in strong, medium and weak meat systems in meat emulsions along with non-meat ingredients such as sodium caseinate, textured soy-protein, potato starch, hard wheat flour, non-fat dry milk and soy-isolate. Although the stability and textural data for each ingredient decreased as the meat block strength decreased, the rate of decrease was variable. High stabilities were observed for all ingredients in the strong system, whereas in the weak system the stabilities covered a broad range. The superior textural performance of lean beef was evident in all three meat systems. Tripe, starch and milk powder performed relatively better in the strong system than in the medium and weak systems. In weak meat systems having low skeletal muscle content and large amounts of filler, e.g. extended products, texture and not stability was the principal concern.

***Collagen*:** The use of enzyme hydrolysed skin collagen as a binder or extender in the emulsions was reported [17]. Hydrolysates of beef or pork skin, when used to replace non-fat dry milk in a meat emulsion produced a sausage with a slightly better water and fat holding ability. Even though the EC of the various skin hydrolysates was slightly lower than the capacity of non-fat dry milk, the greater protein content of the hydrolysates gave the emulsion improved stability during cooking. No alteration in colour or evidence of off-flavour was detected in any of the sausages which contained the skin hydrolysates. Collagen is known to be deficient in the essential amino acid tryptophan and limiting in other essential amino acids such as lysine, threonine and

Table 3. Functional properties of collagen [17].

Material	EC, mL oil/ g sample	ES, mL released/10 g emulsion		Peptide content, %
		Fat	water and suspended solids	
Beef skin				
Pancreatin digest	78.3	0.3	2.0	89.4
Pork skin				
Pancreatin digest	96.7	0.5	1.7	91.0
Papsin digest	101.5	0.4	2.0	88.0
Papain digest	77.0	-	-	91.1
Control				
Non-fat dry milk	40.2	0.6	2.4	--

methionine. Collagen will not lower the nutritional quality if used along with a balanced protein and maintained at a low level, such as would be the case when a collagen hydrolysate is used as a binder or extender in meat emulsions. The functional properties of collagen from beef and pork are listed in Table 3.

Meat condition: The percent salt-soluble protein and EC were similar for prerigor and pre-blended prerigor meats and significantly greater than the other treatments [18]. Pre-blended post-rigor frozen meat emulsified 30% more fat in frankfurters than either fresh post-rigor or post-rigor frozen meat. Intensity of frankfurter colour was greater from pre-rigor and pre-blended meat than for post-rigor meat. Total bacterial counts were decreased by preblending the meat and by freezing. From an industrial view point, preblended meats in actual sausage production would give a processor several advantages over the same non-preblended meats by: (i) increased extraction of soluble protein during comminution, (ii) increased fat emulsifying ability of the extracted protein and reduction of emulsion breakdown and (iii) more desirable colour formation. The amount of salt soluble protein, which could be extracted, was 9% less in frozen meat than in fresh meat [9].

Pre-rigor meats are superior to post-rigor meats in water binding capacity, EC, ES, and in developing the desired texture of the finished product [19]. The amount of salt soluble proteins in prerigor beef was 50% greater than at 48 h post-rigor [20]. Fresh meats are superior to frozen meats. Salt and/or selected phosphates assist in retaining the functional properties of pre-rigor meat even during the freezing process.

Poultry

The increasing availability of mechanically deboned (MD) meats from under-utilised poultry parts (back, neck, wing, turkey frame, spent layer) has presented the meat industry with a potentially valuable raw materials for use in emulsion type meat products. The less popular poultry parts of low market value are the items of greatest potential for use in emulsion type products. The development of mechanical deboning devices has permitted economical removal of meat from bones, thus making available the paste-like product [21].

These paste-like meats (chicken and turkey) were found to have good ES when chopped to temperatures of 7 to 13°C. The MD poultry meat chopped to >13°C was observed to have inferior ES. Hand boned chicken broiler meat was noted to possess good ES at chopping temperatures in excess of 13°C. Combination of hand deboned chicken and turkey meat with MD meat should, therefore enhance the stability of the final MD meat emulsion[22, 23].

Emulsion formation was complete after a short chopping period of 1.5 to 3.0 min. The MD turkey meat exhibited higher EC than beef but lower than pork on a protein equivalent basis [23]. Low protein concentrations (2 mg/mL solution), water soluble and salt soluble protein solutions had similar EC, but at higher protein concentrations, salt soluble proteins were more efficient than the water soluble proteins for emulsifying oils. Increasing pH of MD turkey meat resulted in increased ES and reduced cooking losses. Increasing the protein level from 9 to 15% of the emulsion improved ES [21].

Mechanically deboned poultry meat (MDPM) was subjected [24] to heat pasteurisation temperatures of 59, 62, 65 and 68°C for up to 6 min. The EC and WHC were adversely affected as the time and temperature of pasteurisation increased. Samples which were frozen at -18°C for 25 weeks following pasteurisation exhibited lower EC than non-stored samples; however, length of frozen storage had little effect on the EC. Heat pasteurisation had a stabilising effect on the TBA values of MDPM. The red colour of MDPM showed a slight increase due to pasteurisation followed by a gradual decline as the time of the exposure to heat increased. Pasteurisation also tended to stabilise the colour of MDPM over continued frozen storage for samples stored 10 weeks or longer at -18°C. The MD product from whole fowl carcasses exhibited excellent EC and low TBA values [25].

Light and dark tissues of turkeys, hens and broilers, and composite duck tissues were analyzed [26] for total protein, salt soluble protein and EC. Total protein and salt soluble proteins were insignificantly greater amounts in light than in dark tissues of the same type of poultry. In most cases, the EC of salt soluble proteins were significantly greater for dark than light tissues. Thus, the greater amount of available soluble protein in light tissues was counter-balanced by the greater EC of soluble protein from dark tissues.

MD broiler backs and necks emulsified similar volumes of oils as their hand-deboned counterparts. Pieces of backs, necks and wings emulsified lesser than mixtures of breasts, legs and thighs. The WHC was similar for MD spent hen meat and hand deboned broiler necks and backs. Combinations of MD breasts, legs and thighs gave high EC and WHC [23]. Increasing the amount of skin in MD poultry meat reduced the ES primarily due to increased fat levels in the product [21, 23]. More stable emulsions were obtained when the fat content was in the 23 and 28% range [21].

Natural actomyosin (NAM), synthetic actomyosin (SAM) and chick breast muscle proteins glycerinated myofibrils (contracted and uncontracted), myosin and actin were tested for EC [27, 28]. The EC values varied inversely with protein concentration and pH, with myosin: SAM(+ATP) > SAM(-ATP) > actin. However, oil phase volume differences were small, ranging from 86.5 to 88.1%. The EC of NAM was lower than that reported earlier for myosin, but was equal to it with added ATP or pyrophosphate. Tropomyosin always increased in the acqueous phase relative to myosin regardless of the presence or absence of ATP, while the troponins were more readily removed from solution in the presence of ATP.

Kena (food grade phosphates) improved the stability of poultry meat frankfurter emulsions, whereas sodium-lauryl-sulphate had little effect, and ribonucleic acid and fresh egg yolk were detrimental to ES. Kena decreased the emulsion apparent viscosity, while sodium caseinate increased the apparent viscosity. Chilling spent fowl in Kena prior to deboning improved the ES and ES of the MD products [23]. Frankfurters made from turkey were significantly more tender than those containing broiler or fowl meat. With poultry meats, increasing the protein content of the emulsions resulted in significantly firmer frankfurters [21].

Frankfurters made of chicken and pork fat had higher flavour scores when unheated, but when heated, there was little difference [29]. The effects of fat, protein, source of meat and chop times on the stability of batters made from MDPM were reported [30]. Protein level of 12% released less of gel water and fat than 11% protein during ES tests. Although meat batters prepared from two different sources of MDPM exhibited similar ES, a mixture of meat from the two sources was lower in all components released during the ES tests.

Different flavour tests and TBA values indicated [31] that frankfurters, containing 15% MD turkey meat, were comparable to all red meat frankfurters in flavour and stability if fresh poultry meat was used. The use of MD turkey meat, which had undergone 90 d of frozen storage, resulted in a significantly inferior product as indicated by flavour evaluation and TBA values. The stability of emulsions were determined [32], formulated with MD poultry in combination with various levels (10, 15, 20 and 25%) of rehydrated soy-protein flour (50% protein), soy-concentrate flour (70% protein) and soy-isolate flour (90% protein). Emulsions with soy-flour had significantly better ES than emulsions with soy-concentrate and isolate. Rehydrated flour level had no effect on stability with the exception of higher tensile strength values at lower rehydrated flour levels.

Prerigor poultry muscle was observed to have significantly better EC and ES than that found from post-rigor muscle [33]. The prerigor muscle produced extremely rubbery emulsions. Adjustment of pH of the post-rigor muscle to that observed in the prerigor state restored the original high EC of the prerigor muscle. Factors influencing emulsifying characteristics of poultry meat (chicken and turkey) were reviewed [34]. MD poultry meat sources had acceptable ES especially when mixed with other hand deboned sources. Improved EC was observed with increasing pH and higher salt concentration. The MD meat has less of a protein matrix available for stabilising the emulsion, and processing temperatures may become quite critical. The EC of the salt soluble and water soluble proteins extracted from chicken were similar [35]. Table 4 provides the amount of salt soluble proteins in poultry parts, and Table 5 summarises the functional properties of salt extracted proteins from turkey meat.

Centrifugation of MD poultry meat resulted in a meat fraction that had improved emulsion characteristics. The better EC of centrifuged meat fractions was likely to be related to the higher protein and lower fat contents, compared to the control sample [23]. Texturization of MD poultry meat offered advantages for use in further processed products. Identification of the factors that could alleviate lipid oxidation of MD poultry meats would be advantageous in attempting to improve the flavour attributes of sausages. Additional research is required to further characterise this ingredient with respect to composition and functionality, to improve chemical and functional properties, to prevent flavour deterioration during preparation and storage, and to improve its microbiological quality.

Mutton

NPN sarcoplasmic, fibrillar and stroma protein nitrogen were estimated [36] in different mutton cuts to evaluate the emulsion forming capacity. Meat emulsion of good stability was prepared with mutton from the cut, leg of mutton, when it formed 40% of the sausage mix and 43% when the mutton used was from a composite sample obtained by deboning a whole mutton carcass. Table 6 tabulates the ES of different mutton cuts. The order of decrease in EC is more or less the same as the order of fibrillar group proteins in the different cuts. The minor differences are probably due to variations in stroma and sarcoplasmic proteins that add to the total EC of the mutton.

The salt soluble protein (SSP) from sheep and goat muscle emulsified significantly (at 95% level) more oil than salt soluble protein from muscles of cattle and water buffalo (Table 6) [37]. The extractable EC should more accurately estimate the actual emulsification ability of muscle. There was no age or species affect on the separation of oil (ES) from the sample emulsions, indicating that emulsions with 100 mL oil have similar ES. In a similar study [38], at the given concentration, the maximum phase volume ratio (PVR) of oil in the emulsion for water soluble proteins was in the order: goat≈chicken >> sheep≈pork. For pure actomyosin, the order of PVR was: goat≈sheep >> pork≈chicken. At higher protein concentrations, PVR was observed to exceed 0.6 both in the presence of salt extracted proteins and meat slurries. Sheep and goat fat formed very unstable emulsions in the presence of their respective meat slurries. Experiments indicated that the poor dispersibility of the sheep and goat fat was due to the presence of excessive quantities of saturated fatty acids so that the melting point was too high. When sheep fat was mixed with 50% peanut oil, then mixed fat formed excellent emulsions with the sheep meat slurry and PVR was observed to exceed 0.7. Using model emulsions, sheep meat sausages were prepared and found to be acceptable by a taste panel.

Fish

Comparative studies were conducted [39] between mackerel (fish) and beef muscle for their capacities to bind fat and water in comminuted meat products when corn oil was used. Beef batter increased sharply in water and gradually in fat separation, whereas, in the later, no further increase in water separation and no fat separation were observed. The temperature change of fish meat batter was similar to that of beef meat batter. The pH for fish and beef batter was 6.3 and 6.0, respectively. The difference between water separation between fish and beef meat batters was due primarily to differences in the extent, of protein–protein interaction during chopping.

The effect of the addition of 2 and 5% solid and liquid fats on the binding properties of fish flesh was studied [40] by a stress-relaxation test. Addition of 2% fat or oil had little effect on the binding properties of the loaves, while 5% added oil or fat reduced both the compression forces and the relaxation times, thus indicating poor binding. The effect of added fat or oil on product texture depended on the endogenous fat level of the fish flesh; with lean fish, the addition of either 5% Crisco vegetable shortening or oil reduced the compression forces and the relaxation times of the samples. When the fish was fatty, the addition of liquid oil lowered these parameters only slightly, while solid fat had a marked effect.

Table 4. Amount of salt soluble proteins in bone free poultry carcass parts [67].

Part	Salt soluble protein, g/100 g meat			
	Light fowl	Heavy fowl	Broiler	Turkey
Leg	5.9	5.0	5.2	6.5
Thigh	8.1	6.2	5.9	6.8
Breast	7.8	7.4	8.0	7.7
Neck	8.0	11.9	5.6	5.9
Gizzard	10.8	18.8	13.2	13.5
Skin	1.7	2.2	3.8	5.3
Total carcass	7.8	10.0	5.7	8.5

Table 5. Functional properties of extracted proteins from turkey meat at two pH levels [68].

Turkey meat protein	EC, mL oil/mg protein		Emulsion consistency	mL oil bound in emulsion phase/g protein	
	pH = 7	pH = 6		pH = 7	pH = 6
Myosin	1.24	1.16	Very thick	141.7	49.1
Actomyosin	1.22	1.05	Thick	157.3	59.1
Myofibrils	1.11	0.97	Thick	154.8	23.3
Meat	0.99	0.88	Medium thick	91.4	43.1
Actin, no salt	0.93	0.87	Thin	153.7	151.4
Actin, 1M salt	0.92	0.89	Thin	151.7	155.9
Sarcoplasmic	0.87	1.05	Thin	56.7	89.1

Table 6. Functional properties of mutton cuts [36, 37].

Mutton cuts	EC[a]	Young animal meat	EC[b]	EEC[c]	EC[d]
Shoulder	75	Sheep	23.3	404.3	0.66
Leg	77	Goat	22.2	364.0	0.59
Loin	112	Water buffalo	21.7	326.7	0.65
Breast	137	Cattle	20.5	271.3	0.54
Flank	60				
Rack	121				
Brisket	50				
Hind shank	119				
Fore shank	116				
Neck	113				

a. EC at 14000 rpm, mL melted Dalda per 5 g meat slurry[36]
b. mL oil emulsified per 100 mg of salt soluble protein at pH = 6.0 using Swift et al. (6) method.
c. EEC = (EC) (Extractable protein at pH = 6.0) i.e. Extractable emulsifying capacity.
d. g fat released after centrifugation; method of Saffle[9] from sample emulsion.

It is possible to produce an all fish [41], essentially fat free, frankfurter analog with an acceptable texture by employing a manufacturing system based on the development of a protein gel and red hake surimi. Although the product, as formulated, did not achieve levels of acceptance in consumer tests equal to those of beef containing products, it did compete with a chicken frankfurter, especially if fish surimi was used in its manufacturing. The problems associated with the development of a fish flavour or odour during storage were believed to be related to storage time and temperature of the surimi used in the analog manufacturing. The increase in rubberiness during refrigerator storage, as emphasised by consumer comments and shear measurements, might be a function of the species of fish used. However, no spoilage was detected in the product after 21 d of storage at 2°C.

The emulsion prepared from mechanically separated fish muscle tissue resulted in a cooked product with lower texture ratings than for hand process tissue [42]. The work on fish myofibrillar protein and fish protein concentrate indicated that chemical and/or enzyme modification has the potential of improving the functionality in processed muscle foods [43]. A fish protein with its low NSI (2.6) was not able to contribute better emulsification properties as compared to many other non-meat proteins tested [44]. However, fish protein concentrate and isolate can be used in comminuted sausage formulations [45]. These products enhance the binding of water and fat, and increase the product yield. Up to 15% of total proteins, these products did not induce any significant undesirable rheological or sensory properties of the sausages.

Other Meat Products

Rabbit: The functional properties of rabbit meat were compared [46] with those of beef and chicken meats. Protein solubilities, water holding capacity, emulsifying capacities, and binding strengths were approximately equal. Only the greater water loss exhibited by the chicken meat in the press test was significantly different from that of the beef. Frankfurter emulsions made from rabbit and chicken were formed more easily than those from beef and were more stable. Frankfurters from beef were firmer and were coarser in texture. Sensory evaluations for flavour, texture and overall acceptability demonstrated that the frankfurters made from rabbit meat were equal to those from beef and slightly superior to those from chicken. Frankfurters processed from rabbit and chicken meats were light coloured. The wood smoke browned the surface of the rabbit and chicken frankfurters to give an appealing exterior appearance. Quality and sensory scores for rabbit frankfurters containing high protein (15%), low fat (20%) and salt (1.7%) were also very acceptable.

***Egg white*:** The performance of native and heat-treated egg white and beef in wieners was examined [47]. The egg white products replaced 40% of the beef in both high and low protein formulations. Native and heat-treated egg white improved cook stability in the high protein formulation while only heat-treated egg white compared favourably to the all meat controls in low protein formulations. All replacers had an adverse effect on texture with the exception of heat-treated egg white in the high protein formulation. The level of protein and the physical state of the ingredient affected comminution energy as measured by the Universal Food Rheometer. The results indicate that a certain amount of meat protein must be available before advantages in cook stability and texture can be achieved by using native egg white.

Blood proteins and tissue powder: Ultra-filtered and spray-dried blood protein concentrate were used [48]. The blood protein concentrates improved the consistency of sausages compared with products in which no additives were used, but the improvement was lower than that caused by potato flour and milk protein concentrate. Undesirable taste imparting components of the proteins can be removed by the ultra-filtering method. The results did not encourage the use of blood protein concentrates as a substitute for additives in use presently.

Blood protein concentrates are excellent emulsifiers [49]. The whole blood proteins exhibited ES and EC equal to or greater than that of the proteins of other organs and tissue concentrates including muscle proteins. All the protein isolates approached the theoretical oil phase maximum at a protein concentration of 0.5 g/100 mL. However, neither a temperature nor a lactose effect on EC of these and globin proteins were observed. Functionally, the plasma isolate proteins were more responsive to drying treatments than the globin proteins. The solubility of the plasma proteins was reduced during the spray drying operation. However, lactose could be incorporated prior to drying to maintain the solubility. These protein isolates were found to be excellent emulsifiers and good foaming agents. Thus, plasma and globin protein isolates are a source of large quantities of protein, which has potential as a nutrient in human foods and are microbiologically safe. Isoleucine and methionin are limiting amino acids in these proteins.

The soluble protein of blood excelled that from any other tissue in its ability to emulsify fat (Table 2) [50, 51]. Blood proteins, both globins and plasma have excellent functional properties and show real promise as a protein extender, replacer and fortifier. Studies have shown that small amounts of blood (2 to 3.5%) may be added to wiener without causing significant changes in appearance or taste [52]. To reduce the problems of dark colour, blood may be added to meat products as a decolourised emulsion. Homogenisation by high pressure (15-30 MPa) increased the degree of dispersion [53, 54], thereby decreasing the dark colour. The minced containing blood (up to 5%) yielded lighter meat loaves upon heating than did minced containing blood emulsion [55], even if the amounts of extractable hemoglobin and myoglobin in the minces were equal.

Cattle blood at 1500 *g* for 15 min. was centrifuged [7] and the upper layer was decanted for use. At low proportions of non-meat protein, the largest stabilising effect was shown by blood plasma. Information on the functional properties of various high protein by-product tissue powders was collected [50, 51] (Table 2), and their suitability in emulsified meat products was evaluated. The soluble protein from kidney had the least ability to emulsify fat. Powders from tissues such as blood, lung, brain and stomach possessed an EC comparable to that of lean beef. Tissue powders from spleen and kidney had poor emulsifying properties. Tissue powders from brain and duodenum, which had from high to moderate EC, produced relatively unstable sausages. Tissue powders, which had a low EC (spleen, heart and kidney), produced sausages with a low ES. The appearance of all sausages, except the sausage containing blood powder, was comparable to the control. Sausages made from kidney, spleen and lever powders were equal to or better than the flavour of the control sausage. No one sausage had a definite objectionable flavour. These tissue powders were very shelf stable, because of the absence of fat and moisture. Meat powder used did not form stable emulsion and EC was relatively low due to its non-homogeneity [56].

Purified muscle protein: The salt soluble proteins (myofibrillar) are the muscle proteins primarily responsible for obtaining good functional properties in sausage emulsions. However, sarcoplasmic and connective tissue proteins play a role in ES and finished product texture [19]. Myosin has been identified as the primary emulsifying agent in sausage emulsions. Muscle proteins were ranked [57] from the greatest EC to the least in the following order: actin in the absence of salt, myosin, actomyosin, sarcoplasmic proteins extracted in water, and actin in 0.3 M salt solution.

Purified muscle proteins in meat emulsions were used [58]. Myosin emulsions were more stable than actin emulsions. After myosin was heated, it was able to hold water during centrifugation and remained in the tube as a gel mass upon inversion of the tube. Cooked actin solutions lost some water after centrifugation and collapsed completely from the tube following inversion of the tube. Sarcoplasmic proteins could not withstand centrifugation of tube inversion. The weight loss due to cooking of myosin emulsions decreased as the protein concentration changed from 2 to 6 mg/mL. When the myosin concentration ranged from 6 to 10 mg/mL, the weight change due to cooking appeared to plateau. The slight increase over 100% observed at 8 and 10 mg/mL was probably due to binding of water. The weight loss for actin at 8 and 10 mg/mL was approximately 20%. The EC of all the proteins decreased as the protein concentration increased, and the EC became equal at a concentration of 12 mg/mL.

Meat Fat

There were signified differences in the amount of various animal fats, which could be emulsified in a model system [59]. However, the actual amounts of different animal fats emulsified were within a relatively narrow range. Table 1 shows various animal fats and the quantity, which could be emulsified by the same amount of meat protein. The highest on the list are beef loin and flank fat, followed by various pork fats. A very low correlation was found between the amount of fat emulsified and acid values, iodine numbers, and specific gravities of the fats and oils studied.

Increasing proportions of fat and moisture were related to increases in juiciness and tenderness [60]. Juiciness and tenderness of bologna were considerably more dependent on moisture than fat content. Low fat formulations produced a redder, less juicy and a lower cooked yield [13]. The changes in fat content affected the structural and mechanical properties of both sausage emulsions and finished sausages [61]. An increase of fat content changed sausage emulsion apparent viscosity. The fat acted as a plasticising component as the strength of the bonds, holding dispersed fat particles in the system, was comparatively low. Under the convenient manufacturing conditions for products of a macroscopically homogeneous structure, the fat should lie within 20-30%. While fat content in emulsion products increased, their tenderness was decreased, when these products were eaten cold; when these were heated, the difference was not so marked.

Malted pork fat was emulsified [62] with solution containing stabiliser by sonic hydrodynamic unit and mechanical homogeniser. The following optimal parameters of sonic emulsification were established: frequency of ultrasound = 11.2 kHz for hydrodynamic sonic homogeniser, time of emulsification = 7 min, concentration of stabiliser: sodium orthophosphate = 0.13%, gelation = 0.75%, sodium caseinate = 3% and non-fat dry milk = 5%. The pre-emulsified fat in the meat emulsion resulted in an increase in the amount of emulsified fat, an increase in water holding capacity and apparent viscosity of sausage emulsion, yield of the finished product and a more uniform distribution of the fat component in the structure of the emulsion. The high melting fats yielded stable emulsions [63] and low melting fats yielded unstable emulsions irrespective of the temperatures attained during emulsification. The melting characteristics of the fat have an influence upon ES [19].

Some increase in temperature during emulsification is ideal for fat dispersion; but if the temperature is too high, the protein matrix is incapable of preventing the dispersed fat from coalescing [64]. Thus, the fatty acid composition and other factors which determine the melting point of a fat are important variables in the manufacture and stability of emulsified meat products. The fat obtained from beef tissue should be emulsified to a higher temperature than those from pork [19]. Melted sheep and goat fats formed very unstable emulsions in the presence of their respective meat slurries [38]. The poor dispersibility of these fats was due to the presence of excessive amounts of saturated fatty acids, imparting high melting points.

It is possible to add melted fat to a comminutor both in the liquid and the solid states [61], but heated fat aggravated comminution conditions, and solid fat was emulsified poorly and distributed unevenly. Emulsion was less stable as compared to that from the fatty tissue. When using melted fat, a higher percentage (1 to 2%) of phosphates was needed for stabilisation. The lower the fat melting temperature, the better was fat emulsification. Fats containing short chain acid radicals were emulsified better; those containing radicals without double bonds poorer. The effect of fat level on the water binding ability of frankfurters was minimal, as there was no consistent effect of fat level over the temperature range and salt levels used [65]. This indicated that very little of the water in these products was bound in a true oil-in-water emulsion.

Conclusions

The choice of meat raw material has an important influence on the yield, texture and microstructure of comminuted sausage products. The materials obtained from various meat systems need to be evaluated for their functional properties prior to use in meat emulsions. Fundamental studies are needed with various meats to determine relationships between processing variables and ingredients for different operating conditions. Further investigations are required to determine the effects of various ingredients in structure forming properties of the sausages.

Further research is needed in the improved methodology to measure the functional properties of meat systems. It is difficult to evaluate the large amount of data due to the use of varying techniques in obtaining these data. Hence, standardisation of these methods is required. Emphasis should be placed on proper experimental design and statistical analysis methods. Mathematical models are required to describe the behaviour of various meat systems in meat emulsions. These models will assist in the optimisation of the functionality of final product, and the optimum and proper utilisation of different meat products.

References

[1] Hansen, L.J. 1960. Emulsion formation in finely comminuted sausage. Food Technol. **14**:565-569.

[2] Kinsella, J.E. 1976. Functional properties of proteins in foods –a survey. Crit. Rev. Food Sci. Nutr. **8**:219-280.

[3] Livingston, D.J. and Brown, W.D. 1981. The chemistry of myoglobin and its reactions. Food Technol. **35**(5):244-252.

[4] Hermansson, A.M. 1984. Properties of meat as a raw material for comminuted meat systems. Proc. 30th European Congress of Meat Research Workers, Bristol, pp. 334-335.

[5] Borton, R.J., Webb, N.B. and Bratzler, L.J. 1968. Emulsifying capacities and emulsion stability of dilute meat slurries from various meat trimmings. Food Technol. **22**(4):162-164.

[6] Swift, C.E., Lockett, C. and Fryar, A.J. 1961. Comminuted meat emulsions - the capacity of meats for emulsifying fat. Food Technol. **15**:480-482.

[7] Nilsson, R., Persson, K., Nilsson, B. and Schaff, L. 1971. The effect of non-meat proteins on the emulsion capacity of meat proteins. Proc. 11th European Congress of Meat Research Workers, Bristol, England, p. 781.

[8] Porteous, J.D. 1979. Some physico-chemical 'constants' of various meats for optimum sausage formulation. Can. Inst. Food Sci. Technol. J. **12**(3):145-148.

[9] Saffle, R.L. 1968. Meat emulsions. Adv. in Food Res. **16**:105-160.

[10] Parks, L.L., Carpenter, J.A., Rao, V.N.M. and Reagan, J.O. 1985. Prediction of bind value constants of sausage ingredients from protein or moisture content. J. Food Sci. **50**:1564-1567.

[11] Smith, D.M. and Brekke, C.J. 1984. Functional properties of enzymatically modified beef heart protein. J. Food Sci. **49**:1525-1528.

[12] Hwang, P.A. and Carpenter, J.A. 1975. Effect of pork hearts, additives and pH adjustment on properties of meat loaves. J. Food Sci. **40**:741-744.

[13] Rongey, E.H. and Bratzler, L.J. 1966. The effect of various binders and meats on the palatability and processing characteristics of bologna. Food Technol. **20**(9):134-137.

[14] McMillan, K.W., Sebranek, J.G., Rust, R.E. and Topel, D.G. 1980. Chemical and physical characteristics of frankfurters prepared with mechanically processed pork product. J. Food Sci. **45**:1455-1459, 1462.

[15] Hoogenkamp, H. 1985. Super emulsions. Meat Process. **24**(2):32-35.

[16] Comer, F.W. and Dempster, S. 1981. Functionality of fillers and meat ingredients in comminuted meat products. Can. Inst. Food Sci. Technol. J. **14**(4):295-303.

[17] Satterlee, L.D., Zachariah. N.Y. and Levin, E. 1973a. Utilization of beef and pork skin hydrolyzates as binder/extenders in sausage emulsions. J. Food Sci. **38**:268-270.

[18] Acton, J.C. and Saffle, R.L. 1969. Preblended and prerigor meat in sausage emulsions. Food Technol. **23**(3):367-371.

[19] Webb, N.B. 1974. Emulsion technology. Proc. Meat Industry Research Conf., pp. 1-15.

[20] Saffle, R.L. and Galbreath, J.W. 1964. Quantitative determination of salt-soluble protein in various types of meat. Food Technol. **18**:1943-1944.

[21] Randall, C.J. 1977. Use of mechanically deboned and manually deboned poultry meat in meat emulsions: a review. Can. Inst. Food Sci. Technol. J. **10**(3):147-152.

[22] Froning, G.W. 1970. Poultry meat sources and their emulsifying characteristics as related to processing variables. Poultry Sci. **49**:1625-1631.

[23] Froning, G.W. 1976. Mechanically-deboned poultry meat. Food Technol. **30**(9):50-63.

[24] Mast, M.G. and MacNeil, J.H. 1976. Physical and functional properties of heat pasteurized mechanically deboned poultry meat. Poultry Sci. **55**:1207-1213.

[25] Cunningham, F.E., Mugler, D.J. and Froning, G.W. 1971. Utilization of mechanically deboned meat from spent hen carcasses. Poultry Sci. **50**:1568-1574.

[26] Hudspeth, J.P. and May, K.N. 1967. A study of the emulsifying capacity of salt soluble proteins of poultry meat. 1. Light and dark meat tissues of turkeys, hens and broilers, and dark meat tissues of ducks. Food Technol. **21**(8):1141-1142.

[27] Galluzzo, S.J. and Regenstein, J.M. 1978a. Role of chicken breast muscle proteins in meat emulsion formation: natural, actomyosin, contracted and uncontracted myofibrils. J. Food Sc. **43**:1766-1770.

[28] Galluzzo, S.J. and Regenstein, J.M. 1978b. Role of chicken breast muscle proteins in meat emulsion formation: myosin, actin and synthetic actomyosin. J. Food Sci. **43**:1761-1765.

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

[30] Mayfield, T.L., Hale, K.K., Rao, V.N.M. and Angulo-Chacon, I.A. 1978. Effects of levels of fat and protein on the stability and viscosity of emulsions prepared from mechanically deboned poultry meat. J. Food Sci. **43**:197-201.

[31] Froning, G.W., Arnold, R.G., Mandigo, R.W., Neth, C.E. and Hartung, T.E. 1971. Quality and storage stability of frankfurters containing 15% mechanically deboned turkey meat. J. Food Sci. **36**:974-978.

[32]Thompson, L.D., Janky, D.M. and Arafa, A.S. 1984. Emulsion and storage stabilities of emulsions incorporating mechanically deboned poultry meat, and various soy flours. J. Food Sci. **49**:1358-1362.

[33]Froning, G.W. and Neelakantan, S. 1971. Emulsifying characteristics of prerigor and postrigor poultry muscle. Poultry Sci. **50**:839-845.

[34]Cunningham, F.E. and Froning, G.W. 1972. A review of factors affecting emulsifying characteristics of poultry meat. Poultry Sci. **51**:1114-1119.

[35]Vadhera, D.V. and Baker, R.C. 1969. The nature and properties of the water and salt soluble extracts of chicken meat. Poultry Sci. **48**:1884-1889.

[36]Baliga, B.R. and Madaiah, N. 1970. Quality of sausage emulsion prepared from mutton. J. Food Sci. **35**:383-385.

[37]Turgut, H. 1984. Emulsifying capacity and stability of goat, water buffalo, sheep and cattle muscle proteins. J. Food Sci. **49**:168-171.

[38]Chattoraj, D.K., Bose, A.N., Sen, M. and Chatterjee, P. 1979. Physico-chemical studies of model meat emulsions in relation to the preparation of stable sheep and goat meat sausage. J. Food Sci. **44**:1695-1699.

[39]Deng, J.C., Toledo, R.T. and Lillard, D.A. 1981. Protein-protein interaction and fat and water binding in comminuted flesh products. J. Food Sci. **46**:1117-1121.

[40]Weinberg, Z.G. and Angel, S. 1984. Effect of type and level of added fat on heat induced binding in a fish loaf product. J. Food Technol. **19**:469-473.

[41]Buck, E.M. and Fafard, R.D. 1985. Development of a frankfurter analog from red hake surimi. J. Food Sci. **50**:321-324, 329.

[42]Hardy, E.R. 1973. Influence of mechanical separation on the functional properties of fish muscle tissue. M.Sc. Thesis, N.C. State Univ., Raleigh, N.C.

[43]Brekke, C.J. and Eisele, T.A. 1981. The role of modified proteins in the processing of muscle foods. Food Technol. **35**(5):231-234.

[44]Inklaar, P.A. and Fortuin, J. 1969. Determining the emulsifying and emulsion stabilizing capacity of protein meat additives. Food Technol. **23**:103-107.

[45]Sadowska, M., Naczk, M., Sikorski, Z. and Ziminska, H. 1981. The use of fish protein preparations in meat sausages. Proc. 27th European Congress of Meat Research Workers, Wien, Austria, pp. 449-452.

[46]Whiting, R.C. and Jenkins, R.K. 1981. Comparison of rabbit, beef and chicken meats for functional properties and frankfurter processing. J. Food Sci. **46**:1693-1696.

[47]Raymond, D.P., Randall. C.J. and Voisey, P.W. 1980. Functionality of native and heat treated egg white and beef in a meat emulsion system. Can. Inst. Food Sci. Technol. J. **13**(4):174-177.

[48]Knutar, U., Rämö, M. and Tuominen, R. 1977. Effects of ultra-filtered and spray dried blood protein concentrates on the quality and consistency of cooking sausages. Proc. 23rd European Congress of Meat Research Workers, Moscow, USSR, p. 08:1-08:9.

[49]Tybor, P.T., Dill, C.W. and Landmann, W.A. 1975. Functional properties of proteins isolated from bovine blood by a continuous pilot process. J. Food Sci. **40**:155-159.

[50]Satterlee, L.D., Free, B. and Levin, E. 1973b. Utilization of high protein tissue powders as a binder/extender in meat emulsions. J. Food Sci. **38**:306-309.

[51]Satterlee, L.D. 1975. Improving utilization of animal by-products for human foods - a review. J. Anim. Sci. **41**(2):687-697.

[52]Slinde, E., Mielnik, J., Martens, M. and Tenningen, A. 1982. Utilization of animal blood for human consumption. Sensory evaluation and measurement of surface color of meat products, and determination of hemoglobin and myoglobin in raw materials. Proc. 28th European Congress of Meat Research Workers, Madrid, Spain, **2**:340-343.

[53]Wismer-Pedersen, J. 1978. Utilization of blood in comminuted meat products. Proc. 24th European Congress of Meat Research Workers. Kulmbach, Germany, PH4-8.

[54]Wismer-Pedersen, J. 1979. Utilization of animal blood in meat products. Food Technol. **33**(8):76-80.

[55]Oellingrath, I.M. and Slinde, E. 1985. Color, pigment and iron content of meat loaves with blood, blood emulsion, or mechanically deboned meat added. J. Food Sci. **50**:1551-1555.

[56]Plimpton, R.F., Ockerman, H.W., Cahill, V.R., Potter, J.C. and Neer, K. 1972. Emulsion characteristics and processing feasibility of sausage products incorporating unconventional protein sources. Proc. 18th European Congress of Meat Research Workers, Guelph, Canada, pp. 448-455.

[57]Hegarty, G.R., Bratzler, L.J. and Pearson, A.M. 1963. Studies on the emulsifying properties of some intracellular beef muscle proteins. J. Food Sci. **28**:663-668.

[58]Tsai, R., Cassens, R.G. and Briskey, E.J. 1972. The emulsifying properties of purified muscle proteins. J. Food Sci. **37**:286-288.

[59]Christian, J.A. and Saffle, R.L. 1967. Plant and animal fat and oils emulsified in a model system with muscle salt-soluble protein. Food Technol. **21**(1):1024-1027.

[60]Swift, C.E., Weir, C.E. and Hankins, C.G. 1954. The effect of variations in moisture and fat content on the juiciness and tenderness of bologna. Food Technol. **8**:339-340.

[61]Garbatov, V.M., Zayas, Y.F., Sokolov, A.A. and Janoushkin, N.P. 1973. Technological role of animal fats in the production of comminuted meat products. Proc. 19th European Congress of Meat Research Workers, Paris, pp. 818-819.

[62]Zayas, J.F. 1985. Structural and water binding properties of meat emulsions prepared with emulsified and unemulsified fat. J. Food Sci. **50**:689-692.

[63]Swift, C.E., Townsend, W.E. and Witnauer, L.P. 1968. Comminuted meat emulsions: relation of the melting characteristics of fat to emulsion stability. Food Technol. **22**:775-778.

[64]Allen, C.E. and Foegeding, E.A. 1981. Some lipid characteristics and interactions in muscle foods - a review. Food Technol. **35**(5):253-257.

[65]Trout, G.R. and Schmidt, G.R. 1984. The effect of processing temperature and effective salt concentration on the binding ability of frankfurt type sausages made with and without added fat. Proc. 30th European Congress of Meat Research Workers, Bristol, England, pp. 336-337.

[66]Toledo, R. 1973. Preparation and properties of low temperature extracted animal protein concentrates. J. Food Sci. **38**:141-144.

[67]Maurer, A.J., Baker, R.C. and Vadehra, D.V. 1969. Kind and concentration of soluble protein extracts and their effect on the emulsifying capacity of poultry meat. Food Technol. **23**:575-577.

[68]Neelakantan, S. and Froning, G.W. 1971. Studies on the emulsifying characteristics of some intracellular turkey muscle proteins. J. Food Sci. **36**:613-615.