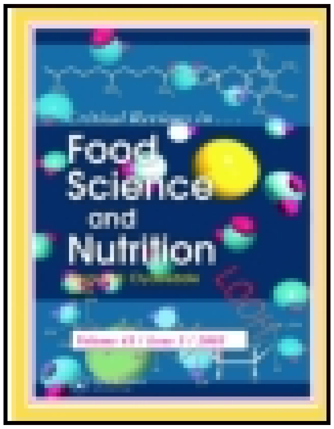

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Factors Influencing Meat Emulsion Properties and Product Texture: A Review

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FACTORS INFLUENCING MEAT EMULSION PROPERTIES AND PRODUCT TEXTURE: A REVIEW

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Abstract

Emulsion based meat products play an important role in modern meat industry. Though meat batters have been prepared traditionally since long back in the history, the scientific principles and the knowhow are significantly important in case of commercial products. In India, the market for emulsion meat products is gaining importance in the recent years and the native producers are in critical need for the scientific basis of production of emulsion meat products with better yield, good sensory qualities and nutrition. Hence this review will throw light on some of the important factors which influence the properties of meat emulsion such as stability, structure, etc. and the product texture and yield as the revealed by past researches which will be useful to the meat processors in their practical application in preparing meat emulsion products.

Key words: Meat batter, emulsion stability, meat processing, meat proteins

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Meat batters, considered as oil-in-water emulsion are heterogeneous composite materials composed of protein-coated fat globules (oil droplets) dispersed in myofibrillar protein gel matrix (Dickinson, 2012). In emulsion meat products, following thermal processing, the dispersed emulsion droplets set in as active filler particles (Theno and Schmidt, 1978). It has been proposed that raw batter is an emulsion and the cooked frankfurter is a gel (Foegeding, 1988). The batter stability and product texture in emulsion based meat products depend on various factors such as the nature and amount of the lean, fats/oils, added water, additives, other non-meat ingredients used, processing methods, etc. Various kind researches had been carried out and still done on the structure and stability of meat emulsion in different kind of products. While protein level and fat type had significant effects on the stability of meat emulsions (Youssef and Barbut, 2009), interfacial protein film thickness and the integrity and density of the surrounding emulsion matrix, and its ability to retain that integrity during thermal processing are major factors for emulsion stability (Jones and Mandigo, 1982). Barbut (1995) reviewed the importance of emulsion theory and physical entrapment theory in meat batter stability which emphasized the importance of fat emulsification and protein matrix in binding the fat respectively. Protein content and origin and differences in fat/moisture and protein/moisture ratios were the two important aspects which influenced the texture of the turkey meat products (Ayadi *et al*, 2009). The amount of soluble protein used, the speed of mixing, the final temperature of the emulsion, and the amount of oil initially added, each influence the emulsifying capacity of the soluble protein (Carpenter and Saffle, 1964). The determination of breaking strength and the energy to fracture by tensile test can be used together with the texture profile analyses, to determine textural properties of cooked meat sausages (Herrero *et al*., 2008)

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FUNCTIONAL PROPERTIES OF MEAT

Meat Proteins

It is well established that proteins are largely responsible for the functional characteristics of muscle foods (Xiong and Kenney, 1999). Muscle proteins can be classified into three groups based on solubility characteristics: sarcoplasmic proteins, the metabolic proteins that are soluble in water or dilute salt solutions; myofibrillar proteins, the contractile proteins that are soluble in concentrated salt solutions; and stromal proteins, the connective-tissue proteins that are insoluble in both (Lawrie, 1991). Muscle proteins are the major structural and functional components in processed meat system and the protein functional properties important in poultry meat products can be broadly classified into three categories: (1) protein-water interactions, (2) protein-fat interactions, and (3) protein-protein interactions (Smith *et al*., 2001).

Sarcoplasmic proteins, soluble in water or low ionic strength solutions represent 30-35% of the total muscle proteins and of relatively low molecular weight, high isoelectric pH, have globular or rod-shaped structures and low viscosity (Asghar *et al*., 1985; Smith *et al*., 2001). In a study of the thermal and functional properties of porcine sarcoplasmic proteins, Miyaguchi *et al*. (2000) found that sarcoplasmic proteins (SP) had poor water holding capacity, forming weak and fragile gels suggesting that functional properties of SP would affect textural properties of emulsion type food, such as sausage and meat patties.

The myofibrillar proteins which are insoluble in water and soluble at salt concentrations above 1% comprise about 50 to 56% of the total skeletal muscle protein. Comprising about 50 to 55% of the total myofibrillar protein, myosin is the single most important ñfunctionalò protein in meat and is capable of forming highly elastic gel matrices and a cohesive, rigid fat globule membrane in comminuted and emulsified meats due to its well-balanced hydrophilicity-hydrophobicity and a large, long fibrous structure (Xiong and Kenney, 1999; Smith *et al*., 2001). It has been established that generally myosin and actomyosin have high emulsifying capacity with good emulsion stability in different muscle types (Hegarty *et al*., 1963; Neelakantan and Froning, 1971 and Galluzzo and Regenstein, 2006).

A characteristic set of physicochemical properties of sarcoplasmic, myofibrillar and stromal proteins determining their functionality in comminuted products necessitated the development of bind constants (Smith, 1988). Researches had shown that water-binding (Fukazawa *et al*., 1961; Richardson and Jones, 1987) and the product texture (Yasui *et al*., 1980) in meat products basically depend on salt soluble myofibrillar proteins especially myosin and actin, which are crucial for the protein gel formation, good sensory properties and good yield in the finished product and hence adequate extraction of myosin is very important in the production of cooked meats (Barbieri and Rivaldi, 2008). Myofibrils swell quickly to about twice their original volume in salt solutions resembling those used in meat processing which is a significant attribute (Offer and Trinick, 1983). It has been demonstrated that disulphide cross-linking between myofibrillar protein coated oil droplets and protein matrix contributed to the stabilization and reinforcement of protein-emulsion composite gels formed in comminuted muscle foods (Wu *et al*., 2011).

It has been reported that in meat emulsions, hardness and cooking loss increased with increased protein level (Youssef and Barbut, 2009; Youssef and Barbut, 2011). Use of collagen improved the protein concentration and emulsion stability (Santana *et al*., 2011; Pereira *et al*., 2011).

Inclusion of purified collagenous material from plaice skin in minced cod muscle improved the water holding capacity during frozen storage and improved the texture upon cooking due to the gelatinization of the collagenous material (Borderías *et al*., 1994). Hence the high water binding capacity of the solubilized collagen reduce drip loss in frozen meat products when cooked where there is a partial loss of water holding capacity of the denatured proteins (Gómez-Guillén *et al*., 2011). Also there is a positive correlation between the total protein and sarcoplasmic protein solubilities and the quality of processed meat products (Young *et al*., 2005).

Emulsion properties are influenced by meat sources. Zorba and Kurt (2006) found that in emulsion of mixtures of beef, chicken and turkey meats, the protein concentration decreased with increasing amounts of beef and increased with increasing amounts of turkey. Also they concluded that the addition of chicken and turkey improved emulsion characteristics significantly and that chicken and turkey can be used with beef to improve emulsion characteristics. Cooked meat emulsion from Large White had superior properties than other breeds with good stability and texture indicating influence of composition and structure of meat (Sorapukdee *et al*., 2013). Sausages made from pale, soft and exudative meat had less rigidity which was improved by addition of mechanically deboned turkey meat extract (Li and Wick, 2001).

Ageing of meat improved the protein gel strength which was explained that ageing increases the amount of lower molecular weight peptides and presumably exposes more reactive sites compared to fresh, intact high molecular weight proteins and more reactive charge sites might have encouraged protein/protein interaction (Farouk *et al*., 2013).

Fat

The role of fat in preparing a stable meat emulsion is highly significant where disruption of the cellular structure to liberate the fat, smaller fat globules for good stability and sufficient solubilized protein to cover the fat surface area (interfacial adsorption) are important factors (Hoogenkamp, 2011). Emulsion stability and water holding capacity improved with increase in fat percentage up to 30% in goat mortadella with pork fat which was due to the increased availability of free molecules or radicals to make links with protein or water (Guerra *et al*., 2011). It has been ascertained that reduction in fat percentage in emulsion meat products caused increase in cooking loss and decreased the hardness (Cofrades *et al*., 1997, Youssef and Barbut, 2011; Álvarez and Barbut, 2013). Claus *et al*., (1990) observed lower tensile strength and higher cooking loss in low-fat (10%) bologna with higher amount of added water (30%) when compared to 30% fat-10% added water. High moisture in mortadella contributed to a better texture and succulence of the final product (Allais, 2010). Goat meat frankfurters with added beef fat had higher fat and lesser moisture percentage than those without added fat, with increased hardness value in texture profile analysis and higher texture score in sensory evaluation (Bratcher *et al*., 2011). Substitution of lard with diacylglycerols (DAGs) prepared from the lard in meat emulsion resulted in better emulsion stability, increased hardness and decreased total expressible fluid (%TEF) of the cooked product which was due to stronger interaction between the fat fraction and the protein gel due to the polar hydrophilic group in the DAGs (Miklos *et al.*, 2011). When the cooked emulsions were allowed to set for 24 h before re-heating the fat binding was improved significantly. The emulsion meat product texture is highly influenced by the consistency of fat which in turn is influenced by the fatty acid composition (Glaser *et al*., 2004; Lawrie, 1998).

pH

The functional properties of muscle proteins depend on pH (Hemung *et al*., 2013). In meat systems high pH favour water-binding ability and emulsion stability (Richardson and Jones, 1987; Young *et al*., 2005). Chan *et al*. (2011) demonstrated that high pH meat had good emulsifying property and gel forming properties and low pH of meat resulted in softer texture of the cooked product. According to Kijowski and Niewiarowicz (1978), salt soluble proteins extracted from normal meat of pH 6.5 had higher emulsifying capacity.

Variations in meat pH during rigor development influence the protein functionality which in turn affects the product quality. In complete rigor mortis of ovine Longissimus Muscle the ultimate pH (5.5) was reached with completion of glycolysis (Wheeler and Koohmaraie, 1994). Various researchers had emphasized the suitability of pre-rigor meat for the preparation of meat products (Cia and Marsh, 1976; Skjervold *et al.* 2001). Claus and Sørheim (2006) observed a higher pH and higher protein solubility with lower cooking loss in pre-rigor ground beef patties than post-rigor treatment. In tumbling of goat hams, the pH and water holding capacity were higher and cooking loss was lower in pre-rigor meat than the post-rigor meat (Dzudie and Okubanjo, 1999).

Zouari *et al*. (2011) found that turkey liver proteins had good emulsion stability at acidic or basic pH. According to Romero *et al*. (2011), crayfish proteins exhibited higher solubility and better emulsion stability at pH 8 when compared to pH 2. Maximum solubility of chicken thigh meat was at extremes of pH (3.5 and 10.5) with highest yield of extracted proteins at pH 12, but the

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protein solubility decreased at higher pH (Omana *et al.*, 2010). In a study on the influence of pH on the phase behaviour of mixtures of iota (i-) carrageenan and salt soluble proteins from bovine, Farouk *et al.* (2013) observed that complex/gel formation and yield decreased with the increase in ultimate pH of meat. In oil-in-water emulsion, bovine collagen exhibited better emulsifying properties at low pH (3.5) which was attributed to the protein surface hydrophobicity caused by the opening of collagen triple helices at this pH where the isoelectric pH of collagen was between 6.5 and 8.5 (Neklyudov, 2003). Acid ($pH_{1.5}$) pH-treated soy protein isolates (SPI) improved the gelling capacity of myofibrillar proteins through hydrophobic association as well as hydrogen bonds which was enhanced by the addition of microbial transglutaminase (Jiang and Xiong, 2013).

NON MEAT INGREDIENTS

Processed meats are heterogeneous systems composed of muscle itself and various nonmuscle ingredients including polysaccharides, flavor agents, salt, and phosphates (Xiong and Brekke, 1999). Various researches had established that water binding capacity of meat was improved by addition of phosphates increasing the pH even at low concentration of NaCl (Whiting, 1984; Puolanne *et al.,* 2001). Hsu and Chung (2001) observed increase in cooking yield of low fat emulsified pork meat balls with addition of salt and phosphate and suggested addition levels of 2.7% salt and 0.17% polyphosphates for more acceptable products whereas Yapar *et al.*(2006) recommended 2.0% salt and 0.50% phosphate in the processing of emulsified fish products. Addition of 0.5% polyphosphate in chicken meat batters with and without crude malva nut gum decreased cooking loss and increased hardness in texture profile analyses (Barbut and

Somboonpanyakul, 2007). Phosphate type, concentration and salt level affected the binding in restructured beef rolls (Trout and Schmidt, 1984).

It has been demonstrated that frankfurters containing vegetable oils and vegetable extracts had soft consistency (Özvural and Vural, 2008; Álvarez *et al.,* 2012) compared to those made with pork back fat whereas Youssef and Barbut, (2009) observed substituting beef fat with canola oil at all protein levels (10ï 15%) resulted in firmer cooked products. In support to this Shao *et al*., (2011) also found that meat batter prepared with soybean oil showed greater hardness, springiness, cohesiveness, chewiness and resilience values than emulsions made with pork fat and attributed this to the increased gel strength of protein gel with small size of fat globule (Sikorski, 1997).

In myofibrillar gels, vegetable oil pre-emulsions improved the gelling capacity and the gel structure was influenced by the type of oil (Wu *et al*., 2011). Inclusion of corn oil in sausage decreased hardness, springiness, and chewiness (Baer, 2012). Cooked burger patties with avocado oils as replacers of pork-back-fat had reduced hardness, gumminess and chewiness (Rodríguez-Carpena *et al*., 2011). Vegetable oil emulsions made with rice bran or walnut extract were more stable than backfat emulsions (Álvarez *et al.,* 2012). Addition of vegetable oil combined with preheated walnut extract favored gel network formation and gel elasticity, with highest gelling capacities, whereas antagonistic interactions between fiber and oil droplets reduced gelling capacity, when vegetable oils were used with rice bran.

Various researches had recommended different types of non-meat proteins as good stabilizing and emulsifying agents (Furlán *et al*., 2010, Yurdaer Aydemir and Yemenicioglu, 2013).

Sodium caseinate was considered as a preferred choice to improve the emulsion stability due to its pliable structure in the interfacial adsorption around the fat globule (Hoogenkamp, 2011). While using pre-emulsified fat stabilized with soy protein and sodium caseinate in Frankfurters, Su et al. (2000) found fat globules of similar size surrounded with a thinner protein membrane which were immobilized and well stabilized without agglomeration during cooking. However, the stability of the products from low fat meat batters depend upon gelling ability and water retention ability of nonmeat ingredients rather than emulsion formation capacity. Feng and Xiong (2002) observed that the gel elasticity of pork myofibrillar protein isolate increased by the inclusion of preheated soy protein isolate.

Corn germ protein flour, nonfat dry milk and sodium caseinate increased the product firmness with good water holding capacity (Hung and Zayas, 1992). Dzudie *et al*., (2002) recommended addition of common bean flour as a potential extender in finely ground meat products which increased the water holding capacity of the raw sausage formulations and decreased the hardness of the cooked beef sausages. Gujral *et al*., (2002) reported increased hardness in goat meat patties with addition of textured soy protein. Serdarogėlu (2005) found slightly increased toughness of meatballs when legume flours such as blackeye bean, chickpea and lentil were used as extenders.

Kalaikannan *et al*. (2005) recommended incorporation of dried albumen in chicken patties which significantly enhanced the emulsion stability and product yield and reduced the product shrinkage. Skim milk powder favoured the texture of cooked lean chicken meat batters with increased hardness and chewiness (Barbut, 2010). Incorporation of whey powder was beneficial in improving cooking characteristics of Turkish type meatballs (Serdaroglu, 2006). While using whey protein concentrate in low-fat sausages it was suggested to be added as a preformed gel rather than dry powder for better water binding and texture (Lyons *et al*., 1999). Incorporation of tapioca starch and whey protein in low fat Frankfurters improved emulsion stability with increased hardness, adhesiveness, gumminess and chewiness (Hughes *et al*., 1998).

Effect of different fat replacers had been extensively studied. ß-Glucan acted as a good fat replacer in reduced-fat breakfast sausage system with good binding capacity (Morin *et al*., 2004). Konjac gel was suitable pork back fat replacer in low fat meat products which presented excellent thermal water binding properties (Jiménez-Colmenero *et al*., 2012) increasing the hardness and chewiness of the product showing compact morphological structure in the micrographs compared to the spongy appearance of the control (Salcedo-Sandoval *et al*., 2013). Ju-Hui Choe *et al*. (2013) observed that use of pig skin and wheat fiber mixture as fat replacers in frankfurter-type sausages resulted in more stable meat emulsions and increased hardness, cohesiveness, gumminess, and chewiness. In the preparation of chicken meat balls, Bhat *et al.* (2013) found that optimally 50% of the meat could be replaced with skin without affecting the emulsion stability.

In a study conducted by Hack-Youn Kim *et al.* (2010) to determine the effects of various bamboo salts on meat batter, it was observed that the meat batters containing bamboo salt had improved WHC, viscosity, cooking yield, emulsion stability, texture and sensory quality. Choi *et al.* (2011) observed that that the solubilities of sarcoplasmic, myofibrillar, and total proteins in heat-induced gels containing rice bran fiber were greater compared to those without rice bran

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fiber, and increasing levels of rice bran fiber resulted in higher sarcoplasmic protein solubility. Inclusion of edible sea weeds in pork meat emulsion/ gels improved the emulsion stability fat- and water- binding capacity, decreased cooking loss favouring the formation of harder and chewier structures (Pietrasik *et al.,* 2005; Cofrades *et al*., 2008).

Inclusion of microbial transglutaminase (TG) in pork sausages increased the hardness values (Katayama *et al*. 2006) and a combination of TG and pea protein produced strong meat gels through improved crosslinking in proteins (Li, 2008; Sun and Arntfield, 2012).

PROCESSING

Myofibrillar protein extraction is greater when fresh unfrozen meat is used compared to previously frozen and thawed meat (Hoogenkamp, 2011). It has been shown that the storage temperature of meat affect the attributes of the emulsion product (Farouk *et al*., 2000). Weaker gels with less water holding capacity were formed from frozen meat (Smith, 1988) and increased freeze thaw cycle decreased the emulsion stability (Xia *et al*., 2010) due to decreased protein solubility during frozen storage. Carballo *et al*. (2000) reported that there was decreased water binding, hardness and chewiness in meat systems due to increased freeze thaw cycles, and high pressure treatment prior to heating formed weaker gel structures whereas pressurizing at thermally denaturing temperatures resulted gel structures with better water binding properties.

Use of bowl chopper had been more advantageous than any other equipment in the preparation of meat emulsion which allows a greater freedom to manipulate emulsion properties and characteristics allowing for staged addition and varying the chopping time and speed in order to optimise quality (Hoogenkamp, 2011). Chicken emulsion made with bowl chopper had better emulsion stability, hydration properties and gel strength when compared with use of food processor and indigenous meat cutter (Devatkal *et al*., 2011). Hamburger which did not involve chopping was composed of more or less intact randomly distributed meat fibres and fibre bundles up to 50ï 70% (Tornberg, 2005). Emulsion stability decreased with increased comminution temperature (Thomas *et al*., 2007).

Processing meat under vacuum improves protein extraction (Roblero, 2009). Tantikarnjathep, (1983) found that more oil was emulsified by sarcoplasmic and myofibrillar extracts from beef and pork under vacuum with proportional increase in water-soluble than salt-soluble extracts. Also vacuum application during chopping improved product stability, with more density and less cavitation by extraction of air during emulsion formation.

Zayas (1985) reported that using pre-emulsified fat in comminuted meat products resulted in increased water-binding capacity and a more uniform distribution of the fat component in the structure of products. In agreement to this Andersson *et al*. (2000) observed that the emulsified fat in sausages was more stable than the fat in beef burgers where a meat protein network formation constitutes the major part of the structure in sausages.

In meat emulsion system, cooking loss increased with cooking temperature (Hack-Youn Kim *et al.,* 2010). Increase in hardness and decrease in chewiness was observed with increased cooking time (Ayadi *et al*., 2009) and increased heating rate (Cofrades *et al*., 1997) which was correlated earlier by Foegeding *et al*., (1986) that slower heating rate allows more time for protein to unfold, thus providing more favourable conditions for proteins to interact. Increased heating rates decreased the gel strength of salt soluble proteins (Camou *et al*., 1989) where Lee and Min

(2004) advocated that the temperature range between 60°C and 70°C during cooking is passed as quickly as possible to improve the textural properties of chicken surimi gel. Barbut *et al*. (1996) clearly depicted the effects of heating temperature on turkey meat batter structure, gel strength and protein extractability. The temperature increase from 50°C to 60°C was shown to be highly critical with drastic increase in gel rigidity and matrix density with decrease in protein extractability.

Conclusion

From the above discussion it is evident that the emulsion properties of the meat products depend on multiple factors and all these conditions need to be optimized to obtain the desirable emulsion properties and product characteristics. Of these, the primary role is played by the protein type and fat quality. Also selection of non-meat ingredients to manipulate the product characteristics has to be given due importance in manipulating the product formulation. Hence it can be concluded that essentially all the above factors are to be considered crucial in the formulation and processing of emulsion meat products.

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