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Autor(en): **Giddey, C. / Güney, Sema**

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Animal Protein Properties and Texturization The Development of Novel Texturization Processes

C. Giddey and *Sema Güney*
Battelle, Centres de recherche de Genève, Carouge-Genève

Nutritional materials are considered to be textured if their physical characteristics differ from those of liquids. Viscous products, gels, solidified food are textured material. Essentially, a texture is formed by the more or less effective immobilization of the liquid medium.

In the last twenty years the term texturization was used to describe vegetable proteins to which a texture was imposed. In this paper, however, we will particularly focus on the texturization of animal proteins, which is a domain of growing importance in food technology.

Why texturize animal proteins

In recent years there has been an extension of the existing technology to encompass meat proteins. New technologies have been developed to texturize this type of raw material and are probably a reflection of the growing need to extend the world meat supply. Around 60–65% of the animal tissue, including muscles can be considered directly edible. However, the animal carcass anatomy is so complex that the recovery of the flesh simultaneously produces a number of by-products, the quantity of which is dependent on the butchering techniques. These products are generally of low quality and have low value for the following reasons:
- high fat/muscle protein ratio
- high collagen tissue/muscle tissue ratio
- very tough muscle texture due to the low flesh/tendon tissue ratio
- small (or irregularly sized) meat pieces (trimmings, scraped meat, etc.)
- untextured meat paste provided by the mechanical flesh-bone separator (mechanically separated meat = MSM)

Although it is technically possible to use a great many different raw materials, including blood and offals, this may not be consistent with the quality image. Textured products in general must simulate an existing meat product which in composition is equal or superior to the product which one has set out to copy.

For reformed or texturized products like chunks, steaks, roast, etc. meat is used which otherwise would be used for the production of hamburgers, sausages, luncheon meat, meat pies, ravioli filling, etc. The viability of reforming and texturization is therefore determined by the value added which should be higher compared to the value added to the raw material in its traditional application.

Texturization is a merge of science and technology. The science outlines the chemistry and physics of the raw material (animal proteins) and of the principles involved in the technics used, and through this knowledge gained, technology tries to optimize the outcome – a high quality texturized product. Starting out with such a concept, we will first summarize the pertinent physico-chemical structure of meat.

Role of proteins in meat texture

The macrostructure of meat consists of large muscle fibre bundles which are made up of fine muscle fibres surrounded by sheats of very fine, connective tissue (perimysium, epimysium, endomysium) and completed by the terminal tendons. The fibres are themselves composed of thousands of finer fibrillar structures of about 1μ diameter – the myofibrils.

The myofibrils, constituted of the elongated multinucleated muscle cells, are composed of two main proteins, the actin and the myosin which are responsible for muscular contraction with the complementary proteins troponine and tropomyosine.

The myofibrillar structure gives the chewiness and the toughness to meat, but complementarily, the connective collagenic tissues and tendons re-inforce the mechanical resistance of the basic contractile structure of the muscle. The role of fat in the structure, final texture and flavor of meat should not be overlooked. Although fat does not contribute to the toughness of the product, it serves as a good cushion between the connective tissue and adds to the overall texture.

Before discussing animal protein texturization methods, the composition of muscle tissue (table 1), should be summarized.

Table 1. Lean muscle composition

	%	Water soluble	Water insoluble
Water	75		
Actin-myosin (myofilaments)	10		x
Sarcoplasmic proteins	6	x	
Elastin, collagen (membranes and tendon)	2	x*	x
Fat	3		
Non protein organic nitrogen compounds	1.6	x	
Carbohydrate	1.2	x	
Mineral salts	0.7	x	

Source: Lawrie, 1968 (1) * Collagen is solubilized by cooking

Table 1 displays that the water content of meat amounts to 75%, the muscle proteins to 18% of which 6% to 8% are partially water soluble. The structural proteins (actin, myosin, collagen, elastin) represent finally no more than about 12% of the raw meat.

Basis of texturization

The methods and technologies of texturization were initially developed for vegetable proteins, where the intention was to create or mimic meat texture. In a second step of this development, mixes of vegetable (meat extenders) and animal proteins were utilized together. The attempt to texturize second quality meat has been a concept based on the developments made in the field of vegetable protein texturization.

The texturization of vegetable proteins includes two following essential steps:

1. Creation, in the hydrated media, of a molecular or macromolecular body which is characterized by a directional structure (anisotropic).
2. Insolubilization of the components of the molecular body and formation of a sufficiently coherent reticulate system able to immobilize the hydrated phase of the product.

The animal protein texturization follows the same processing steps. The preexisting myofibrils of the raw meat material contribute to the success of step one. The second step, the heat insolubilization (coagulation) of the myosin/actin muscle proteins is comparable to the heat coagulation of the texturized vegetable protein.

Protein coagulation

The structure of natural proteins initially depends on the sequence of the amino acids constituting the polypeptide chain (primary structure). The physical (hydrogen bonds) and chemical (disulphide bridges) interactions between the different parts of the chain will determine, together with its hydrophilic and hydrophobic properties, the winding and folding that give the proteins their specific conformation (secondary and tertiary structures).

Because of the energy it supplies, heat breaks the internal interactive forces, in particular those of hydrogen bonds with water, encouraging the establishment of physical and chemical bonds between the protein molecules. The transfer of intra-molecular S-S bonds into inter-molecular S-S-bonds is another consequence of thermal treatment. Heating thus changes the secondary and tertiary structure of proteins and results in denaturation and coagulation.

Thermal coagulation may thus be used to stabilize the artificial structure imposed by the texturization of the protein material. Heat treatment promotes the aggregation and reticulation (cross-linking) of the molecules in the macroscopic state. The thermal denaturation of the proteins determines three modes of solidification of the protein rich water medium:

a) Thermo-reversible gelation (gelatin type)
b) Non-reversible gelatinization
c) Non-reversible coagulation (aggregation)

The molar concentration of the hydrophobic amino acids of the protein chain is one of the elements which determine the type of solidification phenomenon, as has been shown by *Shimada* and *Matsushita* (2).

The molecular weight of proteins is another important factor in their behavior when heated, since initial monomers may form molecular groups (polymers), which can further coagulate.

The phenomena discussed above will play a dicisive part in the vegetable and animal protein texturization process and in establishing the textural organoleptic characteristics of the producs concerned (chewiness, elasticity, water holding capacity, etc.).

The reaction of the myofibrils (actin, myosin), the surrounding collagenic tissues, and tendons, to the application of heat differ considerably. Heat promotes a fast coagulation and shrinkage of myofibrils but in contrast induces the swelling, shrinkage and a subsequent disintegration of collagen (fig. 1)*

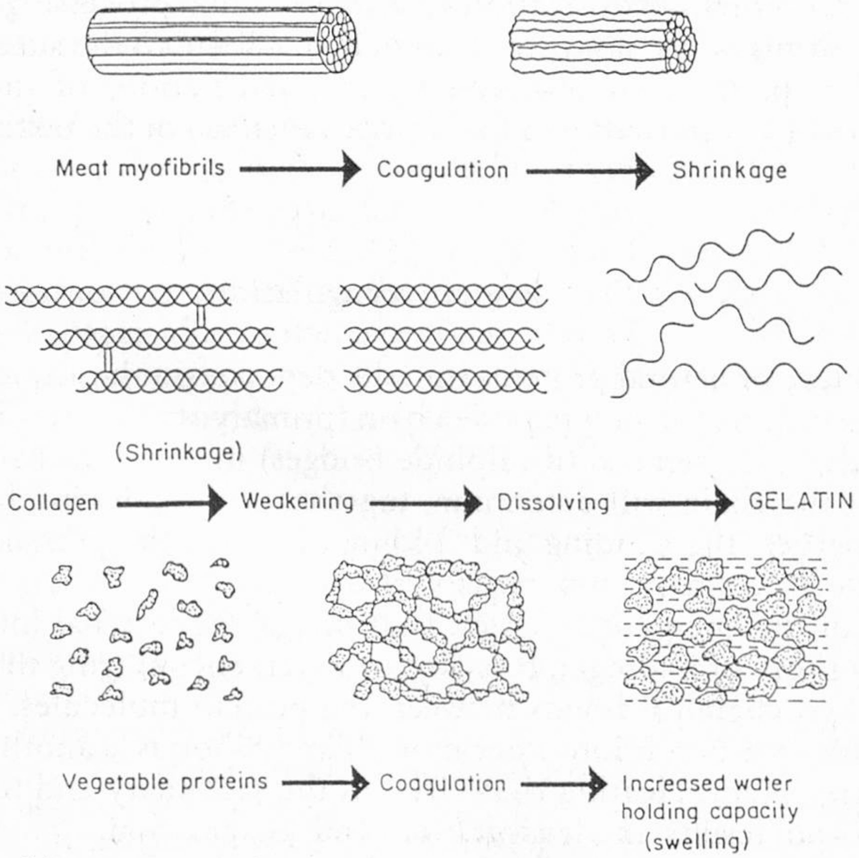

Fig. 1 Effect of heat on proteins

* Elastin on the other hand is not hydrolized upon boiling and therefore does not soften.

There is a rupture of the hydrogen bonds in the tropocollagen molecule, resulting in the separation of the 3 peptides which constitute the original basic helix structure. Thus the membranes, the fibres and the thick tendons progressively lose their toughness and become gelatinous. Over 60 °C the ultimate result of collagen depolymerization is the formation of gelatin. Therefore, cooked meat texture depends on the balance between the physical properties of the coagulated myofibrils and of the degree of depolymerization of the collagenic constituents of the muscle.

Another effect of heating on meat is the subsequent loss of water holding capacity. Heat shrinkage of the original meat myofibrils and the relevant decrease of the water holding capacity (e. g. up to 34% weight loss), are two critical factors for texturized meat products. In contrast, texturized vegetable proteins have the opposite behaviour in regard to water holding capacity (fig. 1). The mixing of heat coagulable vegetable proteins (e. g. soy or sunflower concentrate or isolate) with ground meat therefore, appears to be a good method for balancing the decrease of the water holding capacity of texturized steaks and other similar items. Low quality meat by-products can be easily upgraded with the addition of vegetable proteins. Figure 2 shows the general outline of texturization of a pre-blended animal/vegetable protein composition.

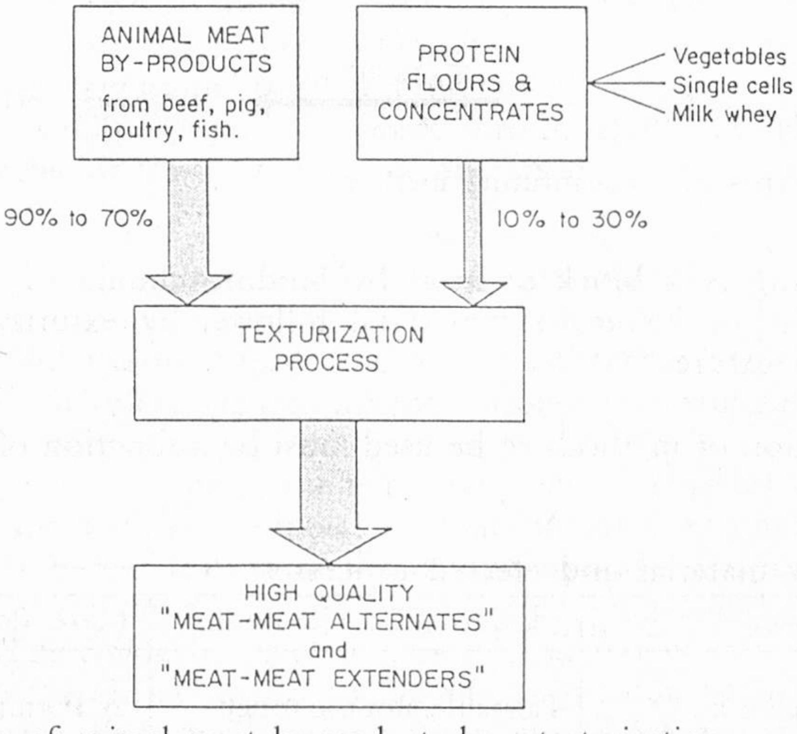

Fig. 2 Upgrading of animal meat by-products by retexturization

Forming and texturization

The types of raw material and process used are the determining factors in the quality of the final product which should have meat-like sensory attributes.

Depending on the raw meat material available two different principles must be considered (fig. 3):

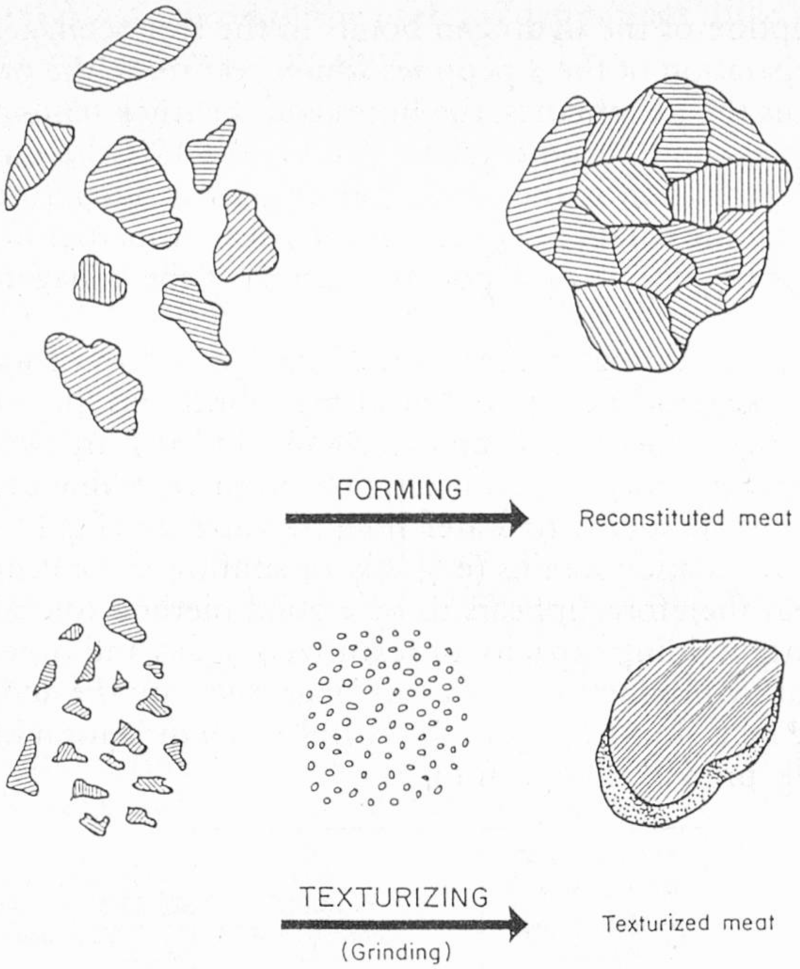

Fig. 3. Two types of reconstituting methods

a) The forming of a block of meat by binding chunks of meat
b) The grinding of the meat raw material, followed by texturization to provide a meat like texture.

The selection of methods to be used must be a function of the raw material (table 2).

Table 2. Raw material and elected processes

Type of raw material	Characteristics of raw material	Process which must be applied
High quality chunks, trimmings, etc.	Palatable, not too tough rather homogeneous composition	a) Forming by pressing and binding chunks
Low quality, trimmings, scraps, etc.	Unpalatable, very tough uneven composition	b) Grinding and texturization
Mechanically separated meat (MSM)	Unstructured thick paste homogenous composition	c) direct texturization

The binding and gelling capacity of the different proteins contribute considerably to texturization. Temperature, pH and salt concentration are factors of importance in the binding of these proteins, through their effect on the degree of cross-linking.

Soluble and heat coagulable proteins in formed and texturized meat products

The proteins of sarcoplasm are water soluble and heat coagulable. Some fractions of the muscle proteins, myosin and actin, are also soluble in water (in the presence of salts like NaCl), and heat coagulable. *MacFarlan* et al. (3) compared the binding power of salt soluble myofibrillar protein myosin, with the actomyosin complex and the sarcoplasmic proteins. They concluded that in the presence of salt, myosin has the greatest binding properties. The mechanism of binding between chunks of meat (table 2), which have been lightly salted is a heat initiated reaction (4) where the salt soluble proteins form a concentrated solution between the meat chunks. A protein matrix develops and upon heating acts as a stable binder between meat chunks. *Schmidt* et al. (5) have comprehensively reviewed the «Functionality of a protein matrix in comminuted meat products».

In our laboratory it was also observed that there was a beneficial effect of the addition of 0.5 to 1% NaCl to comminuted meat, or meat paste (MSM), to be further submitted to texturization (table 2) (after heating, the texture of the meat products was definitively more chewy and resembled more closely the texture of real meat). If salt (NaCl) or a polyphosphate is to be used, a mixing step should preceed the forming or the texturization operation.

Myofibrils and collagen in formed and texturized meat products

The properties of the myofibrils and of the collagenic constituents of the meat play a different role according to the forming or texturization processes used.

In the *forming process* (table 2) the macroscopical structure of the myofibrils and of the collagenic material are intact as the meat is in the form of chunks and not a paste. The inherent texture of the chunks provides a certain chewiness. Cooking coagulates the myofibrils and the accompanying soluble, but heat coagulable proteins. The collagen, depending on its degree of degradation, also contributes to impart the chewy texture to the blocks of reconstituted meat. When chunks of meat are to be formed, a mixing step should preceed where salt is added to the batch to aid in the solubilization of some myosin fractions.

In the *texturization process* (table 2) which start from finely ground meat, both the bundles of myofibrils and the collagenic constituents are ruptured and randomly oriented. In this case also a mixing step with 0.5–1.0% salt addition can be beneficial in giving a firm texture to the end product.

The texturization technologies proposed in this paper are based on the final heat coagulation of the artificially re-oriented myofibrillar constituents and of the soluble and heat coagulable muscle proteins. The non-coagulable collagenic material eventually forms a gel therefore does not contribute appreciably to the texture.

This limited contribution of the collagen to the structure of the «engineered products» represents a handicap in the development of processes for the production of high grade products from ground meat or mechanically separated meat pastes.

Forming and texturization processes

In the pursuit of finding the best possible method to denote a meat-like texture, researchers have developed numerous techniques of forming and texturization.

Forming

In «forming», the concept is to use small chunks of meat, and by adjusting the percentage of fat and lean to form, mould and press the mix to mimic a real cut of meat. It is an unsophisticated but a widely used concept and technique. There are numerous patents of which the process using Comitrol (Urchel, Valparaiso, Indiana) equipment is the best known and industrially used variation. The binding capacity of the salt within the meat system and in some cases additives and pressure are the factors involed in the forming of the final product.

Texturization

In contrast to the forming techniques where pieces of meat with their initial texture are bound together, in texturization, the raw material is a comminuted meat paste (MSM) where the initial texture is totally destroyed. Simply stated, forming techniques make use of the natural texture of meat where as texturization recreates a novel texture and as such is more difficult and complicated to realize.

Extrusion is a technique used in vegetable protein texturization for many years. Again there are numerous patented variations of the technique.

Employment of the concept of applying shear force by extrusion with or without heat, through a die head results in a final specific texture. The technique permits the allignment of formed fibers. Compacting of these alligned fibres improves the role of binding agents. In one variation, fibers from cooked meat are incorporated into the meat mix to reinforce the fibrosity. The final product has a definite texture, but the resemblance to real meat is low. It is, however, currently industrialized especially in pet food production.

Double or multiple extrusion is a merge of the concepts of forming and texturization. Texture is created by the extrusion and binding of two or more materials to form the final product. Double extrusion is a development of the simple extrusion technique where the object is to distribute homogeneously in a mass of red meat, parts of fat or white meat to obtain a product which resembles more closely the marbled structure of natural meat. The Beehive process (6) is the most elaborate co-extrusion system where the configuration of the die head controls the shape and location, and amount of the fat and lean meat. The extruded product is heated directly in the frozen state.

A few methods of texturization through freezing have been patented: variations of gelling, separation of meat fibers to be mixed with a meat paste are some examples. *Stretch-cross-folding* (7) is one of these methods which was mainly developed for vegetable protein mixtures at Battelle and was later adapted very successfully to animal proteins. We will discuss this process in detail.

Stretch-cross-folding «SCF» (7)

This procedure has a very wide range of applicability and is adaptable to different compositions of animal (table 3) and vegetal proteinaceous matter. It is particularly suitable to the texturization of animal/vegetal protein mixes which have a higher solid/water ratio than pure meat (table 4).

Table 3. Typical ground beef a) and mechanically separated chicken meat paste b) used for stretch-cross-folding texturization

	a) Beef trimmings (Commminuted) %		b) Chicken meat from separator %	
Water	68		73	
Muscle proteins (actin, myosin)	15	18.5	14	16
Collagenic material and other proteins	3.5		2.0	
Fat	11.6		9.5	
Ash	1.9		1.6	

Table 4. Example of animal/vegetable protein mix composition for stretch-cross-folding texturization

Components	g	Protein g	Fat g	Water g	Carbo-hydrates g	Minerals g
Beef trimmings	90	16.7	9.9	61.2	0.6	1.2
Sunflower concentrate	10	6.8	0.04	0.8	2.2	0.16
Texturized meat	100	23.5	9.94	62.0	2.8	1.36

Figure 4 summarizes the process of stretch-cross-folding.

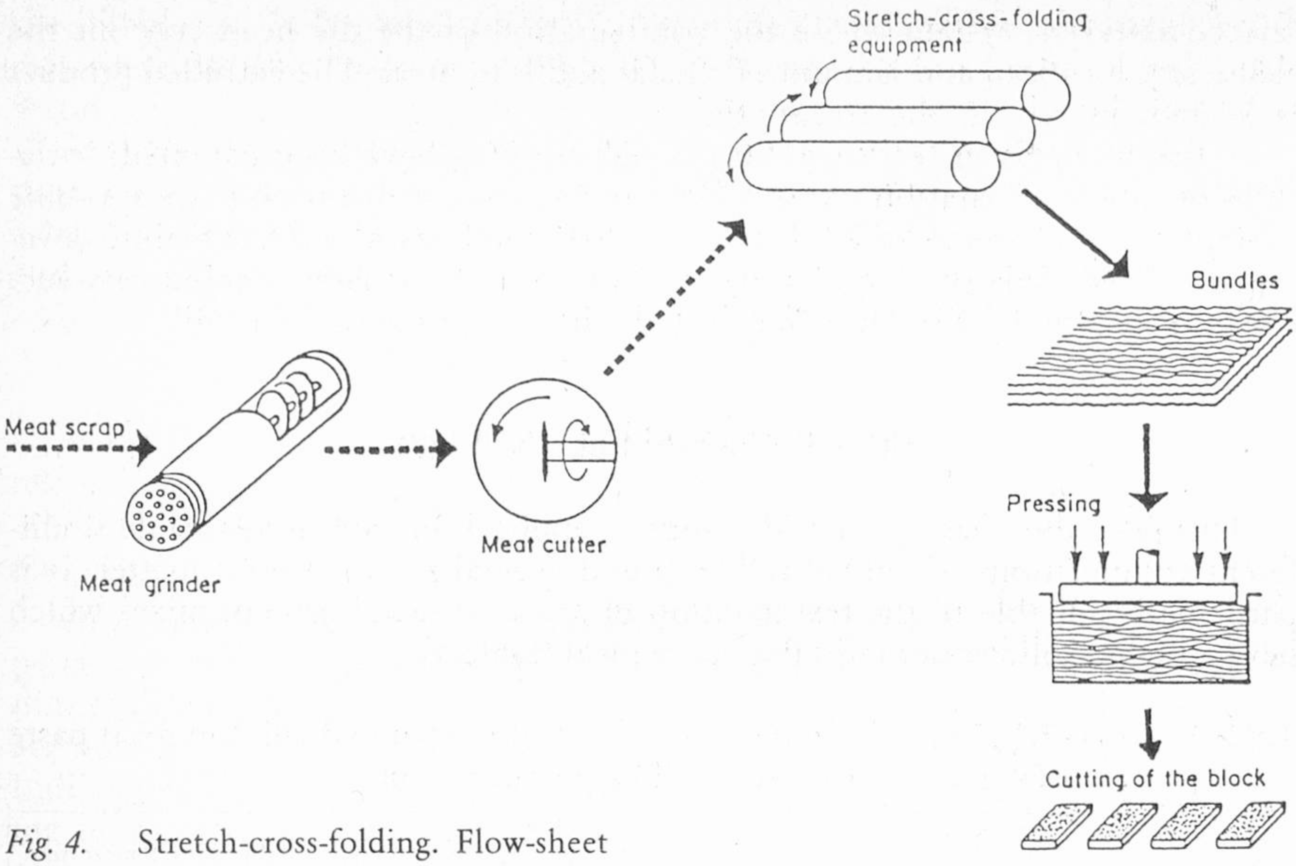

Fig. 4. Stretch-cross-folding. Flow-sheet

The mixture is passed through 3 rolls rotating at desired rpm where it is first stretched into a thin film and later scraped together into small longitudinal folds which resemble the fibrous structure of meat (fig. 5). These small folds are gathered into larger folds similar to the matrix of muscle tissue. This mass is then molded under desired pressure. Extra meat fibers isolated from a separate batch can be added to increase the fibrosity and texture of the final product. The stretch-cross-folded block can be used in many forms, like steaks, cubes, etc.

The characteristics of the process are summarized as follows:

1. a simple proteinaceous mass acting as a media of texturization and binding
2. possibility of flavor or other additive incorporation
3. undenatured final product (before heating)
4. possibility of producing extended products with proteins of different sources (soy, sunflower, etc.)
5. adaptable to all heat coagulable proteins
6. allignment of the meat fibers while passing through the rolls
7. presence of a) natural meat fibers
   b) synthetic folds mimicking real fibers.

The thin film phenomenon exploited in the stretch-cross-folding process is particularly suitable for the texturization of material containing a significant amount of undenatured protein (table 4). The stability and physical characteristics of the final texture will depend on the heat coagulation sensitivity of the constituting proteins.

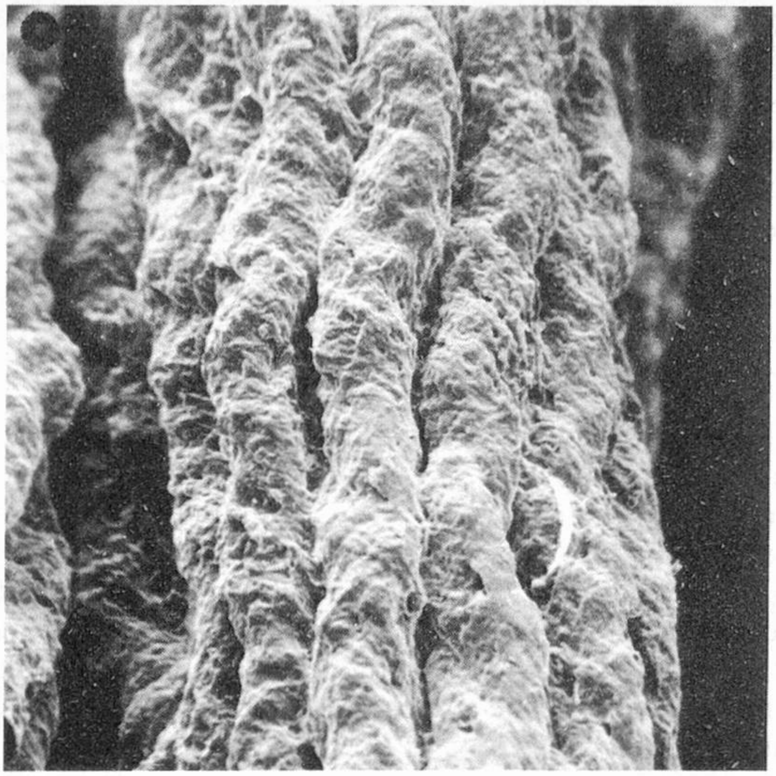

Fig. 5. Artificial meat protein fibers (scanning microscope 70 x): stretch-cross-folding process.

If required, protein denaturation can be carried out after pressing the texturized material into a block. The result of this process is an efficient «coagulation binding effect» which takes place mainly within the interfibrillar zone. The textured material thus forms a cohesive mass.

Conclusions

There are two considerations resulting in the creation of a final textured product; the chemical and physical properties of the meat and the success of the texturizing method. The chemistry of meat is well known. The ingenuity of man, however, will most likely devise newer methods to improve the existing ones to add to the success and the acceptance of texturized products. A successful texturization creates a class of reformed products which are between low-quality meat and high quality fresh cuts and where the quality of the final product depends to some extent on the quality of the starting material. The aim should be to upgrade only second quality meat and denote a texture better than a hamburger, although possibly not as good as a real steak.

There has been progress in the pursuit of methods, which are economical, efficient and capable of providing a high quality texture. The products obtained are generally of good quality and respond to a great consumer demand. Further developments in texturization will depend on technological advances which will control the physico-chemical properties of protein materials and organize and stabilize the three-dimensional conformation of the protein structure. A more cohesive and better orientable protein material will result in a firmer and more realistic texture which will better mimic the texture of meat. Thus a more precisely texturized product will be created to answer the need of the evergrowing market for «engineered products».

Summary

The paper discusses the physico-chemical basis of the texturization methods which make it possible to upgrade the value of several edible animal tissues. The composition, the physical properties and the behaviour of the comminuted meat are examined in relation with texturization. The textural properties of meat, namely the chewiness and the juiciness, depend on the myofibrillar structure of the muscle and to a certain extend, on the connective collagenic tissues. The differences in response to heat treatment of the constituting proteins of meat play a major role in the texture of normal cooked meat, as well as in the texturized meat products. The stretch-cross-folding process is given as an example of meat texturization process.

Zusammenfassung

Die Veröffentlichung behandelt die physikalisch-chemischen Grundlagen, auf denen die Methoden der Texturisierung beruhen und die eine Wertsteigerung tierischer Gewebe erlauben. Die Zusammensetzung, die physikalischen Eigenschaften sowie das Verhalten von Hackfleisch werden im Zusammenhang mit der Texturisierung untersucht. Die physikalischen Eigenschaften von Fleisch hängen von der Faserstruktur des tierischen Muskels sowie den damit zusammenhängenden Collagengeweben ab. Das spezifische Verhalten gegenüber Wärmeeinwirkung der verschiedenen Proteinbestandteile hat einen wesentlichen Einfluß auf die Textur sowohl von normalem gekochtem Fleisch als auch von texturisiertem Fleisch. Das Verfahren «Stretch-cross-folding» wird als Beispiel einer Methode zur Texturisierung von Fleisch angeführt.

Résumé

La publication traite des bases physico-chimiques sur lesquelles sont fondées les méthodes de texturisation permettant d'accroître la valeur de divers tissus animaux. La composition, les propriétés physiques et le comportement de la viande hâchée sont examinés en relation avec la texturisation. Les propriétés physiques de la viande dépendent de la structure myofibrillaire du muscle animal et des tissus collagéniques qui lui sont associés. Les comportements spécifiques à la chaleur des protéines constitutives de la viande jouent autant un rôle majeur dans la texture de la viande cuite normale, que dans celle des viandes texturisées. Le procédé dit de «stretch-cross-folding» est cité comme exemple de méthode de texturisation de la viande.

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Dr. C. Giddey
Dr. Sema Güney
Battelle
Centres de recherche de Genève
7, route de Drize
CH-1227 Carouge