# Update: Functionality of Non-Meat Ingredients

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The turn of the century is only a few years away, and despite the fact that computers and robotics are now an integral part of processed food manufacturing, it seems that the meat processing industry is hindered by the dilemma of "Old-World" fashion and "New-World" evolution.

Red meat further processing can be highly improved if systems are designed that allow automated pre-batching, grinding, emulsion preparation, stuffing, smoking, cooking, chilling and packing, based on computerized technology that synchronizes the individual manufacturing steps into one continuous processing flow. Based on recent equipment and protein technology know-how, it is expected that within the next few years, revolutionary sausage manufacturing systems will become available that will render much of the current technology and equipment obsolete. Obviously, these highly computerized and automated sausage production systems will be a challenging invitation to nontraditional meat companies to enter the playing field.

Since 589 BC, when the Chinese first stuffed sheep cashings with a mixture of pork mutton, soy and seasonings (the first known sausage, *lup cheong*) the stuffing and further processing of sausages always has been labor intensive. As years passed, natural hog or sheep casings were predonnnangy replaced by synthetic collagen, fibrous, and cellulose casings. To meet increased consumer demand, new semi-automatic stuffing and hanging equipment soon became available.

Though very effective for many years, semi-automatic filing systems show some inherent drawbacks in a fast changing world where increasing labor costs and environmental issues, such as recycling of peeled-off cellulose casings, have moved to the forefront of management's attention.

In the early '80's, some "visionary" meat equipment experts conceived of a completely automated further processing sausage plant. Of key importance was the design of a system that would allow continuous sausage extrusion.

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At the request of the speaker, this paper is taken from the author's text, "Vegetable Protein", (pages 81-94) in lieu of a separate paper. With the approval of the author, minor editing of the text has been made to conform with the Proceedings format and policies.

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Although the idea behind the simultaneous nozzle extrusion of a meat batter and a collagen paste that produced the casing was sound, some key problems needed to be solved, mainly the organoleptic and behavioral characteristics of the collagen, and the travel of the individual sausages through the various processing zones. Now, however, fully automated co-extrusion technology is perfected enough to seriously challenge traditional further processing equipment and methods. For ultra-high quantity processing, co-extrusion is the only viable way to design systems that can operate with a minimum of labor and produce products of consistent equality.

## Processing Principles

To better understand the functionality of non-meat protein ingredients in meat emulsions, a brief discussion of co-extrusion technology is needed. Co-extrusion is based on the principle of simultaneous extrusion of the sausage batter and the collagen fiber paste. A continuous rope of sausage batter and collagen "dough" (made from the inner layer of cattle hides) is extruded by two separate filler pumps, one of which handles the meat batter, and the other the collagen. These two single components are uniquely brought together by a co-extrusion nozzle that coats a continuous "rope" of meat batter. Immediately after the co-extruded sausages leave the nozzle, a conveyor belt picks up the sausage rope and pulls it through a brine bath to provide the initial setting of the collagen skin.

Directly after the rope leaves the brine bath, it travels to a series of cutting blades that close very gradually to secure the integrity of the individually shaped sausages.

An essential part of this process is the crimping. Done correctly, crimping ensures that the sausages have "old-fashioned" roundshaped ends without the risk of the collagen retracting or loosening. After crimping, the individual sausages pass through a cascading unit to optimize the load for the thermal processing tower. The actual stabilization of the skin and the initial temperature-induced gelation of the meat batter starts in the pre-drying zone of the tower.

But first, the collagen skin needs to be given more mechanical handling strength by removing some water. This is accomplished by regubbng incoming air temperature and humidity so that the humidity remains low enough to absorb the moisture released from the skin. That helps to preset the collagen skin. During this process, air velocity plays an important role, and care should be taken that the dew point never allows an unfavorable water vapor saturation in the air.

These functions need to be fine-tuned, but after the right levels have been established, the entire process is computer-controlled. If the sausages are smoked, the conveyor belt extends into a separate smoke und positioned halfway between the initial drying tower and the cooking tower.

Optimum results are usually obtained if about 5% of the liquid smoke is added to the collagen paste prior to co-extrusion. This in-line smoke addition will precondition the collagen, improving cross linking of the collagen fibers when heat is applied later in the pre-drying stage.

The actual smoking process determines the intensity and flavor of the product through controlling dilution of the liquid smoke. Liquid smoke is applied onto the sausage by either a dipping bath or with nozzle spraying. It is important that excess liquid smoke be removed from the sausage skin as soon as possible to ensure even development of the smoked color. Removal of liquid smoke with hot-air dryers mounted in the smoke unit is especially important if a light smoke color is required.

Keep in mind that diluting liquid smoke to a very watery appearance allows it to flow quickly down to the underside of the sausage, producing color defects after the water has evaporated. Liquid smoke that is continuously heated ages rapidly, and will impair color fixation and flavor. It is wise to preheat the liquid smoke only at the start of the manufacturing process.

Finally, the smoke-treated sausages travel from the smoke unit back into the main drying tower and cooking unit. The smoke-coated sausages are picked up again by a sloped, cylinder-shaped conveyer belt in the main tower and are further conditioned for drying and cooking. The drying tower, or sausage conditioning unit, heats the fresh incoming air that is required for pre-drying and removes moisture from the air to optimize the capacity for additional moisture pick-up during the drying of the sausage skin. These steps require constant monitoring of temperature and climate within the main drying tower.

After the sausages have been sufficienty dried to allow color fixation and stabilization, the sausages move into the steam cooking unit for cooking or pasteurization to 90°C (194°F) during a continuously adjustable pedod of 6 to 30 minutes. However, the core temperature of the sausages almost never exceeds 72°C (162°F).

When the cooking stage is passed, the sausages travel into cooling zones, either water cooling, brine cooling or air cooking. Usually, water or brine at a temperature of 13°C (55°F) is used to initially cool the sausages to about 40°C (104°F). This is followed by air cooling in which air with a temperature of -2° to 5°C (28° to 23°F) reduces the core temperature to about 2° to 4°C (36° to 40°F).

The co-extruded sausages are now ready for final packing. Here is a choice for canning, vacuum packing, cryogenic freezing and gas flush packing. All these systems can be designed to allow the use of computer-controlled robots. The fully automated coextrusion technology also is very energy efficient and low in microbial hazards. No human hand ever touches the product throughout the process.

## Formulation Variables

Recipe formulations play a key role in successful production of extruded sausages. The ever-changing variables in meat quality and specific co-extruder design parameters demand the presence of functional ingredients that can withstand high extrusion pressures, as well as modify or "plastify" the viscosity of the raw meat batter just enough to climate deformation of the fresh co-extruded sousage rope. in co-extrusion, the vacuum stuffer needs to maintain high pressure on the meat batter to optimize product output and extrusion diameter accuracy and to facilitate travel through the continuous processing zones of crimping, pre-drying, smoking and cooking.

These functional ingredients also need to provide strong gelling and binding properties during the thermal processing, while still optimizing yield.

Now let's turn to the emulsion. Before thermal processing of comminuted and semi-comminuted sausages occur, the meat matrix can be regarded as a (coarse) dispersion of water, fat protein and all other added non-meat ingredients, such as seasonings, binders and salts. Depending on the degree of fat reduction and the degree of solubility of the myofibrillar salt-soluble proteins, a coherent emulsion can be formed that is dispersed throughout the meat matrix and can, under certain conditions, improve the sausage texture after the thermal processing. Because processing variables such as meat quality, batter viscosity, co-extrusion pressure, and changes in pH, temperature and relative humidity can affect the organoleptic quality of the sausage, non-meat proteins are generally used to even out these variables.

Additionally, non-meat proteins are used to manipulate viscosity of the raw meat batter and assist in maintaining gel rigidity. in meat batters with sub-optimal meat protein extraction or in which no non-meat proteins are used, the high co-extrusion pressures needed to maintain sausage diameter and production output can prematurely damage the extracted or swollen protein fractions of the meat. That unfavorably affects rigidity of texture during thermal processing.

Therefore, it is important to choose a non-meat protein that behaves synergistically with the properties of the non-swollen, swollen and solubilized fractions of the myofibrillar proteins, and cooperatively integrate with the connective tissue and fat. When the microstructure of a protein-gel matrix, in which non-meat proteins are present, goes through temperature-induced transitions, it is important that physical protein-to-protein "associations" develop to improve texture and minimize purge.

Thermally induced gelation is normally a two-step process consisting of unfolding and reassociation of proteins. This means that proteins need to be denatured before they can associate into a gel matrix. A possible exception to this protein association involves sodium caseinate. This protein will not gel (it remains pliable at the fat-water interface), and thus the emulsion depends on native protein-to-protein interaction. When added properly, sodium caseinate increases gel strength and improves cooking stability of comminuted sausage. However, sodium caseinate will reduce textural properties and in a co-extruded formula can be regarded as an ingredient that will enhance elasticity of the meat batter.

Obviously, these binders should not be considered as functional proteins to replace part of the meat block. Their role is to maintain optimum co-extrusion conditions before, during and after thermal processing.

## A Choice of Ingredients

Usually, isolated soy protein is used when the organoleptic properties need to be maintained or fat needs to be reduced. There is affinity and interaction between these types of vegetable proteins and the myofibrillar proteins, myosin and actomyosin. However, these interactions usually take place at different temperature zones.

Does physical or molecular protein association occur in meat systems containing nonmeat proteins? That's an extremely difficult question to answer. Certain proteins behave antagonistically, and as a result, diminish each other's individual performance. On the other hand, under certain circumstances, meat proteins and non-meat proteins behave synergistically and produce a stronger gel.

Apart from the typical non-meat protein properties that can be studied in model systems, the overriding problem always is the enormous complexity of the constantly changing meat variables, such as pH, aging time, freezing method, time and temperature at which extraction occurs. These variables significantly influence protein associations, interaction and possible peptide bonding. It is important for meat scientists to study these variables, but in a way, it is the same old story: advances in meat science and regulatory control can hardly keep pace with product innovation. In the meat processing industry, the trial-and-error approach in developing meat products is still a very important part of the fine-tuning process.

Although it is known that meat proteins and isolated soy proteins have a different denaturing tract, an affinity exists between the two types of protein. This affinity ranges from single meat rephcement and improvement of batter properties all the way down to the affinity of isolated soy protein as reinforcement to increase gel strength in low-fat products.

The degree of protein affinity can suffer when the isolated soy proteins are not fully hydrated, and a weakening of the gel matrix can result. Therefore, it is very important to design a system in which the isolated soy protein is fully hydrated before the onset of thermal-induced gelatin.

Non-meat proteins are often able to be augured as a dry powder into a mixer or blender. However, it is imperative to have sufficient water available to allow the proteins to hydrate. Depending on the percentage of lean meat, one can choose to add the proteins to the water first, then only after a protein/water gel has been formed, add the ground meats, followed by the other ingredients such as phosphate, salt, curing salts and fatty meats. Or, one might opt to first extract the meat proteins with the assistance of water/ice, salt and phosphate, and when the optimum amount of meat proteins have been extracted, then auger dry isolated soy proteins into the blender, together with additional water.

For maximum performance, however, these functional isolated soy proteins should be hydrated in a stand-alone hydrator. Then the coherent gel can be metered into a blender. The method optimizes hydration of isolated soy protein to assist non-molecular aggregation within the meat emulsion.

Future research may well reveal that within the swollen and non-swollen meat protein network and the aggregation of solubilized meat proteins, isolated soy proteins (and possibly hydrocolloids such as carrageenan) are conformationally conditioned to perform as a reinforcement phase in meat emulsion. This allows a wider range of processing variables and raw material choices, while maintaining product characteristics. When ultra-low-fat sausages are produced (at up to 97% fat-free), it is even plausible to postulate the existence of a reversed dispersion of the matrix distributed within the gel phase.

In comminuted and semi-comminuted sausage formulas, phosphates are nearly always used. Not only does phosphate improve myofibrillar protein extraction, it also reduces the viscosity of the meat batter. In classical sausage preparation, the slackening of the viscosity of the meat batter is generally a major plus. However, this is not always the case when co-extrusion technology is used. To withstand sufficient pressure in the vacuum stuffer and from the hydraulic piston, the viscosity needs to be somewhat firmer and more "plastic-like", while at the same time maintaining a smooth appearance. Nonmeat ingredients, such as isolated soy proteins, caseinates, modified starches and phosphates, are used to manipulate raw batter viscosity and texture while contributing to sufficient firmness to permit pressure build-up during extrusion.

Prepare a raw batter that is too soft and an uneven co-extrusion results with deformation of the sausage shapes, including the flattening of the wet and still unstable extruded collagen skin. These problems become especially apparent if phosphates are used in combination with starch. Since phosphate is a very useful ingredient to assist in the extraction of the myofibrillar proteins, sometimes improvement in the directional hold of raw co-extruded sausage rope is obtained when starches are reduced or eliminated. In some cases, it might be useful to reduce the level of phosphate from 0.5% to 0.3%.

## Low-Fat Options

When low-fat co-extruded sausages are made, more variables come into play. Organoleptic and nutritional properties need to be harmonized with functionality to deliver market acceptance. Isolated soy proteins are nutritionally complete, based on amino acid composition, digestibility and ability to meet human amino acid and protein requirements, as determined by nitrogen balance and biologic studies in humans.

Isolated soy proteins have proven commercially successful in reducing fat and calories in processed meat products. Depending on the typical starting formulation, fat and calorie reductions of 20% to 75% are possible. It is possible to obtain significant reductions in cholesterol (specifically LDL cholesterol) for hypercholesterolemic people who are eating a balanced, low-fat diet that includes isolated soy protein.

In terms of functionally and organoleptic properties, low-fat co-extruded sausages are prone to package purge and flavor reversion. High-moisture products generally bring out a stronger spice and seasoning sensation. Thus, substitution of fat (versus water) soluble spice extracts need to be made. To increase shelf life, sodium or potassium lactate is beneficial, especially the new purified sodium or potassium lactates, which have a very clean flavor. Calculated on dry matter, 2.0% is permitted in the United States.

Native or modified food starches are useful ingredients to reduce package purge. Generally speaking the lower the fat content, the higher the package purge. Increasing the starch from 2.0% to 3.5% greatly reduces package purge. Unfortunately, at higher starch levels, raw batter consistency decreases to such an extent that the co-extruded sausage rope may flatten and become prone to conveyor belt "scars."

Other ingredients, in conjunction with isolated soy protein, that have shown beneficial effects on the reduction of package purge in low-fat frankfurters are methyl cellulose kappa carrageenan and especially konjac flour. These hydrocolloids are currently not permitted in the-United States in meat products with a standard of identity. isolated soy proteins are allowed up to 2.0% of the content. USDA has ruled that these proteins are to be labeled as part of the ingredient declaration.

## Processing Variables

Deformation of the sausage shows up as a flattening effect immediately after the collagen dough has been extruded. Flattening is irreversible, with the flat side of the sausage prone to conveyor belt marks and uneven smoke adhesion. Primary and secondary conveyor belt marks cause the still-unstable collagen skin to partly sink into the belt, resulting in white stripes or marks on the flattened side of the sausage. Reduce or eliminate the food starch and "thicken" up the viscosity wdh isolated soy protein. This way, a more resistant raw sausage rope will be created, which also withstands crimping and brine immersion without visible deshaping or damage to the still-fragile coliagen skin. Generally, between 1.2% and 2.0% of isolated soy protein is required.

Perhaps the most important single advantage of isolated soy protein is its ability to maintain the directional integrity of the co-extruded sausage. This strong directional "hold" enables processors to improve cosmetic quality and appearance and maximize output. Because of the unique cascading system that is part of the co-extrusion technology, the increased output will also increase the efficiency load in the pre-drying, smoking and cooking zones.

When mechanically deboned meats or meat of lower functional quality are incorporated, the batter resistance can be improved by increasing the amount isolated soy protein to approximately 4%. The same percentage can also be used for economic reasons if part of the lean meat needs to be substituted.

Because of the typical gelatinization process of wet collagen during liquid smoking and thermal processing, it was impossible until recently to create co-extruded sausage with proper "snap." Based on a major improvement in the preparation of collagen dough (a new type made mainly from hog guts) the technology is now also available to mimic the sought-after characteristics of natural casing. "Natural skin" co-extrusion technology produces frankfurters with a natural degree of "knack" or snap, a feature that may widen the popularity of co-extruded sausages even further.

Another breakthrough is the development of co-extruded fresh pork links, which are neither smoked nor heated. A process had to be designed in which co-extruded collagen skin would stabilize without the skin-hardening caused by liquid smoke and high temperatures. The setting process of the co-extruded fresh sausage is accomplished by adding glyoxal to the collagen and manipulating temperature and relative humidity in the pre-drying zones and drying zones (glyoxal is not yet permitted in the United States).

Automation of further processed meat production now has become a viable alternative to traditional processing. Innovative product creation, reformulation of existing products, and strategic partnering with key ingredient suppliers for joint marketing of name brand products, are no longer vague propositions. The modern consumer will opt for traditional organoleptic quality coupled wfth a perception of health and convenience. These trends in new product development need to be married with sound nutritional performance, attention of food safety, economic viability and avoidance of perceived environmental concerns.

The fascinating co-extrusion technology will open up new market segments, along with the potential for an entirely new category of meat products to be created, from basic sausages to snack foods. The versatile capabilities of isolated soy protein and other innovative ingredients that mimic fat will allow researchers to develop lite, healthy foods in which part of the tractional meat block can be supplanted by modified or native starches, cooked rice, cereals and fibers, surrounded by a strong, coherent protein gel encased in a co-extruded casing, with a virtually identical "natural" appearance.

Production and marketing of innovative meat products demands reliable processing methods and reliable ingredients. Proteins will play an increasing role of importance, and non-meat proteins are not only a single source for a spectrum of technical solutions, but also a cost-effective way to maximize one's innovative options.