Application of vegetable protein ingredients

Pan 2: Proteins in meat based convenience products improve the cooking behaviour and appearance

Time-tested emulsion technology using animal or vegetable protein is discussed in conjunction with concerns related to ecological sustainability of meat products. Besides soy protein, pea and rice bran proteins are increasingly seen as environmentally low-impact solution to successfully produce (hybrid) meat-based foods.

By Henk Hoogenkamp

There are many different vegetable protein ingredients commercially available, and it can be a very time consuming and difficult exercise to determine which specific protein delivers high performance and most value for a product. For example, soy protein isolate contains 86% protein (on a as is basis), therefore 1 part of soy isolate plus 3 parts of water gives 21.5% protein – the equivalent protein content to fat-free lean meat. Soy protein concentrate contains 65% protein (on a as is basis), therefore 1 part of soy concentrate plus 2 parts of water gives 21.5% protein. Subsequently, to maintain protein and fat contents in the final emulsified meat, fat-free meat should be replaced on a 1:3 basis when hydrated with soy isolate or 1:2 when hydrated with functional soy protein concentrate.

Controlling the variables

Apart from differences in protein properties in relation to meat replacement, water-holding capacity, and fat emulsification, key processing variables need to be taken into consideration. For example, high-energy equipment (bowl choppers) together with staged addition of ingredients tends to favour soy protein isolate. Lower energy equipment (colloid mills or mixer/emulsifiers) tend to favour soy protein concentrate, especially when limited amounts of formulation water and/or salt are added early on in the processing cycle. In other words, the meat-size reducing equipment greatly determines the performance of functional vegetable ingredients – not the other way around.

Functional powdered vegetable proteins are designed to perform like salt-soluble meat protein. Usually vegetable protein sources have a relatively high pH value compared with meat protein, while also the molecular structure and gelation properties are different from those of meat protein. Some antagonistic effects might surface at increasing levels of functional soy protein starting at 4% and more in emulsified products. These are specifically related to colour, flavour and texture.

Colour can be adjusted or corrected by selecting one or more of the following additives:
- Liquid or dried blood (hemoglobin)
- Fermented rice (Monascus purpureus) also known as Red koji or Ang-kak
- Erythrosine
- Carnine (Cochineal)
- Beet root
- Sandalwood
- Paprika extract
- Red 2G

Texture reduction is most probably caused by an increase of pH in the meat emulsion. At increasing levels of lean meat replacement by soy protein at a 1:1 ratio, hardness and chewiness of the product decreases. To offset these negatives it is recommended to add 0.1% to 0.2% of acid sodium pyrophosphate (SAPP), while also reduction of fat and/or starch can be a viable solution.

Flavour can be harmonised or balanced by adjusting one or more of the following additives:
- Addition of MSG
- Addition of garlic
- Addition of liquid smoke
- Increase salt level
- Increase seasoning level

Since there are so many protein ingredients available on the international market, it is difficult to discuss specific suitability parameters for all products. In general terms, high gelling soy proteins are preferred for low-protein formula meat products, whereas low-viscosity soy or pea proteins usually have superior results for high meat formula meat products.

Observing gel strength

An often-recurring discussion is about the gel strength of protein ingredients. Physical properties and application properties should not be confused. When protein ingredients are used in meat products, it makes sense to base the evaluation test with added salt. The presence of salt can play havoc and reduce the gelation properties, most notably soy protein ingredients. A water protein ratio of 5:1 is usually a good base for measurement, as well as the type of equipment used to prepare the gel. Again, when gels are made for inclusion in a processed meat product, a bowl chopper (cutter) is the preferred method as this equipment allows the addition of salt at the end of the chopping. When typical laboratory mixers or blenders are used, the strong gel formed makes it extremely difficult, if not impossible, to distribute the salt throughout.

It is of great importance that the preparation conditions are identical when different protein ingredients are evaluated. This means the use of distilled water and the same ambient temperatures and identical thermalisation cycles. To make matters a bit more complicated, there is no clear-cut definition of “gel strength”. What measurement of force compression is chosen – single or repeated compression? The frequency can influence gel strength, as well as presence of salt, temperature and energy impact. An initial strong gel does not always carry through in a strong emulsion. In other words, forces can be synergistically and antagonistically at work that can reinforce or dilute the meat emulsion structure.

Perfecting the pre-emulsion stage

Pre-emulsions are made from fat, water and functional protein. Pre-emulsions are especially suitable when beef or mutton fat is used. The protein:fat:water ratio is typically 1:5.5. However, many more protein-fat-water ratios are possible. When soy or pea protein based pre-emulsions are made, it is recommended to start by chopping the water and the protein into a smooth gel. Once a viscous gel has been obtained, the fat is added to the chopper while changing the knife speed to fast. After four minutes, chopping the fat/water emulsion is complete. Typically, 10% to as much as 20% of a premade emulsion is added to a base meat emulsion.

The term food emulsions, including pre-made fat-water emulsions, should not be con-
fused with meat emulsions or meat batters. Meat emulsions are a complex combination of a number of ingredients, phases and structures and will be discussed separately.

From the viewpoint of product stability, pre-emulsions are generally the preferred method to incorporate animal fat sources, such as beef fat or pork leaf (flare) fat, which are difficult to stabilise. This is especially true for products that have a high fat content or when vegetable oil is used and there is a need to withstand higher thermal processing temperatures.

Pre-emulsions are labour-intensive and require additional manufacturing steps, including provision of adequate cooling or freezing capacity. However, for a number of specific products and in geographical areas with a shortage of animal fat, pre-emulsions remain important. In Middle Eastern countries like Iran, or Indonesia for that matter, it is quite normal to use vegetable oil for pre-made emulsions. Because of the lack of cellular fat structure, a ratio of 1:4:4 is recommended. Generally speaking, heat-stable emulsions should be able to withstand a core temperature of 120 °C, without any visible fat or gel separation in the processed product.

Apparently, the required temperature is not as critical for sausage or spread products that are pasteurised. Stable pre-emulsions nearly always give better final results than unstable pre-emulsions or when the non-meat protein is added in a dry powder form. A standard pre-emulsion is made from 1 part functional vegetable protein, 5 parts fat and 5 parts water.

The chopping sequence:

- Add 5 parts water to a bowl-chopper.
- Add 1 part of vegetable protein isolate and chop at low speed until the protein powder is well dispersed. Continue to chop until a smooth and shiny gel has been formed.
- Add 5 parts fat. Change to fast chopping speed and continue for 3 to 5 minutes.

Sea salt consists of more than 90% sodium chloride and is for some consumers an “all-natural” substitute of regular table salt.

The chopping time depends on temperature of water, friction of chopper knives, type of soy protein or pea protein and type of fatty tissue.

- Add 2% sodium chloride (salt) during the final minute of chopping. Salt acts as a preservative, balances the final product and helps the emulsion firm up to improve handling during processing.
- Fill the emulsion in containers or trays in layers of about 20 cm deep to ensure rapid cooling. If kept under refrigeration at < 4 °C, emulsions can be stored for up to 72 hours.

It is also possible to withhold some water during the early chopping process. For example, 1 part of vegetable protein can be emulsified with 5 parts fat and 4 parts hot water. Upon completion of the emulsification, 1 part ice is added to the chopper (cutter). This will somehow reduce the temperature, which accelerates cooling.

An ice-cooled emulsion is generally less firm, but this property can be advantageous for some products. For example, smoother emulsion consistency distributes more rapidly when a mixer/blender is used for final product preparation. When maximum stability is not necessary, it is entirely possible to use warm water or even regular tap water for emulsion preparation. The resulting emulsions can be used for pasteurised products that are cooked to a core temperate of 80 °C, as an example. The chopping sequence is similar to that of hot-water emulsion method, although it is clear that this method is not suitable for animal fat that is difficult to stabilise. For example, pork leaf fat (flare fat) and beef suet need hot emulsification temperatures. If this is not possible the protein-fat-water ratio needs to be adjusted to 1:5.4.

On the other hand, when pork skin (finds) is used, it is possible to pre-blanch the skin for about 20 minutes at 80 °C. This will soften the collagen tissue, thus reduce the stress when used in a pre-emulsion. Pork skin needs to be added into the chopper prior to addition of fat and chopped to a fine particle size. The presence of pork skin allows an increase in the pre-emulsion ratio to, for example, 1 part of soy protein isolate, 8 parts of pork skin, 5 parts of fat and 6 parts of water.

The heat stability in fat-water emulsions made with functional vegetable protein is slightly less than milk protein (sodium caseinate). For maximum stability in retorted meat products (at 120 °C), soy or pea protein isolate should be used at a 3:4 ratio of protein-fat-water.

For taste, flavour and stability considerations, it is usually not recommended to use pork leaf fat (flare fat) and beef suet for products, such as canned frankfurters or liver spreads, that need maximum stability. However, for pasteurised products, pre-emulsions made with vegetable protein using leaf fat or beef suet, can be made using hot or warm water to assure optimal protein performance.
Functional protein blends

Traditionally, animal protein sources were used as stabilisers and binders in processed meat products. These animal protein ingredients included milk protein, collagen protein and albumen plasma protein. Steep cost increases have largely made use of milk proteins obsolete in most emulsified and coarse-ground meat products. Collagen and albumen plasma sources continue to serve as raw materials to manufacture functional ingredients that can be used as stabilisers and binders in processed meats.

Animal derived plasma protein is very compatible to meat in terms of flavour and emulsion enhancement. Pork or beef plasma protein has typically 70% protein and have very good synergistic performance in meat emulsions or meat batters. In this sense these proteins are superior to vegetable protein performance. Plasma albumen protein has excellent solubility and possesses a good ability to form strong and elastic irreversible gels at increasing temperatures. The latter makes albumen protein an ideal emulsifier for canned meat products that need to withstand retorting temperatures, not to mention a wide spectrum of all other processed meat products.

Some processed meat products can benefit from co-application of plasma protein, along with vegetable protein ingredients in a complex meat emulsion system. Generally speaking, albumen proteins should then be used to (pre)-emulsify part of the fat and water, while functional vegetable protein should be used to support and enhance the meat formation and textural performance. Wheat gluten has beneficial effects on general texture improvement of ultra-low meat containing hot dogs such as typically formulated with less than 20% lean meat.

Soy protein isolate and soy protein concentrate can be seen as cost beneficial functional ingredients. However, it should be noted that because of possible negative consumer perception towards soy, there is a worldwide increase in the use of pea protein. The negative perception of soy is also fuelled by the fact that soy is increasingly associated with allergenicity. Besides improving protein digestibility and bioavailability, functional ingredients improve texture, water binding gel formation and fat immobilisation. Functional soy protein reduces syneresis, especially when used in tandem with supporting functional ingredients. Vegetable protein blends often contain sweet whey powder and stabilised rice bran to reduce costs, togetherness with a small percentage of carrageenan and cogum flour.

All-natural formula

Increasingly, food processors are expected to use all-natural ingredients to provide functional properties that are usually imparted by phosphates, lactic acid, erythorbate, food starches and traditional sources of nitrite. Developing a “clean label” for processed meat-based convenience products can be a real challenge. Replacing traditional ingredients and additives with chemical sounding names, and substituting by all-natural ingredients can be accomplished by considering innovative solutions.

For example, cultured celery juice contains nitrates and nitrites that provide cured colour and inhibit Clostridium botulinum. To some extent this is also true for cultured beef juice. It has been known for some time that cherry and prune juice/powder contain antioxidants as well as a high concentration of ascorbic acid (vitamine C), which increases the speed that nitrite reduces to nitric oxide. This compound on its turn reacts with myoglobin and becomes nitrosylhaemochrome when heated. Cultured corn sugar which contain acetic acid (vinegar) as well as lemon juice have demonstrated positive effects to prevent bacterial growth most notably Clostridium monocyogenes. Sodium bi-carbonate or baking powder is known to buffer pH and as such can increase water-holding capacity in emulsified meats.

For some reason, sea-salt has a superior consumer perception and, hence, is often used as an “all-natural” substitute of regular table salt. Unrefined sea salt has a higher mineral content and generally consists of some 90% sodium chloride. A similar story can be told about turbinado sugar (= unrefined cane sugar). Also turbinado sugar has a very positive consumer perception and is usually added to both emulsified and whole muscle meat products to increase dry solids to counteract the often-sharp taste of salt as well decrease water activity.

Functional fibres, especially stabilised rice bran, are also used as innovative all-natural ingredients to provide functional properties in processed meat products, including formed and portioned products such as burgers. Rice bran containing healthy oil, dietary fibre and protein have functional properties to bind water and contribute to enhanced yields and juiciness. Rice bran also finds applications in the rapid growing segment of gluten-free foods.

Meatless™

There is a distinct and clear trend that processed meat products will undergo some major changes in the future. Both in anticipation of environmental concern, ecological sustainability as well as emerging health issue, it is expected that processed meat products will become hybrid in the sense that increasing amount of non-meat components are an integral part of the formula. In very basic sense, these non-meat components are either based on multi-vegetable protein extracted meat-analog fibres (shreds) and a vegetable-protein based intermediate “paste”.

For example, Meatless™ is a 100% vegetable based compound that can uniquely be integrated into hybrid meat products. This semi-moist product can be used as a stand-alone hybrid for coated finger foods, as well as a carrier for emulsions based sausage, and dry fermented sausage such as salami. The objectives are to reduce calorie content of traditional- formulated meat products without affecting consumers’ expectations together with addressing the need to improve sustainability and thus stretch the available lean meat resources. Ultimately it can be expected that both extruded vegetable multi-protein ingredients together with a meatless intermediate compound will be the base for a wide range of new generation convenience hybrid foods and meat free alternatives.

Addressing the concerns of future sustainability, vegetable ingredients such as soy, pea, and rice protein are increasingly considered as low-impact solutions for the environment including the remarkable reduction of greenhouse gases.

Author’s address

Henk W. Hoogenkamp, hoogenkamp@eu.com

Henk W. Hoogenkamp is a publicist and author and has previously been President of DVM USA (now Friesland Campina), and Senior Director Strategic Technology, Solae LLC (a DuPont Bunge Company).