SAUSAGE EXAMINATION

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sausages

such as soy protein. Frankfurters produced in South Africa or the Philippines

the entire recipe is madefrom MDM meat, fat and skin emulsions, and up to 15% of non-meat ingredients such as soy protein and starch.

The term ‘emulsion’ is used universally for a finely cut sausage with novisible fat, although this is technologically incorrect. The term ‘emulsion’ isonly justified if the fat material processed is liquid, e.g. oil, because onlythen are the water and fat present in their liquid form within the raw uncookedproduct. The solubilized, or activated, protein acts as the emulsifier betweenthese normally non-mixable materials, resulting in a fat-in-water emulsion.

Most of the fat in such a system is present as finely cut solid fat, although the

temperature rise where the knives in the bowl cutter come into contact with

the meat liquefies some of the fat, resulting in a small amount of emulsion

present in the suspension.

1- Selection of raw materials

higher proportionsof lean meat in the product contribute positively towards a firmer bite and

texture as well as a stronger curing colour.

As in all other meat products, the microbe count of the meat and fat

material to be processed should be as low as possible. Fat is often neglected, but fat with a high microbe count affects rancidity, flavour, shelf life and colour stability in the finished product. The number of bacteria on meat used for cooked sausages should be between 102 and 104 per gram of product and a pH between 5.7 and 6.0 is preferred.

If fresh chilled meat and fat is processed, thetemperature should be between 0 and 4 ∞C. Low temperatures delay bacterialgrowth and optimize solubility of the main myofibrillar proteins, myosinand actin

Myosin, actin and partly tropomyosin are responsiblefor binding water in muscular protein.

The lean meat in a sausage affects the immobilization of added water, the emulsification of fat, and the texture, bite, colour and taste of the product.

the length of time that meat andfat materials can be stored is largely determined by the fat content. If frozenmeat is thawed before being processed, then ice should be added to keep thetemperature low during the cutting process. Frozen and semifrozen materials are commonly processed because significantly less ice has to beused. Adding water instead of ice is more economical and also gentler on theknives of the bowl cutter. When fully frozen meat is processed, it is generallyflaked or minced before being placed in the bowl cutter to prevent damageto the knives.

Beef is commonly used in cooked sausages, and some DFD beef can be used without harming the finished product, although using large amounts of DFD beef should be avoided. Too much DFD beef can result in a poor curing colour and shorter shelf life because of its high pH.

Neck meat has a large amount of connective tissue, which in turn contains much collagen. Collagen turns into gelatin during cooking, which contributes

to firmer texture and bite. The blood in this type of meat also leads to a stronger red colour in the finished product.

Meat from sows, or choppers (old female breeding pigs), is widely used in cooked sausages. Sow meat contains high levels of myoglobin owing to the age of the animal and, once in contact with nitrite, contributes to a strong curing colour. The water content in muscle tissue of older animals is lower than that of a young pig.

Chicken sausages should be pale coloured or white,and the majority of meat processed should be chicken breast. When breastmeat is too expensive, some thigh meat can be used, and the finished productthen whitened by the addition of chicken skin emulsion. Adding 2–3% starch,or more, also helps to lighten the colour. Chicken thigh meat contains somecollagen, which contributes to firmness.

If coloured casings were used in the product to be reworked,the new product may have coloured dots. Rework should be used as quicklyas possible and should have a low bacteria count.

2- Production and use of pork and chicken skin emulsion:

Pork or chicken skin contains around 55% water, 35% connective tissue (mostly collagen), around 5–10% fat and 0.5% ash. Emulsions made of chicken or pork skin are widely used in cooked sausage production as they are inexpensive and add bite and firmness. Tendons or ligaments are also used for the same reason, and all these raw materials are very high in connective tissue and therefore collagen.

Chicken skin (mostly minced) is added to the bowlcutter and the total mass is cut at high speed until a finely cut mass isobtained with the maximum temperature

being around 10–14 ∞C. Slightlyfrozen skin and some ice are used to prolong the cutting time, ensuring thata fine paste is obtained.

Salt(and nitrite) is used to extend the shelf life of the emulsion and is added at

the end of the cutting process and mixed in gently.

Iced water, and some ice, is gradually added afterwardswhile cutting under a high speed.

, and the smallamount of soy protein is only added to emulsify the usually small amount offat attached to the skin. This type of emulsion can also be passed through anemulsifier to obtain an even finer paste, and salt can be introduced at the endof the cutting process as well.

Skin emulsions can also be stored in the freezer, and the finished emulsion

is placed in trays in layers not higher than 10 cm so that the temperature of

the emulsion falls quickly. If the layers are any thicker, cooling takes much

longer and there is a risk of bacterial growth.

1.1 Use of hot-boned meat (warm-meat effect)

Warm, or hot-boned, meat is very useful for producing cooked sausages with

no added phosphates, and beef is occasionally prepared this way.

meat that hasbeen frozen before the onset of rigor mortis contains the proteins actin andmyosin in a separate, and therefore highly soluble, state. The pH for meatwhere the WME has been preserved via fast freezing is around 7.0–7.2

Hot-boned meat that was frozen using nitrogen (N2) or carbon dioxide

(CO2) must not be fully thawed before processing because rigor mortis

would take place very quickly during thawing (in the bowl cutter). Actin and

myosin would therefore link together and all the advantages of hot-boned

meat, or the WME, would be lost. When frozen or tempered hot-boned meat is processed, salt and ice, and/or water, is added to the bowl cutter during cutting, because it solubilizes the proteins by widening the gaps between actin and myosin as they thaw, thus preventing the actomyosin complex from forming.

1.2 Fat

Fat stabilizes the solubilized protein gel network in a sausage and contributes to succulence and texture. Fat also helps to prevent shrinkage of the protein during cooking by acting as a filler. Pork fat is the most commonly used fat in cooked sausages. Fat from the loin, belly and neck is the most suitable fat for cooked sausages because of its low unsaturated fatty acid content. However, fat from loin or neck is often used for products such as salami as those products are generally sold at a higher price than cooked sausages. Fat from all the remaining parts of a pig such as shoulder and leg is frequently used for cooked sausages but the inclusion of loin or neck fat as well as bellies is of advantage. Shoulder or leg fat has a lower melting point than fat from the neck or loin and the risk of fat separation in the finished product is enhanced if the temperature during emulsification exceeds 16–18 ∞C.

Very economical sausages are often produced using fatty trimmings from beef and mutton (old sheep), both high in saturated fatty acids, without any added pork or prior preparation of a beef-fat emulsion. Here, the sandy and tacky mouth feel is accepted by the consumers simply because they cannot afford to pay a higher price for sausages and food in general

1.3 Oil

Vegetable oil is used when no solid fat is available. Cooked sausages produced with oil are lighter in colour than those made with solid fat. Oil is essentially 100% fat, while solid fat is only around 85% fat.

Cookedsausages made with oil are true emulsions, as both water and fat are presentin liquid form, and activated, or solubilized, protein acts as the emulsifier.

Oil must be chilled before use to keep the temperature of the total sausage mass low and therefore to allow enough time for the oil to be emulsified

3- Production and use of fat emulsion in cooked sausages

Another source of fat is a fat emulsion. Fat emulsions are generally made from protein, low-value fat and water, with soy isolate being the protein most commonly used. Low-value fats include lard and kidney fat from pigs and cattle, beef suet and chicken fat. In most cases, these types of fat are disposed of, and sometimes the disposal has to be paid for. If added directly to a sausage emulsion, these fats cause a smeary, greasy and tacky mouth feel, and sausages containing a large amount of these fats can leave a thin layer of fat sticking to the gums in the mouth. Beef fat also results in a rough or sandy mouth feel if added directly to the sausage mass. Low-value fats have a large number of saturated fatty acids and are therefore quite hard, which makes them difficult to emulsify. To counteract the disadvantages and still to use inexpensive fats, a fat emulsion is produced and then incorporated

into the sausage mass. The emulsion stabilizes the fat and reduces the sandy texture in the finished product.

The fat used for fat emulsions must not be rancid and must have a low bacteria count. These fats are commonly not treated or chilled properly and often have a high bacteria count but, even though they are low value, they should be treated like high-quality meat from a microbiological point of view.

Fat emulsions are generally produced in a ratio of 1:5:5, with one part of soy isolate being cut with five parts of water and five parts of fat. Fatemulsions can be produced by hot or cold methods.

The shelf life of afat emulsion under chilled conditions is between 3 and 5 days, depending onthe original bacteria count of the fat and storage temperature. Using rawmaterials with a low bacteria count and storing the emulsion at 0 ∞C is optimal.

Fat emulsion can also be produced with oil, usually inthe ratio of 1:4:5. Thus 1 part of soy isolate is processed with 4 parts of oiland 5 parts of water, because oil represents 100% fat. Fat emulsions with oilare made using the cold method, and stabilizing oil first in an emulsionreduces the risk of fat separation in products made using oil, especially if thecontent of meat (protein) in the product is low.

4- Selection of additives

Phosphates are the most efficient additive forsolubilizing muscular protein, and generally 3–5 g of phosphate are used per kilogram of total mass. Total mass includes all lean meat, fat, water or ice, other emulsions as well as all additives and binders. Therefore, 300–500 g of phosphate will be added for 100 kg of total mass. Most countries permit 0.5%, or 5 g, of phosphorus pentoxide (P_2O_5) per kilogram of product,

which represents around 8 g of phosphate added per kilogram of total mass. Such high levels of added phosphate do not result in increased functionality and 6 g of phosphate per kilogram of product can be seen as the absolute maximum level from a technological viewpoint. Special blends of phosphate, primarily containing diphosphates, are available for emulsified sausages and act quickly on protein during chopping or mixing–emulsifying.

Phosphates are always added at the beginning of the cutting process, so that they can act on the protein right from the start.

Salt is the oldest additive and acts synergistically with phosphates . Salt is added at the beginning of the comminutionprocess. The amount of salt in cooked sausages varies considerably butshould be above 12 g per kilogram of total mass in order to activate proteineffectively.

Salt is also added at the beginning of the cutting process, together with phosphates, because this raises the ionic strength to its maximum level and promotes the solubilization of muscular protein. Salt-soluble proteins, such as actin and myosin, have better emulsification abilities than water-soluble proteins because of the presence of hydrophilic as well as lipophilic groups. Solubilized myosin mainly emulsifies fat, while activated actin immobilizes water strongly. However, solubilized myosin and actin should be viewed as working strongly in synergy, rather than separately.

Water or ice as such is not an additive, but it fulfils major technological functions in the production of cooked sausages for several reasons. Firstly, water is required to activate, or solubilize, muscular protein. Without water, little or no protein can be activated, and high levels of activated protein are required for a firm texture, the proper immobilization of added water and the

emulsification of added fat. Secondly, ice is commonly used to counteract the heating effects of the high cutting and shearing forces generated by the knives on the bowl cutter. Where cutter knives turn at 3000–5000 rev/min, temperatures can reach 120 ∞C in certain areas on the knives, and so ice is essential to keep the temperature of the sausage mass down. Without ice, the temperature of the sausage mass would rise very quickly, shortening the time available for cutting and hence making it difficult to obtain a homogeneous emulsion without any visible fat particles and to activate the maximum amount of protein.

Acid salts enhance theswelling of the fibre structure owing to higher ionic strength but do notseparate or solubilize actin and myosin as effectively as the combination ofphosphates and salt. Citrate is applied at 3–5 g per kilogram of total massand practical experience shows that a combination of 2 g of phosphates inconjunction with 20 g of salt per kilogram to total mass solubilizes aroundfive times more protein than a combination of 5 g citrate in conjunction with20 g of salt per kilogram of total mass.

Sausages produced with salts of food-grade acids are generally dull in appearance and the product also commonly lacks bite, firmness and texture, because of the lower amounts of solubilized protein. The risk of obtaining water and/or fat separation in the product during thermal treatment is also higher. The curing colour should develop quickly; so nitrite is used rather than nitrate. Depending on the maximum level ofresidual nitrite permitted in the finished product, which differs from countryto country, around 150 up to 300 ppm of nitrite are introduced per kilogramof total mass. As a general rule of thumb, around 50–60% of added nitriteacts on colour and flavour development, up to 30% is oxidized to nitrate.

Spicesadded to the sausage contain nitrate, and starter cultures such as Staph. carnosus are added because they can reduce nitrate to nitrite. The filled

sausage is tempered at 45–50 ∞C for 1–1.5 h before final thermal treatment to allow the reduction of nitrate to nitrite and to allow the resulting nitric oxide (NO) to bind effectively to myoglobin to form nitrosomyoglobin.

Colourenhancers such as ascorbic acid,

ascorbate, erythorbate and GDL are used to intensify and speed up the development of curing colour in cooked sausages, and to stabilize the curing colour during storage. The addition of a colour enhancer only makes sense when nitrite, and not nitrate, is used in the product. Ascorbic acid is added at 0.4–0.6 g per kilogram of total mass while ascorbate, or erythorbate, is added at 0.5–0.7 g per kilogram of total mass. Excess levels of ascorbic acid or erythorbate can cause the product to turn green, while ascorbic acid, or ascorbate, reduces the EH value and improves shelf life.

Ascorbic acid is most commonly used as colour enhancer in cooked sausages, because it speeds up the formation of NO, which is needed for the formation of nitrosomyoglobin.

GDL is occasionally added at around 1.0–1.5 gper kilogram of total mass. Citric acid is rarely used and, if so, added ataround 0.1–0.2 g per kilogram of total mass. When either GDL or citric acidis added, the pH value of the sausage mass is slightly reduced, which increasesthe amount of undissociated HNO_2 thus increasing the amount of NO obtained.

Ascorbate and erythorbate can be preblended

with nitrite, but development of curing colour requires prolonged periods of time for myoglobin to be denatured. Where individual additives are used, preblending of nitrite with materials such as ascorbic acid, GDL or citric acid must be avoided as the moisture content of air is sufficient to cause nitrite reacting with those materials.

The most commonly used colours are carmine, fermented riceand a combination of fermented rice and carmine. Red wine powder, beet redand allura red are occasionally used as well. When using pure carmine,

Different types of sugar are frequently added to cooked sausages, at around 5–15 g per kilogram of total mass. Added sugars round up the flavour and also hide the salty taste if large amounts of salt have been used. The flavour of lactose goes very well with meat flavour, and corn syrup solids with a DE value of around 15–25 are commonly added to products such as hot dogs as a bulking agent to increase the dry-matter content of the product.

Proteins are frequently added to cooked sausages and vast amounts of economy products contain soy protein.

Soyprotein, either isolate or concentrate, contributes to texture, bite and firmness,

and isolates also emulsify fat effectively. High-gelling soy proteins should be cut first with water to hydrate the material fully before the meat and fat is placed to the bowl cutter. Specialized low- to medium-gelling soy proteins can be added at the same time as the meat and fat without prior hydration and are also suitable for mixer–emulsifier systems where all additives are added to the meat and fat materials in a mixer. The amount of soy protein added to cooked sausage varies enormously, and levels between 1% and 14% are found. High amounts of soy protein in a sausage increase the pH slightly, which raises WHC. Soy protein is frequently used in cooked sausages to compensate for the use of less expensive, or more fatty, ingredients. Another

method of lowering the cost of cooked sausage is to replace some of the lean meat with a mix of soy isolate and water in a ratio of 1:3. Soy isolate contains around 90–92% protein and every 4 kg of lean meat taken out of a recipe can be replaced with 1 kg of soy isolate and 3 kg of water. However, replacing lean meat with soy protein and water affects texture, firmness, flavour and bite, since meat protein contributes very positively to these parameters.

Starch is very common in cooked sausages and the amount used varies between 20 and 100 g per kilogram of total mass. Starch is used for its ability to bind water and also for its contribution to firmness and texture of the product, especially in sausages with a low meat content. Starch also acts synergistically with activated meat protein.

Using starch reduces the risk ofwater separation in the product during thermal treatment and also reducesthe amount of purge in sliced vacuum-packed products. Other carbohydratebasedfillers such as rusk, flour and cereal binder are used in cooked sausages

5- Manufacturing technology

Becauseof the number of raw materials, additives and types of machinery used. Theend result should be a homogeneous, finely cut smooth-textured product, which can withstand thermal treatment without the separation of fat or water showing firm texture and good bite.

5.1 Emulsification

Emulsification of fat and immobilizing added water in a meat product at the same time is a complicated process. The aim of the manufacturer of cooked sausages is to solubilize as much protein as possible, because solubilized

protein immobilizes added water and emulsifies fat at the same time. Solubilized protein creates a thin layer around the finely cut particles of fat, which prevents separation of fat during thermal treatment. The thickness of the layer of protein covering the particles of fat determines to a large degree the stability of the emulsion, and thicker layers of protein are better. In activated or solubilized protein, myosin has a greater tendency to emulsify fat than has actin, which shows a higher affinity towards water. During thermal processing, the layer of protein surrounding the fat particles is denatured and the fat is kept in the layer of protein, forming a three-dimensional matrix. This network of protein also prevents fat particles from unifying with other fat particles. Salt-soluble proteins such as actin and myosin have greater fat emulsification capacity than water-soluble proteins.

, the amount of salt addedrelates directly to the amount of protein solubilized. Salt increases ionicstrength, and maximum protein solubility occurs at a salt concentration ofaround 5% added salt, which is not acceptable from a taste point of view.

Undercutting occurs ifthe cutting or emulsifying process is too short, in which case the fat isinsufficiently comminuted and visible particles can be seen in the final product.

A short cutting process does not activate the optimal amount of protein and so there is only a thin layer of activated protein covering large particles of fat during heat treatment. This results in an elevated risk of obtaining fat and water separation during thermal treatment. Overcutting is when the sausage mass is cut for too long, and this results in too large a fat surface area, owing to the countless very small particles of fat in the emulsion. Generally, smaller particles of fat are easier to emulsify than larger particles, but there is only

a certain amount of activated protein to cover the surface of the fat particles.

At least six knives should be used formanufacturing cooked sausages. The knives should be kept sharp and rustfree and be adjusted so that they are fully balanced during rotation.

In large-scale production, it is common practice to carry out online analysis of the fat content of a batch being processed in order to standardize every single batch. If a large batch contains more protein, or lean meat, than specified in the recipe, the costing of the sausage will be incorrect and money would be lost because lean meat is more expensive. If there is not enough protein in the batch, there is a greater risk of fat and water separation and the firmness of the sausage will be poor. In both cases, the finished product will not be standard, which is a problem because customers today demand consistent product quality.

Peeling of skinless sausages such as frankfurters can be more difficult if the fat within the product is very finely cut or large amounts of collagen-rich materials such skin emulsion are used. High levels of starch within the product also can have a negative impact on ‘peelability’.

There are three different methods for working with a bowl cutter.

1 Lean-meat method.

2 All-in method.

3 Fat method.

The correct, or optimal, cutting process to create the most stable emulsion is still heavily debated among experts. The optimum cutting time is as short as possible in order to save energy while being long enough to ensure that as much protein as possible is activated and that fat is cut enough that it is not

visible in the finished product. Prolonged cutting of fat should be avoided because it creates a large surface area, thus reducing the stability of an emulsion. Optimum cutting depends on a range of parameters, including the amounts of meat, fat and water in the recipe, the types of meat and fat processed, and the machinery available. No universal formula for optimum cutting time can be established as a result of the great variations in ingredients, recipes and methods.

The total cutting procedure in a bowl cutter can be divided into two phases. The first phase begins when the functional additives and water (or ice) have been added to the meat and fat. During this initial cutting, the temperature of the sausage mass is between –1 and 3 ∞C and its viscosity is low.

Most of the protein activated during this phase is activated by the cutting of muscle cells, destroying large amounts of sarcolemma. Additives such as phosphates and salt, in conjunction with added water (ice), start to solubilize myosin and actin by turning these fibrous proteins into a liquefied material. After a period of cutting and solubilizing, the viscosity of the sausage mass increases and, as the temperature rises to 4–6 ∞C, shearing forces come increasingly into play. From this stage onwards, the protein is activated by shearing forces rather than cutting and, overall, shearing forces are responsible for most of the total protein solubilized. This explains how a stable emulsion can be obtained using fairly blunt knives, because blunt knives create large shearing forces, solubilizing large amounts of protein. However, working with sharp knives is better because protein is also activated effectively during the initial phase of cutting.

6- Emulsifying in a grinder–emulsifier system

Large-volume production of cooked sausages is frequently carried out in a mixer–grinder system. In such a system, the all-in method is used. Frozen, semifrozen and/or chilled meat and fat materials are flaked, chipped or minced and placed in a large mixer, typically a paddle or ribbon mixer. If fat or skin emulsions are used, they are added to the mixer at the same time as all the other meat and fat materials. All the additives are mixed in; then the ice and water are introduced and mixing continues until all the ice and water is properly absorbed and a tacky mass is obtained. Generally, the amount of ice and water introduced is between 20% and 35%, while the amount of lean meat varies greatly, between 20% and 40%. Fat is commonly present at between 22% and 30% and additives, or compounds of additives, are applied between 4% and 15%. A low-cost frankfurter would contain around 60% hard MDM, 5–10% skin emulsion, 15–20% water or ice and 10% additives, with proteins such as soy commonly being among the additives. The percentages of the different ingredients vary greatly, based on the expected cost structure and quality of the product being made.

The temperature of the meat and fat materials in conjunction with added water or ice is adjusted so that, after a certain period of mixing, generally between 5 and 10 min, the mixed and tacky mass has a temperature of around 2–6 ∞C. Mixing occasionally takes place under a vacuum. The mixed

mass is then passed through an emulsifier, or colloid mill, and the high shearing forces experienced as the emulsion passes through the emulsifier activate high levels of protein. Fat is cut down to a size that is not visible in the final product after passing through the emulsifier and the sausage mass has a final temperature of around 8–12 ∞C

The advantage of a mixer–grinder system is that a large volume of sausage mass can be mixed at once and, after it has been emulsified, several filling or stuffing machines can be fed at the same time. Often, two large mixing machines can feed a single emulsifier so that the emulsifier operates continuously. The emulsified mass is pumped in pipes to the respective filling stations. This is a continuous process, the opposite to the batch production obtained using a bowl cutter.

Cooling must be rapid to reduce the riskof bacterial growth, because the raw sausage mass contains all the substratesfor bacteria. The cooled sausage mass is then stored under chilled conditionsand can be filled the next morning. Sausage mass that is going to be filledstraight away after production should be stored at low temperatures and iscommonly placed in the same room with the bowl cutter and filling machines.

7- Filling

The sausage mass should be filled into the desired casings and heat treated as soon as possible after it is made. Souring can occur if there is a long time between procedures especially if the sausage mass is exposed to an elevated temperature or even room temperature. Souring makes the taste and flavour of the sausage unacceptable and impairs the binding in the emulsion owing to the drop in pH, which reduces WHC. The process of filling also affects the

sausage mass mechanically, which is never advantageous.

Filling should take place at a moderate speed and the filling pipe, or filling horn, used should be as wide as possible for the casing being filled. Generally, the larger the diameter of the casing, the slower is the filling speed. Small-diameter and short sausages such as cocktail sausages can be filled at faster speeds because they consist only of a fine emulsion. Products containing show-meat must be filled more slowly. Using a wide filling horn allows the sausage mass to flow naturally, without being redirected. The filling horn should be as short as possible, because a long filling horn squeezes the sausage mass more during filling, which is not desirable.

A vacuum should be applied during filling to prevent air pockets, as they affect the firmness, texture, colour and colour stability of the final product, as well as increasing the risk of fat and water separation within the air pockets themselves. The colour in air pockets quickly changes from red to green or grey during storage of the finished product. Applying a vacuum during emulsification as well as during filling results in a pore-free product with greater firmness, texture and bite. A vacuum filler by itself removes most, but not all, of the air present within the emulsion.

Cooked sausages are filled into natural casings such as sheep and hog casings, as well as large natural casings from cattle such as bungs. Most large-diameter cooked sausages are filled into waterproof casings (see Chapter 35, Section 35.4). Casings must not contain any residual water, which could be trapped during filling and would be present in the final product.

Casings have to be treated according to the manufacturers' recommendations

before filling. Soaking times, temperature of the soaking water, filling speed and other specifications have to be followed in order to obtain all the benefits from the chosen casing. Tremendous improvements in filling have been made in the last couple of years, especially regarding speed and accuracy of filling Emulsified sausages with show-meat may also be filled into specialized non-waterproof casings, which can be smoked prior to moist thermal treatment. Large filling machines are commonly based on a rotorlike system, where the sausage mass comes down from the hopper and is moved in a circular way. Residual air is removed during this circular movement, before the sausage mass finally goes into the filling horn. Other filling machines operate a double-screw system, where two screws rotate in opposite directions to each other to move the sausage mass forwards. Small filling machines operate on a cylinder-type mechanism, where a cylinder pushes the sausage mass up or down into the filling horn. Most small filling machines cannot fill under a vacuum.

If an automatic, or semi-automatic, clipping machine is used, the clip must be placed correctly around the casing. The clip must fully cover the bundle of casing without cutting it. This can be a problem if a ready-made clip is placed too firmly on or around the casing, and especially if an ‘endless’ metal cord is used. In the latter, the clip is cut from the metal cord before being placed around the casing and this frequently results in sharp edges. If the casing is pierced even slightly, it will burst during cooking and this can result in large amounts of rework. Normally, working with automatic filling and clipping machines correctly hardly ever causes bursting

8- Smoking, cooking and cooling

Large amounts of cooked sausages are smoked. Smoking has a profound impact on colour, taste, appearance, flavour, shelf life and bite in the final product . Sausages in small-diameter sheep, hogor beef casings have to be conditioned before they are smoked so that the levelof moisture and temperature on the surface of the product are consistent. This step is very important when large smoking chambers are used as it takes a considerable time to fill a large chamber with smoke trolleys. The products on the smoke trolleys that were put in the smoking chamber first often have different surface moisture levels from those that were placed in the chamber last. If smoking begins straight away, the differences in surface moisture will result in an uneven and irregular smoke colour. To prevent this, when the chamber is full, the products are showered for 1–2 min so that they all demonstrate the same level of surface moisture before smoking begins. Another way to wet the product is to start the smoking programme with a reddening step at around 50–55 ∞C and a high RH, around 90%. During this period, the high temperatures and high levels of moisture speed up the formation of curing colour by wetting the surface, while temperatures below 55 ∞C do not denature proteins. The length of the reddening cycle depends on the diameter of the sausage. Large-diameter casings such as beef runners, with a diameter of around 32–40 mm, are reddened for around 30 min, while sausages in sheep casings (diameter, 20–22 mm) are reddened for around 15–20 min.

Higher levels of moisture during smoking result in a darker

smoke colour. The length of the smoking cycle depends on the desired colour and the desired intensity of smoke flavour as well as the amount of smoke generated by the machine itself. Generally, sausages such as frankfurters in sheep casings are smoked for around 15–20 min, followed by a short drying stage once smoking is completed in order fix the colour on the product even more before moist thermal treatment starts. Occasionally, two shorter smoking cycles are carried out instead of one long smoking cycle, with a short drying stage of around 5 min between the two smoking cycles. The process of smoking therefore could consist of 10 min smoking, 5 min drying and another 10 min of smoking.

As a general rule, smoking begins after the curing colour is fully developed, because some of the substances present in smoke, such as phenols and other organic acids, have a negative effect on the development of curing colour.

If collagen or cellulose casings are used, the manufacturer will provide specific instructions regarding the reddening, drying and smoking times required. The process normally does not differ significantly from that for products in natural casings.

Smoking using liquid smoke takes place after conditioning and drying at 55–60 ∞C for 10–15 min, or as long as necessary to obtain a dry surface with an RH level of 20–40%. Liquid smoke is atomized for around 10–15 min under a low RH, with the chamber closed off and all dampers and valves closed. After around 5 min, there is a short drying stage of around 5–10 min at 65 ∞C, and the exhaust valves are opened again before drying. The cycle

of atomization, standing and drying is repeated, generally twice, before the final moist heat treatment takes place. When liquid or conventional smoke is applied on products such as skinless frankfurters which are filled into cellulose casings with the casing being removed afterwards, smoke should penetrate at least 1 mm into the product to form the hard surface ring. If the layer of smoke is very thin, the colour on the actual product fades in 1–2 days after the casing has been removed, because most of the smoke colour was present on the casing.

9- Slicing, packing and storage

After cooling, products in waterproof casings that are not going to be cut or sliced are stored between –1 and 4 ∞C. Although 4 ∞C is considered safe from a microbiological perspective, storage temperatures are most commonly below 2 ∞C because for every single degree below 4 ∞C the shelf life is extended greatly. Waterproof casings often act as the packaging as well and no secondary packaging is needed, which saves on packaging and labour costs.

Portioned cooked sausages are commonly vacuum packed, and a full vacuum, –0.98 bar or more, has to be applied before the bag is sealed. The sealing process must not cut the bag and care must be taken to ensure that none of the product is placed across the seal as this would allow air to penetrate into the bag. Vacuum packing eliminates the growth of aerobic spoilage bacteria such as Pseudomonas spp. and, in combination with low storage temperatures between –1 and 2 ∞C, improves the shelf life of the product. Vacuum-packed products are also frequently packed in vacuumshrink bags and then placed in hot water, at 90 ∞C, for 2–4 s, i.e. the PPP

process; even this short immersion in hot water improves shelf life by reducing the bacteria count on the surface of the product.

PPP also shrinks the bagtightly on to the product, which is more visually attractivePortioned products can also be packed in a modified atmosphere. The packaging generally contains 30–40% CO_2 and therefore 60–70% N_2. As N_2 is an inert gas, it replaces O_2 and the final level of O_2 in the packaging should be less than 0.6%. CO_2 forms carbonic acid on the surface of the packed product, which improves shelf life. In addition, CO_2 also interferes with the metabolic activity of countless pathogens thus increasing shelf life once more.

if the modified-atmosphere packing usesonly CO_2, the product will appear vacuum packed because the high solubilityof CO_2 causes 'shrinking' of the packaging material. Products such as frankfurters are generally packed on the same day as production, which shortens the time during which recontamination could take place and excess loss in weight is avoided as well. The formation of condensation must be avoided during packaging because any freelyavailable surface water on the product can be used by bacteria for growth, even if the product is vacuum packed. Condensation can result in a slimy purge and discolouration, mostly greening. Milkiness in purge tends to be the accumulation of Lactobacillus cells rather than a metabolic by-product of the bacteria.

Heterofermentative Lactobacillus spp. that survive the production and packing processes cause gassing, or the formation of CO_2, in packed products. Lactobacillus spp. are facultative anaerobes, which mean that they can live

with or without O2, and packages where Lactobacillus spp. are highly active blow up like balloons. Heating the product to 70 ∞C deactivates Lactobacillus spp. Greening inside a cooked sausage is frequently caused by Lactobacillus viridescens, which produces hydrogen peroxide (H2O2), a strong oxidizing agent. Microbiological greening is differentiated from chemical or metallic greening by the fact that it spreads across the product. Greening is occasionally seen in the outside layers of a cooked sausage and is most likely a combination of oxidation and elevated numbers of greening bacteria.

Sausages are a meat product usually made from ground meat, often pork, beef, or poultry, along with salt, spices and other flavourings. Other ingredients such as grains or breadcrumbs may be included as fillers or extenders. Some sausages include other ingredients for flavour.

Sausages may be preserved by curing, drying , smoking, or freezing. Some cured or smoked sausages can be stored without refrigeration. Most fresh sausages must be refrigerated or frozen until they are cooked.

Classifications

Cooked sausages

Cooked smoked sausages

Fresh sausages

Fresh smoked sausages

Dry sausages

Bulk sausage

Vegetarian sausage

Samples

Twenty samples of sausages of different origin were divided into four groups and used for comparison of selected textural parameters. Each sample consisted with 5 pieces of sausages. Description of tested groups: Group 1 (traditional sausages purchased directly from producer), Group 2 (traditional sausages purchased from butchery), Group 3 (non-traditional sausages purchased from supermarket) and Group 4 (non-traditional sausages purchased from hypermarket).

The ground propolis was initially weighed (6 g) and then transferred to the glass jars. Then 70% grain alcohol solvent (60 mL) (v/v) at a ratio of 1:10 (w/v) was added and submitted to the effect of microwaves for 20 minutes at 70 °C.

After the end of extraction, the extract was filtered on filter paper and centrifuged at 3000 rpm for 20 min. The supernatant was subsequently concentrated in a rotary evaporator (Fisatom 802), packed in amber bottles, and stored in a freezer (–18 °C) until analysis.

Formulation of Tuscan-style sausage.

Raw materials and ingredients	**Quantity (g/100g)**
Pork meat	85
Bacon	15
Water/ice	3
Salt	2.5
Seasoning for Tuscan-style sausage (BREMIL)	0.5*
White pepper powder	0.1
Flavor enhancer	0.05
Garlic	0.2

Raw materials and ingredients	Quantity (g/100g)
Seasoning (BREMIL)	0.25
Fixative (BREMIL)	0.25

3 Microbiological analyses

The analyses were performed regarding counts for psychotrophic and mesophilic microorganisms ,positive and negative-coagulase *Staphylococcus*; coliforms at 35 °C and 45 °C; sulfite-reducing *Clostridium* and *Salmonella*spp .The analyses were performed on days 0, 7, 14, 21, 28, 35, 42, 49 and 56 of storage at 4 °C.

2.4 Statistical analysis

The data were evaluated by analysis of variance (ANOVA). The means were compared by Tukey's test, with a significance level of 95% ($p < 0.05$) using SPSS 17.0 statistical software.

Results and discussion

Counts of mesophilic aerobic microorganisms are commonly used to indicate the sanitary quality of food and to detect the number of aerobic or facultative mesophilic bacteria, which are present both in vegetative form and also as spores in food.

Microbiological analysis of Tuscan-style sausages during storage at 4 °C.

Mesophilic aerobic bacteria ($Log_{10}CFU.g^{-1}$)	**0% PE***	**0.5% PE**	**1% PE**	**2% PE**
Day 0	4.72 ± 0.083^{a}	4.78 ± 0.144^{a}	4.79 ± 0.081^{a}	4.73 ± 0.015^{a}
Day 7	4.57 ± 0.063^{a}	4.51 ± 0.133^{a}	4.60 ± 0.048^{a}	4.56 ± 0.058^{a}
Day 14	4.45 ± 0.079^{b}	4.44 ± 0.093^{b}	4.60 ± 0.078^{a}	4.37 ± 0.054^{b}

Mesophilic aerobic bacteria ($Log_{10}CFU.g^{-1}$)	**0% PE***	**0.5% PE**	**1% PE**	**2% PE**
Day 21	3.97 ± 0.043^{a}	3.98 ± 0.021^{a}	3.97 ± 0.022^{a}	3.85 ± 0.036^{b}
Day 28	3.94 ± 0.038^{a}	3.87 ± 0.048^{ab}	3.84 ± 0.010^{b}	3.59 ± 0.079^{c}
Day 35	3.82 ± 0.042^{b}	3.87 ± 0.035^{b}	3.99 ± 0.020^{a}	3.64 ± 0.082^{c}
Day 42	4.64 ± 0.048^{b}	4.83 ± 0.064^{a}	4.53 ± 0.048^{c}	3.70 ± 0038^{d}
Day 49	5.97 ± 0.022^{a}	5.41 ± 0.091^{b}	3.84 ± 0.130^{c}	3.73 ± 0.043^{c}
Day 56	6.44 ± 0.034^{a}	5.98 ± 0.021^{c}	6.11 ± 0.047^{b}	4.85 ± 0.045^{d}
Psychotrophic bacteria ($Log_{10}CFU.g^{-1}$)	C	T1	T2	T3
Day 0	4.26 ± 0.057^{b}	4.49 ± 0.117^{a}	4.06 ± 0.035^{c}	3.94 ± 0.061^{c}
Day 7	4.55 ± 0.050^{a}	4.58 ± 0.068^{a}	4.54 ± 0.061^{a}	4.45 ± 0.104^{a}
Day 14	4.53 ± 0.052^{a}	4.68 ± 0.076^{a}	4.56 ± 0.103^{a}	4.62 ± 0.053^{a}
Day 21	4.32 ± 0.055^{a}	4.34 ± 0.037^{a}	4.13 ± 0.095^{b}	4.14 ± 0.056^{b}
Day 28	4.47 ± 0.048^{a}	4.28 ± 0.075^{b}	4.20 ± 0.142^{bc}	4.04 ± 0.051^{c}

Mesophilic aerobic bacteria ($Log_{10}CFU.g^{-1}$)	**0% PE***	**0.5% PE**	**1% PE**	**2% PE**
Day 35	4.23 ± 0.263^{a}	4.26 ± 0.041^{a}	4.03 ± 0.038^{a}	3.39 ± 0.030^{b}
Day 42	4.74 ± 0.050^{a}	4.75 ± 0.053^{a}	4.89 ± 0.092^{a}	3.97 ± 0.260^{b}
Day 49	6.00 ± 0.029^{a}	5.88 ± 0.048^{a}	5.28 ± 0.122^{b}	4.75 ± 0.128^{c}
Day 56	6.73 ± 0.044^{b}	6.68 ± 0.119^{b}	6.96 ± 0.036^{a}	5.39 ± 0.067^{c}
Coagulase-negative *Staphylococcus* ($Log_{10}CFU.g$)				
Day 0	3.56 ± 0.078^{a}	3.50 ± 0.031^{a}	3.34 ± 0.070^{b}	3.26 ± 0.024^{b}
Day 7	3.56 ± 0.046^{a}	3.33 ± 0.053^{bc}	3.41 ± 0.037^{b}	3.30 ± 0.037^{c}
Day 14	3.79 ± 0.111^{a}	3.71 ± 0.036^{a}	3.59 ± 0.026^{b}	3.43 ± 0.040^{c}
Day 21	3.32 ± 0.145^{ab}	3.41 ± 0.096^{a}	3.47 ± 0.047^{a}	3.21 ± 0.090^{b}
Day 28	3.43 ± 0.133^{a}	3.38 ± 0.059^{ab}	3.26 ± 0.099^{ab}	3.21 ± 0.088^{c}
Day 35	3.29 ± 0.059^{a}	3.27 ± 0.094^{a}	3.48 ± 0.114^{a}	3.11 ± 0.068^{c}
Day 42	3.33 ± 0.085^{a}	3.19 ± 0.073^{bc}	3.31 ± 0.026^{ab}	3.15 ± 0.079^{c}

Mesophilic aerobic bacteria ($Log_{10}CFU.g^{-1}$)	**0% PE***	**0.5% PE**	**1% PE**	**2% PE**
Day 49	3.57 ± 0.073[a]	3.22 ± 0.102[b]	3.06 ± 0.064[c]	2.81 ± 0.087[d]
Day 56	3.73 ± 0.029[a]	3.41 ± 0.087[b]	3.29 ± 0.070[bc]	3.14 ± 0.118[c]
Coagulase-positive *Staphylococcus* (Log_{10} CFU.g^{-1})				
Day 0	< 1.00	< 1.00	< 1.00	< 1.00
Day 7	< 1.00	< 1.00	< 1.00	< 1.00
Day 14	< 1.00	< 1.00	< 1.00	< 1.00
Day 21	< 1.00	< 1.00	< 1.00	< 1.00
Day 28	< 1.00	< 1.00	< 1.00	< 1.00
Day 35	< 1.00	< 1.00	< 1.00	< 1.00
Day 42	< 1.00	< 1.00	< 1.00	< 1.00
Day 49	< 1.00	< 1.00	< 1.00	< 1.00
Day 56	< 1.00	< 1.00	< 1.00	< 1.00
Total coliforms at 35 °C ($Log_{10}CFU.g^{-1}$)				
Day 0	3.28 ± 0.149[b]	3.50 ± 0.037[a]	3.16 ± 0.128[b]	3.21 ± 0.111[b]
Day 7	3.18 ± 0.107[a]	3.44 ± 0.452[a]	3.16 ± 0.054[a]	2.98 ± 0.059[a]
Day 14	3.04 ±	2.95 ±	3.16 ±	2.87 ±

Mesophilic aerobic bacteria ($Log_{10}CFU.g^{-1}$)	**0% PE***	**0.5% PE**	**1% PE**	**2% PE**
	0.033^{b}	0.026^{b}	0.039^{a}	0.043^{c}
Day 21	3.92 ± 0.040^{a}	3.21 ± 0.123^{b}	3.25 ± 0.046^{b}	3.04 ± 0.033^{c}
Day 28	3.63 ± 0.145^{a}	2.87 ± 0.066^{b}	2.85 ± 0.101^{b}	2.83 ± 0.047^{b}
Day 35	2.80 ± 0.059^{ab}	2.91 ± 0.030^{a}	2.68 ± 0.070^{b}	2.53 ± 0.116^{c}
Day 42	2.81 ± 0.039^{a}	2.79 ± 0.071^{a}	2.90 ± 0.013^{a}	2.55 ± 0.071^{b}
Day 49	3.71 ± 0.100^{a}	2.66 ± 0.065^{b}	2.50 ± 0.059^{c}	2.33 ± 0.064^{d}
Day 56	2.61 ± 0.040^{b}	2.82 ± 0.022^{a}	2.67 ± 0.063^{b}	2.28 ± 0.078^{c}
Coliforms at 45 °C ($Log_{10}CFU.g^{-1}$)				
Day 0	< 1.00	< 1.00	< 1.00	< 1.00
Day 7	< 1.00	< 1.00	< 1.00	< 1.00
Day 14	< 1.00	< 1.00	< 1.00	< 1.00
Day 21	< 1.00	< 1.00	< 1.00	< 1.00
Day 28	< 1.00	< 1.00	< 1.00	< 1.00
Day 35	< 1.00	< 1.00	< 1.00	< 1.00
Day 42	< 1.00	< 1.00	< 1.00	< 1.00

Mesophilic aerobic bacteria ($Log_{10}CFU.g^{-1}$)	**0% PE***	**0.5% PE**	**1% PE**	**2% PE**
Day 49	< 1.00	< 1.00	< 1.00	< 1.00
Day 56	< 1.00	< 1.00	< 1.00	< 1.00
***Salmonella* spp./25g of sample**				
Day 0	absent	absent	absent	absent
Sulfite-reducing *Clostridium* 46 °C/ 25g of sample				
Day 0	< 1.00	< 1.00	< 1.00	< 1.00

Texture

by breaking the sausage against its curvature were found (P = 0.112). However, crispness and juiciness were particularly high for 20%S, as opposed to WBS and 10%S. The sausages without added bran (WFS, 10%S, and 20%S) were correlated with low chewing time before swallowing and a low degree of grainy texture in contrast to WBS and RBS, which had relatively high ratings in these parameters.

Odor

WBS differed significantly from all the other sausages by having the highest score in cereal odor.

Appearance

Color parameters were determined in triplicate with a Chroma Meter by measuring lightness (L^*), redness (a^*), and yellowness intensities (b^*).

WFS, 20%S, and 10%S were similar in appearance

low intensity of brown color of both the interior and exterior

exterior surface and the intensity of pricked appearance and structure. The two sausages with added bran, RBS, and WBS, were similar in appearance and

received high ratings for pricked exterior surface and inner structure as well as the intensity of the brown color, although WBS received the highest intensity rating for the exterior brown color. Furthermore, WBS had the most uneven exterior surface, whereas RBS was similar to WFS, 20%S, and 10%S in this attribute.

Flavor and taste

Similar to the results for sausage odor, sausage flavor was highest for WFS, 20%S, and 10%S, while RBS and WBS received lower ratings for this attribute. Furthermore, cereal flavor was highest for WBS, followed by RBS and finally WFS, 20%S, and 10%S, which received scores close to zero. Salt taste did not differ significantly in any of the sausages ($P = 0.166$), and bitter taste was highest for WBS, although this could not be distinguished from the bitter taste of RBS, 20%S, or 10%S. Furthermore, WBS differed from the rest of the sausages with respect to smoky flavor, which was low in intensity for WBS but high in intensity for RBS, WFS, 20%S, and 10%S. Finally, 10%S differed from all the other sausages by having the most intense spicy flavor (the sensation in the mouth when eating chili or peppercorns), followed by RBS, WFS, and 20%S, and finally WBS.

Summary of sensory attributes

Of the two sausages with added bran, RBS was the one most similar to the high fat sausage, 20%S, and there was no significant difference between these two sausages with regard to the following attributes such as smoky odor and taste, spicy odor and taste, uneven exterior surface, bitter taste, crispness, and crumbliness. It appeared that the taste and odor of sausage were negatively correlated with cereal taste and odor. The same applied to crispness, which was negatively correlated with firm and grainy. In many cases, the differences between WBS and the sausages without added bran were explained by these attributes, thus representing two contrasting groups.

Firmness and chewing time

As seen from our results, the fiber source could be an important determinant for firmness, with wheat bran increasing firmness as opposed to rye bran, compared with a sausage with no bran but the same fat content. Since no other studies have made a direct comparison between wheat and rye bran as sources of dietary

fiber, discussion of the fiber source is limited to the results from the present study.

Juiciness

Many factors could have an impact on the juiciness of the sausages. The contents of fat and soluble dietary fiber from the bran are important factors for consistency.Dietary fibers are only capable of compensating for the reduction in fat content to a certain degree

Odor and flavor

The fiber contents of RBS and WBS varied to a certain degree, possibly due to cereal variation, differences in sausage drying loss, or analytical error. Nevertheless, the differences in sensory results between RBS and WBS are believed to be due to the different proportions of soluble and nonsoluble dietary fiber in rye and wheat bran.

Instruments

Determination of the selected textural parameters was performed with the TA XT2 plus texturometer using the Heavy duty platform / Warner Blatzer set.

Determination of water activity aw was performed with FA-st lab.

Determination of protein content was performed with 8200. Kjeldahl method

Determination of fat content was performed with Soxhlet Selecta DET-GRAS N.

Determination of Cu, P, Mg, Fe, K, Na, Cu and Zn was performed with AES-ICP.

Measurement

Analysis of samples was performed: each sausage was sliced into 1 cm wide rings (6 rings per one piece of sausage, total number of pieces per sample was 30), which were placed into the water activity meter and water activity was measured.

Consequently, rings of sample were placed into the central position of texturometer base table. Each sample was measured and the mean value was calculated for each selected textural parameters:

firmness (maximum peak force in kg) and toughness (peak area - work of shear in kg.s-1).

Statistical analysis

Statistical differences between two groups of sausages (traditional and non-traditional) and two groups of sausages (fresh and stored) in relation to firmness and toughness was evaluated with one-way MANOVA. Differences between samples were considered as statistically significant at $p < 0.05$. Subsequently, the Principal Components Analysis (PCA) was performed to reducing the original data and show position of products according to the textural parameters firmness and toughness. Also, the Principal Components Analysis (PCA) was performed with the Hierarchical Clustering Procedure (HAC) to show differences between the results of paired samples of fresh and stored sausages in relation to firmness and toughness. Evaluation of the organoleptic characteristics of sausage samples was performed using the Kramer and Friedman test.

First decision to make during the microbiological testing of foods is:

a. A surface sample.
b. A homogenized sample of the food.

Sausage Analysis

The following statistical values were obtained: R (correlation coefficient) = 0.997 and SEC (standard error of calibration) = 0.002 for water activity, R = 0.966 and SEC = 0.023 for pH, R = 0.995 and SEC = 0.970 for dry matter content, R = 0.995 and SEC = 0.045 for salt content, R = 0.965 and SEC = 0.652 for non collagen muscle protein, R = 0.996 and SEC = 0.559 for fat content. The results of the study showed that FT-NIR is a suitable method for rapid analysis of physical and chemical properties of sausages

NIR spectroscopy is an accurate and validated method for measuring fat, protein, moisture in many food products including sausages.

Another study measured different parameters such as water activity, pH, dry matter, salt, and NCMP.

Fat	$R^2 = 0.99$
Protein	$R^2 = 0.98$
Moisture	$R^2 = 0.97$
Water Activity	R2 = 0.997
pH	R2 = 0.966
Dry Matter (%)	R2 = 0.995
Salt (%)	R2 = 0.995
NCMP (%)	R2 = 0.965

A. SURFACE SAMPLING

1. <u>Swabbing</u>

2. **Contact plates**
3. **Excision method**

B. HOMOGENIZATION METHODS

1. **Blender**
2. **Colwell stomacher**

C. METHODS TO DETERMINE TOTAL MICROBIAL NUMBERS

1. **Standard Plate Count (SPC)**
2. **Spiral Plate Counter**
3. **Dry Petrifilms**
4. **Most Probable Numbers**
5. **Membrane filters**
6. **Dye Reduction**
7. **Impedance**

D. Molecular Methods to Detect Bacteria or Metabolites:

1. **Oligonucleotide DNA Probes**
2. **Polymerase Chain Reaction (PCR-DNA Amplification**
3. **Enzyme-Linked Immunosorbant Assay (ELISA).**
4. **Immunoprecipitation**