SESSION 7. FERMENTED MEAT PRODUCTS

REVIEW: PERSPECTIVES OF FERMENTED MEATS

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SUMMARY

Fermented meat products are known for centuries, and are increasingly liked today, since they are 'naturally' preserved. All meats for wich microorganisms (bacteria, yeasts or moulds) could be beneficial for their preservation, flavor or appearance should be thoroughly studied, with the intention to optimize their 'bio-preservation', if possible by decreasing other additives. In using better control-devices for the extrinsic factors (temperature, relative humidity, air velocity, etc.) and intrinsic factors (a_w, pH, pO_2, etc.) of fermentation, an optimization and the automation of processes becomes feasible. Little is known about the topography of the fermentation processes, and this should emerge as a promising research area. Fermentation should be controlled by starter cultures, the hitherto available strains could be improved by better selection, as well as mutation and genetic engineering.

FERMENTED MEATS

Fermented sausages are raw meat products stabilized by a reduced a_w and/or pH. In Europe raw sausages are fermented with microorganisms, mainly lactic acid bacteria, and this process is known since about 250 years and probably has originated in Italy (Leistner, 1986 b). The Chinese raw sausage (Lup Cheong) is known since more than 1000 years, and this product is stabilized by a_w only, because a low pH caused by fermentation would be undesirable (Leistner, 1986 d). Raw hams which are known in Europe and China since at least 2500 years (Leistner, 1986 c) are stable due to a reduced a_w and generally are not fermented, since the bacterial count in the interior of high quality raw hams is low and bacteria contribute little to the flavor and stability of such products. However, if raw hams are cured without refrigeration, and this is true e.g. for Turkish Pastirma (dried beef), then lactic acid bacteria may contribute to the stability of the meat (El-Khateib et al., 1987). It also has been suggested to stabilize raw hams made from DFD-meat by the injection of lactobacilli which grow at 8°C (Hammes and Arnold, 1986). Some fermented sausages (e.g. Italian or Hungarian salami) and raw hams (e.g. Bündnerfleisch of Switzerland and Südtiroler Bauernspeck of Italy) are mould-fermented, and the desirable mould growth on the surface of such meats improves the appearance, flavor and preservation of these products (Leistner, 1986 a).

The flavor of raw and cooked hams might be influenced by bacteria present in the cover brine (Leistner, 1958; Petäjä et al., 1973) or by bacteria injected into the hams. Also for Bologna-type sausage (Brühwurst) the use of bacteria as starter cultures has been suggested (Petäjä, 1977; Schiefer and Schöne, 1980) with the intention to improve the flavor and the color of the products. For Gelderse Rookworst (Brühwurst), a product of the Netherlands which formerly was stabilized by lactic acid bacteria, now the addition of GdL is preferred (Leistner, 1985 a). It was also considered that the addition of selected 'protective' cultures to fresh meat to be vacuum-packaged (Hanna et al., 1980; Schillinger and Lücke, 1986; Renerre and Montel, 1986) and to minced meat (Reddy et al., 1970; Fetlinski et al., 1979) may contribute to the control of undesirable bacteria.

In general, all processes for the preservation of meat in which desirable microorganisms occur should be thoroughly investigated, with the intention to optimize the appearance, flavor and shelflife of the products by using suitable starter or protective cultures and at the same time reduce the addition of substances, such as nitrate/nitrite or sodium chloride, which are less desirable from the toxicological or nutritional point of view. Such a 'bio-preservation' of meats would find approval, especially of the younger generation of consumers.

TECHNOLOGY OF FERMENTATION

The traditional fermentation processes for meats have been developed over centuries by trial and error. Their intention is to give desirable microorganisms an advantage, and this in turn will suppress undesirable microorganisms which could cause spoilage or food-poisoning.

The extrinsic factors most important for a proper fermentation process are the temperature, relative humidity and air velocity as well as the time these parameters are applied to the product. Of the intrinsic factors the a_w, pH and pO_2 (partial pressure of oxygen) are of paramount importance; much is known about the a_w and pH of fermented sausages and raw hams, however, the measurement of the pO_2 needs improvement. The extrinsic and intrinsic factors important for the fermentation of raw sausages have been recently reviewed by Rödel (1985). As Leistner (1986 b,c) has pointed out, the stability of raw sausages and hams is due to a sequence of hurdles active in the products, i.e. in fermented sausages the hurdles are nitrite curing salt, followed by pO_2, competitive organisms, pH and a_w, whereas in raw hams the hurdles pH, temperature and a_w secure stability. Furthermore, in accordance with the HACCP-concept, for the production of fermented sausages and raw hams guidelines have been suggested, i.e. 19 critical control points for fermented sausages and 15 for raw hams (Leistner, 1985 b).

In recent years the construction and control of the ripening rooms for fermented sausages have become more sophisticated, but at the same time also much more energy consuming. Stiebing et al. (1982) suggested a simplification in the essential control of the relative humidity (RH) during the ripening of fermented sausages by using fresh air for RH control, and were able to save in this manner as much as 70 % of the energy required for the production of fermented sausages. However, even further improvements are feasible. For instance, by the continuous measurement of the pH and a_w inside of the product, i.e. in one representative sausage, and by using these data to control the extrinsic factors of the ripening room, the production of fermented sausages could be optimized and even automated.

TOPOGRAPHIE OF FERMENTATION

Whereas many results are already available on the technology and microbiology of the ripening of fermented sausages little is known about the topography of this process. So far the extrinsic and intrinsic factors of the ripening process as well as the counts and types of microorganisms important for fermented sausages were intensively studied, however, hardly any attention was given to the fact that the natural flora as well as the added starter cultures are not evenly distributed in a fermented sausage, but are arrested in little cavities of the sausage mix, i.e. the ripening flora can only grow in nests. The distance between these cavities or nests varies between 100 and 1500 µ (Katsaras and Leistner, 1987).

If the properties of a sausage are changing during the ripening process in the desired direction (nitrate reduction, lactic acid production, catalase activity, etc.), then 'large areas' of the sausage which are located between these cavities must be influenced by the bacteria growing in the nests. Since the microorganisms are trapped and cannot be released from these nests, the ripening of sausages can be regarded as a solid-state-fermentation.

It must be assumed that the microorganisms which grow in such nests are in keen competition. If such a nest is made up by chance of a pure culture, e.g. of lactobacilli, then the individual bacteria will compete for the nutrients and impair each other with their metabolic products, e.g. lactic acid. Therefore, after some time the growth ceases, because the cell division will be delayed, and this we observed in nests of lactobacilli as well as of apathogenic staphylococci (Katsaras and Leistner, 1987). Furthermore, inhibitory substances such as lactic acid which are produced in 'lactobacilli nests' will diffuse and thus inactivate microorganisms, e.g.

salmonellae or pathogenic staphylococci, present in other nests. Frequently different types of bacteria are trapped in one cavity and then the competition will be fierce, but lactic acid bacteria will have an advantage due to their tolerance of low pO_2, low pH and low a_w.

An investigation of the topography of the fermentation of meats, using scanning electron microscopy, should lead not only to a better understanding of the processes, but probably also to their improvement. For instance, a more even inoculation of the sausage mix with starter cultures might prove more important than previonsly assumed, and could be achieved by using liquid cultures. Therefore, studies on the topography of the fermentation processes for meats should be expanded, and may become a promising research area.

MICROBIOLOGY OF FERMENTATION

The microbiology of fermented sausages has recently been reviewed by Lücke (1985 a). Furthermore, Lücke (1985 b) has described the microbiological events occurring during the ripening of raw sausages and hams, and Hechelmann (1985) reported on spoilage problems of these products. The significance of food-poisoning organisms for raw sausages and hams was discussed for salmonellae (Schmidt, 1985), Staphylococcus aureus and Clostridium botulinum (Katsaras et al., 1985) as well as for toxigenic moulds (Hofmann, 1985) recently too. Moreover, Lücke and Hechelmann (1985 c) described the composition and effects of starter cultures recommended for raw sausages and hams.

Excellent fermented sausages can be manufactured without addition of starter cultures, because if suitable ripening conditions are maintained then the desired ripening flora will prevail, even if only few lactobacilli and micrococci are present in the raw material. Nevertheless, the use of selected starters, added as pure or in controlled mixed cultures, generally is beneficial for the quality of fermented sausages with respect to the standardization and stability of the products.

In the United States, the importance of lactobacilli for the fermentation of raw sausage was recognized early (Jensen and Paddock, 1940). However, since lactobacilli proved initially difficult to lyophilize, Pediococcus cerevisiae was introduced as starter culture (Deibel et al., 1961 a,b). Still today many starter cultures for fermented sausage contain pediococci (P. pentosaceus, P. acidi lactici), but more frequently lactobacilli, especially Lactobacillus plantarum, even L. sake and L. curvatus prevail in fermented sausages. Of course, the main function of lactic acid bacteria in the fermentation of meat is the production of lactic acid, which lowers the pH and stabilizes the food. However, many strains of lactic acid bacteria may form other bacteriostatic compounds, too. These include peroxides (in the presence of oxygen), acetic acid (from gluconate, pentoses or in the presence of oxygen), and possibly bacteriocin-like compounds.

In Europe, a suitable starter culture for meat products was first introduced by Niinivaara (1955). His Micrococcus strain (M 53) proved beneficial, because it rapidly reduced nitrate, improved color and flavor and inhibited undesirable bacteria (Pohja and Niinivaara, 1957). This strain was later replaced by a 'fermentative Micrococcus' isolated by Pohja (Licentiate Thesis, Helsinki, 1960) and other Micrococcaceae including Staphylococcus carnosus (renamed by Schleifer and Fischer, 1982). Micrococcaceae are beneficial due to the production of nitrate reductase and even more for their catalase formation which destroys peroxides and thus prevents color and flavor defects of fermented meats. Nurmi (1966) recommended a combination of L. plantarum and Pohja's 'fermentative Micrococcus', because this controlled mixed culture caused a rapid reduction in pH without inhibiting color and flavor development. Combinations of lactic acid bacteria and Micrococcaceae are now widely used as starters for fermented sausages.

Yeasts occur frequently in fermented sausages, especially on the surface of unsmoked products. Debaryomyces are predominantly found (Leistner and Bem, 1970; Comi and Cantoni, 1980) and often also Candida; but several species of the latter genus are pathogenic. Yeasts accelerate the color formation in sausages and might improve their flavor (Miteva et al., 1986) and appearance. Especially in France some yeast growth ('fleur de saucisson') is regarded as desirable, and therefore yeast starter cultures for surface inoculation are available. Rossmanith et al. (1972) observed that the color and flavor formation in fermented sausages could be improved by addition of selected Debaryomyces strains to the sausage mix. Coretti (1977) recommended for this purpose a combination of D. hansenii, lactobacilli and micrococci as starter cultures.

Moulds contribute to the characteristic aroma, flavor and appearance of mould-ripened sausages and hams. The mould growth on the surface might also delay the rancidity of the products. Traditionally the mould colonisation of the mould-fermented meats was achieved by the 'house-flora' of the ripening rooms, and moulds found on such products are predominantly Penicillia (Leistner, 1986a). However, since most Penicillia are toxigenic, starter cultures were introduces which produce none of the known mycotoxins. The first starter culture for mould-fermented meats was developed by Mintzlaff and Leistner (1972); and today six such starter cultures are on the market, which represent three biotypes of Penicillium nalgiovense. These starter cultures should not only prevent mycotoxin formation in meat products, but also suppress undesirable moulds which could cause color and flavor defects in mould-fermented meats.

Generally, a distinction should be made between 'starter cultures', which improve the sensory properties of a food, and 'protective cultures', which suppress undesirable microorganisms such as salmonellae, pathogenic staphylococci, Clostridium botulinum, and toxigenic moulds. However, it would be ideal if both purposes are fulfilled by one culture.

Undoubtedly, for the suppression of salmonellae in fermented sausages, expecially in quick ripened products, starter cultures containing lactobacilli are very useful. Schmidt (1987) achieved the best control of salmonellae, if lactobacilli and GdL were added simultaneously, since probably lactobacilli form acetic acid from gluconate. Whether bacteriocin-like substances produced by lactobacilli could contribute to an inhibition of salmonellae and other food-poisoning bacteria needs further investigation.

If fermented sausages are ripened at temperatures above 25°C, then also Staphylococcus aureus and his enterotoxin formation are risky for the consumer. S. aureus grows much better in the surface layer then in the core of fermented sausages (Barber and Deibel, 1972), since this organism tolerates the inhibitory factors (pH, a_w, nitrite, etc.) of sausages better at a higher partial pressure of oxygen. The growth of S. aureus in fermented sausages is inhibited by chemical acidulation (addition of GdL) and/or by microbial acid formation (addition of lactic acid bacteria), as reported by Daly et al. (1973).

Clostridium botulinum (types A, B and E) is not a risk in fermented sausages common in Germany. This demonstrated a thorough investigation conducted by Hechelmann et al. (1980), because the multiplication and toxin formation of C. botulinum is inhibited by the pH, a_w and the antagonistic effects of the usual ripening bacteria, whereas nitrite is not even necessary for this inhibition. The formation of botulinum toxin was reported by Christiansen et al. (1975) in 'summer sausage' of the US, if ripening temperatures above 30°C were employed and no sugar was added, i.e. the pH remained high. Also Incze and Delényi (1979) observed botulinum toxin formation in Hungarian salami, however, also under extreme conditions. Whether the fashionable reduction of sodium chloride addition to fermented sausage might increase the botulinum risk, and whether this risk would be overcome by the addition of other a_w-reducing substances (such as freeze-dryed meat) deserves further investigation.

In the case of mould-fermented meats, the possible mycotoxin formation by mould starter cultures hitherto regarded as safe, is an important field of study. After a protocol for a reliable toxicological evaluation of mould starter cultures has been established (Fink-Gremmels et al., 1987),

the commercially available mould starter cultures are now under investigation for mycotoxin formation, including those mycotoxins for which analytical standards are not available. A result of this study could be the introduction of new starter cultures for mould-fermented meat products.

New starter cultures of bacteria and yeasts are also in the store for the refinement of fermented meats, and this applies to an improvement of the sensory quality of the products as well as to their safety, i.e. the protection against undesirable organisms. For instance, by using selected starter cultures it may become feasible to produce low-acid, low-salt fermented meats without microbial hazards (F.-K. Lücke, personal communication).

The first step in the development of better starter cultures of bacteria, yeasts or moulds is the precise description of the properties a particular starter should have and not have. Then a large pool of organisms should be screened for these properties, because the selection of desirable strains occuring in nature is not only simpler than the manipulation of microorganisms, but also avoids the various problems associated with an intentional release of genetically engineered cultures. However, if the desired features are not found in the pool of organisms screened, then strain improvement by genetical methods could prove necessary. In this respect, transfer of DNA between strains which exchange genes by 'natural' means anyway should be tried first (conjugation and para-sexual recombination), but in vitro-recombination of nucleic acid from various food-grade microorganisms is also an option.

The result of the latter could be a new generation of starter cultures with novel characteristics, which would lead to a new generation of fermented meats. However, too much emphasis on the role of 'gene manipulation' could have a negative effect on the acceptance of 'bio-preserved' meat products, and therefore the selection of improved starter cultures from nature should have priority.

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