Raw Fermented and Dried Meat Products

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Summary

The paper gives a review of these very special products which can be divided on the basis of acidity (low and high pH products), size of processed ingredients (chopped or intact muscle), type of fermentation (with or without carbo-hydrate; with or without microbial inoculation) etc. These differences in technology do contribute to definite differences in general characteristics of the products e.g. sensory properties, water activity values, but also critical control points may change. Although application of microbial cultures offer several advantages, like fast drying, microbial safety, good sliceability, economic production etc. products of traditional technologies are still in favour among many consumers. Since microbial changes in these traditional products can be influenced mainly indirectly, a vast majority of research work and publications are rather devoted to starter culture fermentations. Although half a century served for investigations in this field, an endeavour to ever improve technics and strains by screening, selection, genetic methods can still be observed. Aims of these investigations are: to get meat products of better sensory quality, of more safety, and to ensure faster production with high reproducibility of uniform quality.

Lactic acid bacteria, major component of starter cultures used in fermentation of meat products, have been thoroughly investigated in terms of their physiological needs (temperature range, pH- range, a_w-range and optimum values for growth, manganese requirement etc.), their inhibitory effect (acid and antibiotic production), yet nutritional and healthful aspects of lactic acid bacteria, a well-known feature of those in case of dairy products, is not a frequent research topic with fermented meat products thus dietary effect might perhaps be a field to be investigated in the future.

Introduction

Drying and fermentation of meat and meat products may be considered as the most ancient way of preservation at least in those parts of the world where, for climatic reasons, no other means could earlier be applied. Fermentation and drying goes "hand-in-hand" in most cases, nevertheless there are processes where high saline concentration and/or fast drying exclude the possibility of fermentation, *sensu strictu*, and there are methods on the other hand where only fermentation and acidification takes place with practically no water-loss, and low pH alone accounts for stability at ambient temperature. (PHITHAKPOL, 1988).

Although the aim with drying and fermentation was originally to supply mankind with food of animal origin all year round irrespective the frequency of hunting and slaughtering, fermentation and drying of meat products have become an "art" with long traditions in the last centuries manufacturing high quality, delicatessen food items.

These products can be classified on the basis of acidity (low and high pH products), size of ingredients (chopped or intact muscle), type of fermentation (with or without added carbo- hydrate; with or without microbial inoculation), presence or absence of mold growth on the surface, etc. These distinctions may look arbitrary, however they involve various technologies, that definitely contribute to basic differences in general characteristics of the products, like sensory properties, water activity values, microflora composition, production economy and safety, just to mention the more important ones. Since these changes in extrinsic and intrinsic factors have an influence on microbial growth, alterations in critical control points and parameter requirements have to be relied on. In this paper main characteristics of low and high acid products will be discussed.

6

LOW ACID FERMENTED MEAT PRODUCTS

Low acid fermented-dried meat products have, most likely, longer history not only in Europe but also in other continents. ERICHSEN (1983) suggests that since more than 3000 years people has been aware of the advantages of sausage making and drying for keeping meat longer time. She also presumes that salami is named after the city of Salamis in Cyprus, which was destroyed more than 2000 years ago. HO and KOH (1984) mention that Chinese pork sausage was known already about 500 years B.C. According to WHITAKER (1978) fermentation of soy sauce is known since 3000 years. LEISTNER (1985) on the other hand considers the known history of dry sausage in Europe only 250 years old.

European "old world style" sausage is in general fermented, dried at low temperature (INCZE, 1987), but interestingly Chinese dry sausage is dried at elevated temperature (LEISTNER, 1985; SAVIC et al., 1988).

The scientific reason for low temperature is evident today but this evidence had a sound basis of experience earlier, too. (The high temperature drying causes microbial inactivation, but the product is entirely different organoleptically from low temperature fermented sausages.) It is generally accepted that in case of traditional, low acid (pH 5,5 and above) meat products low temperature fermentation and drying is of crucial importance. Low temperature is namely the main and sometimes only means of inhibition against undesired microbial growth until salt concentration reaches a certain level (a_w-value drops below 0,96). A great number of traditional, famous low acid fermented-dried meat products are known, e.g. Parma ham, Spanish ham, Ardennes ham, Bündner Fleisch, Südtiroler Bauernspeck, French, Hungarian, Italian, Yugoslavian salami etc. (LEISTNER, 1990). Although they differ from one another in smoking (only some of them are smoked) in mold growth (only a few of them have mold growth on the surface) and in several other features yet, they have two things in common:

a/ all these products are fermented-dried for <u>long time</u>. Being namely high pH products, only slow rate water removal gives a high quality product without drying failures (deformation, case hardening, stop of water migration, spoilage etc.) and this water removing process has to last long in order to get sufficiently low a_w-value: the sole factor for stability at room temperature.

b/either no carbo-hydrate is added, or because of the low temperature no substantial break-down and acid production takes place, consequently <u>pH value</u> of the products is above 5,5 and <u>usually</u> about <u>5.8-6.2</u>. (RADOVANOVIC et al., 1990; LOPEZ-BOTE et al., 1990.)

A clear distinction has to be made between products of intact muscle and that of chopped (ground, bowl-chopped) ingredients for several reasons:

- with intact muscle diffusion time of curing additives may take several weeks depending on shape and size of piece
- in intact muscle, even if marbled, initial moisture, consequently initial a_w-value is remarkably higher than in case of sausages (provided that added amount of salt is the same).
- if meat and fat is chopped and mixed, diffusion time of salt is negligible compared to the time needed for bacterial growth and spoilage.

Bacterial growth is somewhat inhibited by salt already at the beginning of fermentation of sausages. This inhibition is even more pronounced because of lower initial moisture (effect of fat) i.e. lower a_w. Expressed in figures, initial a_w of intact muscles to be fermented is as high as that of fresh meat (0,99) and initial a_w of sausages to be fermented is generally below 0,97, but can be as low as 0,95. Bearing all this in mind it is easy to understand why raw ham curing needs a temperature below 5°C until salt migrates to inner parts (HECHELMANN and KASPROWIAK, 1990) while on the other hand, 10°C may be considered a safe initial temperature for traditional sausages (INCZE, 1987); as a matter of fact this temperature is in several countries often higher.

Changes during ripening

During fermentation and drying physical, microbiological and biochemical changes take place these latter ones induced partly by tissue and partly by microbial enzymes. The main changes can be summarized briefly as follows:

- as a result of drying meat product loses weight. This weight loss may be as high as 40-50 % by the end of the ripening period and the moisture can be as low as 18-22 %.
- as a result of drying a_w-value decreases that causes a selection in the initial microflora. Less salt tolerant microbes are reduced in number and disappear later. Most pathogenic micro-organisms are inhibited, practically only Listeria and Staphylococcus have a chance to grow. E. coli and Salmonella is retarded in growth by lower temperature (<10°C) and by decreasing a_w. In later phase of drying they disappear from the sausages. Aerobic and anaerobic sporeformes have also poor chances to grow because of the inhibitory factors mentioned above. Absence of oxygen (larger diameter) and decreasing a_w inhibit growth of pseudomonads and cause their disappearance.

Lactobacillus, Enterococcus and Staphylococcus strains are not inhibited by lowering a_w and absence of oxygen, growth of staphylococci is practically not inhibited by low a_w, though production of enterotoxin is retarded. The only means of inhibition of staphylococcal growth in case of low acid foods is the low temperature, as pointed out earlier.

- proteolytic enzymes break down muscle proteins producing NPN compounds that contribute to flavour and slightly increase pH (MIHÁLYI and KÖRMENDY, 1967; DEMEYER et al., 1979). In this proteolytic activity calpains and cathepsins play a major role (GIL et al., 1989; VERPLAETSE et al., 1989).
- lipolytic enzymes break down fat producing carbonyls and fatty acids that contribute to favourable changes in palatability and to increase of acid number, without any sign (peroxyde number, sensory characteristics) of rancidity (NAGY et al., 1987).
- nitrite depletion takes place, that is less pronounced if nitrate is used, acting as a nitrite-reservoir. Unlike high acid sausages, rest-nitrite values are usually higher in low acid sausages, ranging between 50-100 mg/kg. To this relatively high value not only nitrite and nitrate contribute but smoking and increase of concentration due to drying, too.
- as a consequence of increased salt concentration salt soluble fractions of myofibrillar and sarcoplasma protein gelify contributing to firm consistency.

All these changes, and others, too, contribute to the characteristic appearance, flavor and aroma and not to forget: to the safety of the traditional, long fermented-dried meat products.

HIGH ACID FERMENTED MEAT PRODUCTS

Unlike traditional, low acid products that in general are not inoculated with micro-organisms in any form, the vast majority of high acid meat products are inoculated with starter cultures or with successfully fermented sausage ("backslopping"). In a few cases normal microflora of sausage is relied on, it has the task to ferment added carbo-hydrate. Addition of carbo-hydrate is a precondition of acid production, since carbo-hydrate content of meat is not sufficient for production of acid in an amount necessary for adequate pH-drop.

Pure cultures have been in use as starters since about 30-40 years in the meat industry, thanks to Niinivaara's pioneering in Europe and that of Niven's in the U.S.A. in this field.

Although originally acid production vs. nitrate reduction was the main aim in U.S.A. and in Europe respectively, acid producing starter cultures, lactic acid bacteria, are now extensively used either alone or mixed with other cultures in many countries. There is however a tendency for lower incubation temperature in Europe (20-24°C) and a higher incubation temperature in the U.S.A.: about 37°C that may go even higher with the aim of inactivation of Listeria. (A good survey on starter cultures available on German market was published by HAMMES et al., 1985 a,b.)

Criteria for starter cultures

A general requirement is that starter cultures of any kind have to be safe: no health risk can be involved upon their application. If starter consists of lactic acid bacteria, a second important requirement is: rapid and always reproducible acid production. This rapid acid production is unfavorable for growth of micrococci (no growth, no NO_3-reduction and no lipolysis below pH 5,4-5,5; COVENTRY et al., 1988; ALLY et al., 1990; HECHELMANN and KASPROWIAK, 1990) but very much desired for inhibition of pathogenic and spoilage microflora; these two extremes, i.e.rapid or slow acid production, have to be met half-way if mixed culture is used.

Until recently inhibitory activity of starter cultures on the basis of acid production was considered as sufficient, nevertheless since Listeria has become a health risk, strains producing other factors (antibiotics, bacteriocin) are being searched for (RODRIGUEZ et al., 1989; GEISEN et al., 1990 and LEISTNER et al., 1990) and applied as starter and protective culture in one.

Factors influencing acid production of starter cultures

As the amount and rate of acid production play a decisive role both bacteriologically and technologically, it is important to note that they are influenced by many factors, here are some:

- temperature
- type of carbo-hydrate
- amount of carbo-hydrate
- salt concentration
- pH
- diameter of sausage
- oxygen
- type and amount of spices
- other additive (soy protein)
- nitrite concentration
- microbial contamination of sausage raw materials
- initial count of starter culture
- activity of starter culture

Effect of temperature is evident. LANDVOGT and FISCHER (1990) and STIEBING and RÖDEL (1990) gave good examples for the combined effect of temperature and water activity. Although there is a simple relationship among temperature, a_w and growth: the higher the temperature and the a_w the higher the growth rate and vice versa, yet it is hard to find an optimum solution. KLETTNER and RÖDEL (1979) and BAUMGARTNER et al. (1980) have found a strong correlation also between temperature and ripening-drying: when elevating temperature by 5°C processes became faster by a factor of 2.

A well known fact is that different carbo-hydrates support acid production different way. It is also known that amount of sugar has influence on acid production, partly as limiting substrate (too low concentration) partly as retarding effect (too high concentration). In this latter case, due to the high concentration of carbo-hydrate in combination with salt, a low a_w value is attained that is delaying metabolic activity of starter cultures favoring thus growth of low-a_w tolerant micro-organisms, e.g. staphylococci.

Initial pH of the sausage may influence final pH and the time until pH 5,3 is attained, in the sense that high pH of raw material means larger buffering capacity, consequently extended period of time is needed until pH can drop below critical level, and sometimes final pH will not go down sufficiently either.

Diameter and oxygen have an interesting effect on acid production as pointed out by PEZACKI (1979) and DEMEYER, 1982; DEMEYER and VERPLAETSE 1987; DEMEYER et al. 1987. With increasing diameter lactic acid production increases, but NH_3 and α-HN_2-N formation is also more pronounced that may even shift pH toward alkalinity. Presence of oxygen (no vacuum- filling) and diffusion of oxygen (small diameter) decreases lactic acid production and pH-drop.

An interesting effect of spices has been known for several years (VANDENRIESSCHE et al., 1980). Some spices have a stimulatory effect on growth of starter cultures causing faster pH-drop. In our experiments (unpublished data) sausage with only nitrite salt needed twice as long time for same pH- drop as similar sausage with spices. NES et al. (1984) also found the stimulatory effect of natural spices and their aqueous extracts on lactobacilli, though no such effect of oleoresins. Later it was shown that the growth promoting factor for lactobacilli is manganese, that is present in traces in several spices. Since manganese is lost during most spice extraction procedures, special treatments are applied to "feed back" trace elements to spice-extract (e.g. Europfeffer). It has also been shown (FARKAS et al., 1988) that glucose content of some spices used in higher concentration does contribute to faster acid production.

Somewhat similar stimulatory effect of other additives, like soy protein has also been detected (DEMEYER et al., 1987). Sodiumnitrite, on the contrary, may show inhibitory effect as pointed out by ALLY et al. (1990). Their results showed lower pH-values at the end of incubation when NO_2-concentration was lower and vice versa. ZAIKA et al. (1976) came to the same conclusion. However, it has to be emphasized that use of nitrite salt (0,4-0,5 % $NaNO_2$ in salt mixture) usually does not give an inhibitory nitrite concentration for starter cultures.

As for the effect of initial count of sausage starter culture and their activity in acid production, it is easy to accept, that the lower the count of contaminating microflora and the higher the count and activity of starter culture, the better result can be expected. Since at the beginning of ripening (incubation) there is only a slight inhibition of undesired microflora by salt and nitrite and elevated temperature of incubation favours their growth anyway, it is of vital importance to keep the viable count of contaminating micro- organisms as low as possible. This contamination level is by all means one of the critical points to be controlled. Since a competition exists among starter culture and contaminating microflora of sausage for nutritives ("nest theory", KATSARAS and LEISTNER, 1988) and an antagonism prevails as well, the final outcome of this "battle" will be determined by the differences in their number and activity. Minimum initial count of physiologically active starter cultures has to be 10^5/g sausage mix, evidently 10^6 or 10^7/g is better, and in general this is also achieved. In case of starter culture fermented products not only competition and antagonism inhibit growth of undesired micro-organisms but lower pH contributes to this most effectively.

Changes during ripening

During fermentation and drying physical, microbiological and biochemical changes take place, in several ways similarly as in case of traditional dry sausage. The main changes can be summarized as follows:

- as a result of carbo-hydrate break-down during incubation lactic acid is formed and pH drops below 5,3. At this acidic pH-value which is close to iso-electric point of meat protein, protein solution gelifies (KLEMENT et al., 1973; DEMEYER et al., 1987) and growth of most undesired microbes is inhibited.
- as a result of drying meat product loses weight. This weight loss is in general lower than that of low acid fermented meat products, since with starter fermented sausage 15-20 % loss is sufficient for the required a_w-drop, that in combination with pH 5,3 gives the expected safety.
- this combined effect of lower pH and a_w causes a selection in the initial microflora that is similar to the changes in low acid fermented meat products, with the important difference: also staphylococci are inhibited because of low pH-value.
- proteolytic enzymes break down muscle proteins. The amount of myofibrillar and sarcoplasma protein decreases, concentration of NPN compounds, polypeptides, amino-N, ammonia-N grows that also causes a slight increase in pH (MIHÁLYI and KÖRMENDY, 1967; DEMEYER et al., 1979; VERPLAETSE et al., 1989). VERPLAETSE et al. (1989) suggest that for this proteolysis endogenous and/or bacterial cathepsins or similar enzymes are responsible favoured by relatively low pH of sausages.

  An excellent review of biochemical changes and stoichiometry of these changes in fermented sausages is given by DEMEYER et al. (1987).
- several starter cultures and meat micro-organisms possess lipolytic activity (NIELSEN and KEMNER, 1989; NIETO et al., 1989) as a result of which aroma compounds, fatty acids are formed. As a consequence acid number increases during ripening without any sign of rancidity (NAGY et al., 1987; CAVOSKI et al., 1988)
- nitrite depletion takes place with a final value of usually below 10 mg/kg.

Chemical acidulants

Since fermentation takes time and too many factors influence growth and metabolic activity of starter cultures, the question seems adequate: why do not add acid directly? Direct addition of e.g. lactic acid however coagulates surface of meat protein making a good bind among meat and fat particles impossible. In order to overcome this problem a way had to be found for a delayed effect of acid: the acid should react with meat protein several hours after stuffing. There are basically two solutions of this task:

a/ Glucono-delta-lacton, which hydrolyzes in water released by meat, yielding gluconic acid, and this reaction takes place only some hours after mixing and stuffing

b/ organic acids encapsulated with special coatings, that is molten by elevated temperature (GRAVES, 1988). Depending on the nature of the coating this elevated temperature can be room temperature, in this case care should be taken to keep temperature low until stuffing to prevent too early reaction, or can be as high as 50-65°C, when cooking has to be applied in order that encapsulated acid sets free.

Coating can be partially hydrogenated vegetable oil, among others. As encapsulated acids citric acid, lactic acid are mostly used; it is interesting to note that also encapsulated GdL is available: when added to sausage mix, no problem of early hydrolysis and stiffening arises in case of mechanical failures (if , on account of breakdown of filling and/or clipping machine sausage filling operations have to be delayed, normal GdL reacts with meat not in situ, in the casing, but before, consequently same problem arises as mentioned with direct addition of lactic acid).

With both types of acidulants pH-drop in fermented dry sausage takes place in a very short time: in some hours compared to several days with starter cultures. This way bacteriological safety is achieved. In general however, sensory properties and shelf-life of starter culture fermented sausages are considered better and longer, resp. than that of the sausages made with acidulant, though this latter technology produces acceptable sausage that should be consumed in a relatively short period of time to avoid organoleptical changes.

Microbiological safety of fermented meat products

Fermented meat products are recognized generally as safe. More precisely if critical points are controlled properly, sausages and hams are really safe because either low a_w-value or combination of reduced a_w-value and reduced pH inhibits growth of undesired micro-organisms.

As pointed out earlier these factors play major role, nevertheless other factors also contribute to the safety of raw fermented meat products (hurdle principle: LEISTNER, 1985a).

While earlier it was common practice to analyze bacteriologically the ready products only, for several years the emphasis has been put on the control of main critical points of raw material, technological steps and storage conditions. This new way of thinking is summarized in the well-known HACCP-concept, three steps of which are as follows:

1. Assessment of microbiological hazards associated with a given raw material or food product
2. Determination of critical control points required to control any identified hazard
3. Establishment of procedures (checklists) to monitor critical control points.

LEISTNER (1985b) gave a good summary of this concept and suggested 19 control points for fermented sausage and 15 control points for raw fermented ham.

Instead of giving a brief review of these critical points, it seems adequate to mention the major ones with special regard to the differences among traditional and starter culture fermented sausages and hams (Table 1).

Table 1. Major critical characteristics in raw fermented meat technology

Critical characteristics		high acid sausage	low acid sausage	long cured ham
Temperature of ferm.	initial	22 - 25 °C	< 12 °C	< 5 - 6 °C
	later	15 - 18 °C	14 - 16 °C	15 - 18 °C
Salt concentration		2,2 - 3,0 % (initial)	2,5 - 3,0 % (initial)	4,5 - 6 % (final)
a_w - value (final)		< 0,95	< 0,88	< 0,90
pH-value	initial	< 6,2 (not critical)	< 6,2 (not critical)	< 5,8 (can be critical)
	final	< 5,3	not critical (usually about 6,0)	not critical (usually about 6,0)

As we can see temperature is a very important factor in enhancing growth of starter micro-organisms (high acid sausages) and in inhibiting growth of undesired microbes (low-acid products). It is also worth mentioning once more that in case of ham where a_w-lowering effect of salt is exhibited only after a longer diffusion process, an even lower temperature has to be kept than in case of sausage.

Initial salt concentration and a_w-value are rather critical with high acid sausages: if salt concentration is too low, undesired bacteria have a better chance to grow, but this is true also for the starter micro-organisms. If it is too high, also starter micro-organisms are retarded in growth and metabolic activity, as pointed out earlier.

Only too low salt concentration is critical on the other hand with traditional, low acid fermented meat products from bacteriological point of view. Too high concentrations cause only sensory refusal and has also a health aspect (high blood pressure), but is microbiologically safe.

It has been mentioned that low final a_w-value is the major "hurdle" with traditional products. As for initial pH a high value may be critical chiefly with ham and less critical with low acid sausages because of low temperature ripening at the beginning and low a_w-value later. Similarly is higher initial pH less critical with high acid sausages because of pH-drop during fermentation. It should be kept in mind however, that if initial pH is too high (6,3 and above), it takes longer until desired pH of 5,3 is reached giving thus a better chance for growth of non-desired bacteria.

Although it has been mentioned several times, how important the low ripening temperature is with low acid products, data are rather scarce about the significance of temperature during the first part of ripening (until pH reaches 5,3) with starter fermented sausage. In the United States the American Meat Institute has worked out the Good Manufacturing Practice for fermented dry and semi-dry sausage as voluntary guidelines (AMI 1982) that considers the relationship between temperature and time until pH-drop as one of the most critical points to be controlled. The other critical point is evidently pH.

a/ pH control

Dry fermented sausages shall attain a pH of 5,3 or lower through the action of lactic acid forming bacteria. These bacteria may be added by a commercially prepared culture at sufficient level (see manufacturer's recommendation), or by a back inoculum ("back-slopping") from a previously fermented and controlled mother batch.

During fermentation of sausages to a pH of 5,3 it is necessary to limit the time during which the sausage meat is exposed to temperatures exceeding 15°C or higher. A controlled environment of 15°C or less minimizes the opportunity of Staphylococcus aureus reaching levels of public health significance. (HECHELMANN et al., 1988 also found that at 15°C no staphylococcal growth occurred.)

b/ time-temperature control

The process is proper according to the guidelines if following time-temperature relationship prevails:

1/ fewer than 720 degree x hours when highest fermentation temperature is less than 32°C

2/ fewer than 560 degree x hours when the highest fermentation temperature is between 32-40°C

3/ fewer than 500 degree x hours when the highest fermentation temperature is greater than 40°C

(Degrees are measured as the excess temperature over 15°C . Degree x hours are the product of time in hours at a particular temperature and the "degrees".) The limitation of the number of degree x hours depends upon the highest temperature in the fermentation process, prior to pH 5,3 is attained (this also refers to variable temperature processes). For constant temperature processes the time-temperature relationships are as follows:

Table 2. Time-temperature relationships and limitations during incubation of starter fermented sausages

Degree x hours	Temperature °C	Allowed hours by guideline (max.)
720	24	80
720	27	60
720	29	51
560	32	33
560	35	28
560	38	24
500	40	20
500	43	18

Experience shows that these guidelines provide a sound basis for taking reliable measures in order to avoid health and spoilage risk with most micro-organisms, not only staphylococci. These guidelines can also be thought-provoking for such fermentations, where, for the sake of micrococcal growth, slower acid production and pH-drop is aimed at.

Dietary, nutritional and sensory aspects

Dietary effect of fermented meat products

We have discussed the importance of lactic acid bacteria in fermented meat products from physical, chemical, technological and hygienic point of view, but their possible role in anticarcinogenicity and immunology has to be dealt with, too, even if references on this topic are scarce. This is even more timely, since meat and meat products have been accused more and more with exhibiting health risk in human nutrition through cancerogenic (genotoxic and epigenetic) substances, like nitroso-compounds, polycyclic aromatic hydrocarbons, pyrolysis products, fats etc. For this reason if there were data available that suggest the existence of special foods, perhaps meat products with anticarcinogenic effect, this could improve the image of meat industry.

FERNANDES and SHAHANI found in their earlier work and in 1990 that ingestion of lactobacilli or food containing viable lactic acid bacteria results in their establishment in the gastrointestinal tract. Presence of lactic acid bacteria in the intestinal tract seems to be prophylactic against undesired micro-organisms but they may reduce risk of dietary onset of carcinogenesis too. In this effect a direct and an indirect mechanism may play a role: lactobacilli reduce procarcinogenic substances and/or reduce activity of enzymes that convert procarcinogens to carcinogens. It has also been found that in short-term studies i.p. administration or feeding of lactobacilli to rodents, implanted tumors are suppressed, where activation of host defense system has been suggested as main mechanism and all this through enhancement of immune system. DE SIMONE et al. (1986) studied the effect of yogurt on human peripheral blood lymphocytes and found that although yogurt alone did not influence immune system, a synergistic effect could be detected by yogurt in presence of concanavalin A: γ-interferon production was synergistically increased.

Although these findings are supported by experiments carried out with pure cultures of lactic acid bacteria or by dairy products it seems reasonable to presume that short-ripened raw fermented meat products with not too low water activity value, consequenly relatively high bacterial count of active lactic bacteria may also play a positive role in this sense. Whether this mechanism works also with starter fermented sausages and to what extent, has to be elucidated.

Nutritional aspects

It is well known and also mentioned earlier that meat protein breaks down during fermentation process to peptides of various length and free amino acids thus enhancing digestibility. ESKELAND and NORDAL (1980) evaluated the change in nutritional quality of the protein during starter fermentation of sausage. Net protein utilization (NPU), true digestibility of protein and that of single amino acids served as criteria. The beef- and-pork sausage was fermented for 22 days, and during this period the protein digestibility increased from 92,0 to 94,1 % and the NPU from 73,8 to 78,7 %. The amount of amino-acids and their true digestibility also increased during fermentation, the largest increase being with threonine.

Less is known about the change in digestibility during fermentation of low acid fermented meat products. Knowing however that protein breakdown follows a similar pattern as that of high acid fermented meat products, a similar change also in digestibility may be assumed.

Although there is no scientific evidence for increased digestibility of fermented sausages on account of lower pH, compared to non fermented or low acid fermented meat products, nevertheless it would be interesting to find experimental support for this phenomenon since it is only a subjective experience now.

Some sensory aspects

The basic differences in sensory characteristics of low and high acid fermented meat products are well known and can be summarized as follows (Table 3).

Table 3. Major sensory characteristics of fermented meat products

Sensory characteristics			
Traditional salami	Traditional ham	Starter fermented sausage	
		short ripened	longer ripened
Salty, round, rich flavour	Salty or mild	Salty flavour	Salty or mild
non acidic	non acidic	strongly acidic (tangy)	acidic - mild
firm texture	firm or tender	softer, "rubbery" or spreadable	firm texture

These characteristics may of course change even to a great extent depending on the technology, therefore this "classification" should serve only for orientation. Evidently higher salt concentration at the beginning means usually higher concentration at the end too, lower moisture means firmer texture etc. What here is meant actually is that higher moisture content gives a sensation of higher saltiness and tanginess, as well as lower pH gives firmer texture influenced of course by moisture, too.

As for tenderness of raw fermented meats not only ripening but some other factors have to be considered, too.

It has been known, and in some countries put into practice, that by the help of some chemicals (growth hormones, ß-agonists etc.) fat/lean deposition ratio can be shifted in animals towards more lean. The basic mechanism can be either promoting of protein synthesis or inhibition of proteolytic breakdown (Demeyer and Samejima, 1990). In this latter case enzymes responsible for fragmentation of myofibrils and for tenderness (calpains) are also inhibited. This phenomenon may also have an impact on tenderness of fermented whole muscle meat products.

The situation may further be complicated by the fact that not much is known about the tenderizing effect of cathepsins on longer ripened products, even if no tenderizing effect is suggested by cathepsins in case of fresh meat. Although "remedies" are also worked out against calpain-blockage induced toughness (Ca^{2+} injection: KOOHMARAIE et al., 1990;

KOOHMARAIE, 1991) the question of growth promoters have to be scrutinized very thoroughly, not only because of the weak consumers' acceptance.

Concluding remarks

Fermented meat products are special consumers' goods: no other technology is capable of developing such richness in flavour and aroma as with fermentation. It is also an important feature of this unique processing that the product can serve the high quality requirement of well-to-do consumers and can also serve the purpose of preservation of meat in countries, where no other way is available for preventing spoilage. For future support and improving of their image a good piece of research work has been and has to be done in the field of health (lower fat, lower sodium, elucidation of the role of lactobacilli in anticarcinogenicity, the role of fermentation and pH in digestibility), safety (more effective starter and protective cultures against staphylococci, listeriae, mycotoxic moulds, improving by selection and genetic methods) as well as economy (less energy consuming, yet more effective drying methods, possible use of newer humectants).

Taking into account all these positive aspects mentioned this type of meat product will probably have a fairly good chance in the future, too.

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