FERMENTED AND INTERMEDIATE MOISTURE PRODUCTS

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SUMMARY: This contribution should give a comprehensive and topical review on fermented and intermediate moisture foods based on meat. At present both product groups gain interest in research and application. Within fermented meats raw sausages as well as raw hams are discussed, even starter and protective cultures are more relevant for the former than the latter. Water activity is the main criterion for stable and safe intermediate moisture meats, and in traditional products a_w is adjusted by drying and common humectants (salt and sugar). However, additional factors (hurdles) often contribute to the shelf-life and wholesomeness of these products too, and most of them are applied empirically. Newly developed intermediate moisture meats are scarce, but traditional products prevail in different parts of the world. Accessible information on such meats known in Europe, Asia, Africa and America is presented. However, more research on traditional intermediate moisture meats seems necessary and would be rewarding.

INTRODUCTION: Most fermented and intermediate moisture products based on meat are stable and safe without refrigeration. A wide variety exists and many are traditional products known in different parts of the world since centuries. The stability of such meat products is primarily caused by a reduced water activity (a_w), however, other factors such as pH, competitive microorganisms, preservatives and sometimes a heating step during processing contribute to their stability. Therefore, the shelf-life and wholesomeness of fermented and intermediate moisture meats is generally the result of combined factors, i.e. hurdle technology, which have originally been introduced empirically, but are now measurable and increasingly better understood (Leistner, 1987a).

If foods are grouped according to the a_w, then they may be devided into three categories: high moisture foods (HMF): a_w = 1.0 - 0.90; intermediate moisture foods (IMF): a_w = 0.90 - 0.60, low moisture foods (LMF): a_w = 0.60 - 0.00 (Leistner and Rödel, 1976). Most fermented meat products are HMF and only some are IMF, whereas the intermediate moisture meats are of course in the category of IMF, but some become during further drying LMF. The essential decrease of a_w is achieved by the addition of humectants (salt, sugar, etc.), and the removal of water (drying). A desired decrease of the pH is achieved by fermentation of added carbohydrates with lactic acid bacteria. Since only a few of these organisms are able to grow below 0.90, most IMF are not fermented. The fermentation of meats can be brought about by the indigenous microflora, but increasingly selected starter and protective cultures are employed for this purpose (Leistner, 1987b; Leistner and Lücke, 1989).

In general, fermented as well as intermediate moisture meats are safe, however, they become a public health risk, if they contain Salmonella spp., Listeria monocytogenes, Staphylococcus aureus, Clostridium botulinum or toxigenic moulds. Therefore, the manufacturing processes should be controlled, and possibly further optimized by using the HACCP concept (Leistner, 1985a, 1987a).

FERMENTED PRODUCTS: Raw sausages and raw hams are subsumptively called fermented meat products, however, the role of microorganisms differs remarkably in these two categories. For most raw sausages, e.g. Italian or German salami, the fermentation by microorganisms which grow in the interior and in some products also on the surface is essential (Leistner, 1987b; Leistner and Lücke, 1989). An exception is Chinese raw sausage (Lup Cheong) which is stabilized by a_w only, because a low pH caused by fermentation would be disliked by the Chinese consumer (Leistner and Dresel, 1986; Leistner, 1988). On the other hand, for most raw hams, e.g. Prosciutto di Parma of Italy or Jamón Serrano of Spain, microbial growth in the interior is unnecessary and undesirable (Leistner, 1986b). However, with hams again there are exceptions, because in Turkish Pastirma (dried raw beef) the lactic acid bacteria may contribute to the stability of the meat (El-Khateib et al., 1987), and for some raw hams (e.g. Bündnerfleisch of Switzerland or Speck of Italy), the growth of moulds on the surface is desirable (Leistner, 1986c, 1990a). The main features of raw sausages and raw hams may be summarized as follows.

Raw Sausages: Apparently in Europe the fermentation of raw sausages has been invented about 260 years ago in Italy. Soon after this event the production of fermented sausages was introduced to other European countries, such as Germany and Hungary. Today a wide variety of fermented sausages exists (Leistner, 1990b), however, the process is based on some general prerequisites. Of the extrinsic factors for a proper fermentation of sausages most important are the temperature, relative humitidy, and air velocity, as well as the time these parameters are applied to the products during the ripening process (Rödel, 1985). Of the intrinsic factors nitrite, redox potential, competitive organisms, pH and a_w are of paramount importance. The stability of fermented sausages is brought about by a sequence of hurdles (Leistner, 1986a, 1987a, 1990b), which are particularly important in certain ripening stages of the products to effectively inhibit food-poisoning organisms as well as bacteria, yeasts, and moulds which might cause spoilage. On the other hand, this sequence of hurdles also favors the selection of the desired competitive flora (lactic acid bacteria, nonpathogenic staphylococci), which contribute to the flavor and stability of fermented sausages. An important hurdle in the early stage of the ripening process of salami is nitrite, added with curing salt, because an addition of at least 125 mg/kg sodium nitrite inhibits the growth of food-poisoning bacteria, e.g. salmonellae. The nitrite hurdle diminishes during the ripening process, since the nitrite depletes. Due to the multiplication of bacteria in salami the redox potential (Eh) of the product decreases, and this in turn enhances the Eh hurdle, which inhibits the growth of aerobic organisms and favors the selection of the competitive flora. The growth and metabolic activity of lactic acid bacteria, which then flourish, cause acidification of the product and thus an increase of the pH hurdle. This is of particular importance in the microbial stability of quick-ripened fermented sausages, which are not completely dried. The preservative (nitrite), Eh, competitive flora, and the pH hurdle diminish with time, because in long-ripened salami the nitrite level and the count of lactic acid bacteria decrease, while the Eh and pH increase somewhat. Therefore, only the a_w hurdle, which increases during the whole ripening process, is mainly responsible for the stability of long-ripened fermented sausages.

It is important to note that the natural flora as well as the added starter cultures are not evenly distributed in a fermented sausage, but are immobilized in cavities of the sausage mix. The distance between these cavities or nests of ripening flora varies between 100 and 5000 µm, as has been demonstrated by electron microscopy (Katsaras and Leistner, 1988). If the properties of a sausage are changing during the ripening process in the desired direction (nitrate reduction, lactid acid production, catalase activity, etc.), then 'large areas' of the sausage matrix 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 nutrients and impair each other with their metabolic products, such as lactic acid. Therefore, after some time the growth ceases, because the cell division will be delayed. We observed this in nests of lactobacilli as well as of apathogenic staphylococci (Katsaras and Leistner, 1988). Furthermore, inhibitory substances such as lactic acid or bacteriocines which are produced in 'lactobacilli nests' will diffuse and thus inactivate microorganisms, e.g. salmonellae, listeria or pathogenic staphylococci, present in other nests. Sometimes different types of bacteria are trapped in one cavity and then competition will be fierce, but lactic acid bacteria will have an advantage due to their tolerance of low Eh, low pH and low a_w. A relatively small distance between the nests of desirable bacteria in the sausage matrix should be advantageous. Therefore, a more even inoculation of the sausage mix with suitable starter cultures might prove more important that previously envisioned.

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 (Lücke and Hechelmann, 1985). As starter cultures for fermented sausages primarily lactic acid bacteria, cocci, yeasts and moulds are used. Lactic acid bacteria (lactobacilli, pediococci) should be homofermentative and thus produce only lactic acid from carbohydrates, the resulting pH decrease improves the sensory properties (flavor, color, texture) as well as the stability (inhibition of food-poisoning bacteria) of fermented sausages. Due to the latter effect, the lactic acid bacteria are also called protective cultures. The starter and protective cultures employed for fermented sausages primarily represent the following species: Lactobacillus plantarum, L. sake, L. curvatus, Pediococcus pentosaceus and P. acidilactici (formerly called P. cerevisiae). Furthermore, Micrococcaceae are often used as starter cultures for fermented sausages, because they reduce nitrate to nitrite, produce catalase and improve the flavour of the products by lipid and protein degradation. The following species are employed: Staphylococcus carnosus, S. xylosus and Micrococcus varians. Widely used are combinations of lactic acid bacteria and Micrococcaceae as starter cultures, because they ensure the beneficial effects of both groups. Also yeasts (Debaryomyces hansenii) are sometimes incorporated into these starter culture combinations, because they could improve the flavor of the products. Mould-ripened salami is inoculated on the surface with starter cultures (Penicillium nalgiovense), which improve the flavor, appearance and stability of the products (Leistner, 1990a, b).

Not only the starter and protective cultures used for fermented sausages have been improved in recent years, but progress was made too in the climatic control and automation of the ripening process. Stiebing et al. (1982) introduced an improved control of the relative humidity (RH) in the ripening rooms during sausage fermentation and achieved an energy preservation of up to 70%. Furthermore, by using the surface a_w of the sausages as control parameter, Stiebing and Rödel (1989) suggested an optimization and automation of the ripening process steered by microprocessors.

The interest in manufacturing fermented sausages is increasing world-wide, even in countries, such as Australia, Brazil and Japan, where these products have not been popular in the past. Generally, the German technology for making fermented sausages is preferred, however, consumers in some countries favor not such a low pH (5.0 - 5.3) as is common for short-ripened fermented sausage of Germany, but less acidified products (final pH 5.6 - 5.8). Especially in China and Japan the consumer considers a sour taste of sausages as an indication of spoilage. However, interestingly in other Asian countries fermented pork products with a low pH are known. Nham is a traditional fermented meat product of Thailand, made of minced pork and sliced pork skin mixed with salt, nitrate, rice and spices. The mixture is tightly packed in banana leaves or plastic films and fermented for about 4 days at 25°C. The product is eaten directly without cooking. During fermentation homofermentative lactic acid bacteria (lactobacilli, pediococci) prevail which lower the pH of Nham to 4.0 (H-Kittikun et al., 1988). Nevertheless, this fermented and very sour meat product is much liked by the Thai consumer.

Raw Hams: These meat products are known in Europe and China for at least 2500 years (Leistner, 1986b), they are stable due to a reduced a_w and generally are not fermented. The essential a_w reduction is achieved by salting and drying. Especially for the interior of large pieces of meat it takes time before the salt has penetrated and the water has been removed. During this time the hams have to be held at low temperature (less than 5°C), in order to prevent growth of relevant food-poisoning bacteria (primarily non-proteolytic strains of Clostridium botulinum type B) and important spoilage bacteria (primarily Serratia liquefaciens) for raw hams (Hechelmann et al. 1980a, b). After the a_w in all parts of the ham has been reduced below 0.96 the products are stable and safe. They are now ready to be further ripened or smoked at room temperature for weeks or months without bacteriological risks. However, the growth of a_w-tolerant moulds has to be prevented too, because most moulds which occur on meats are toxigenic (Leistner, 1984). The inhibition of undesirable mould growth on raw hams may be achieved by smoking, potassium sorbate, pimaricin or garlic. The latter is traditionally used in the paste covering the surface of Turkish Pastirma (El-Khateib et al., 1987).

INTERMEDIATE MOISTURE PRODUCTS: IMF should be sufficiently plastic to eat without further hydration or cooking and should be storable without refrigeration. Some newly developed intermediate moisture meat products have been described, but none has gained much importance in the market, due to an unfamiliar taste and appearance as well as a 'chemical overloading' of the products suspected by the consumer. However, traditional IMF based on meat are enjoyed in different parts of the world and especially in developing countries, since in general, but not always, they are stable and safe without refrigeration. Because the principles of the stability of these products are now quite well understood and measurable, the quality and wholesomeness of traditional intermediate moisture meats from developing countries could be improved, if necessary, in co-operation with well equiped laboratories. For developed countries such traditional IMF could be a highly valuable source of innovation, and thus a co-operation in this area would be indeed a two-way-street (Leistner, 1987c). Furthermore, the knowledge about intermediate moisture meats traditional in one country, should be spread to others, because with some adaption the same IMF could become successful in different parts of the world. Below some IMF based on meat found in Europe, Asia, Africa and America are discussed.

Europe: Genuine intermediate moisture meat products are not common in Europe. However, some traditional European meat products, which are in general high moisture foods, may acquire by further drying an a_w below 0.90, and thus become IMF (Leistner et al., 1981). For instance, dried Bologna-type sausage (German Brühdauerwurst) or blood sausage (German Speckwurst) may have an a_w as low as 0.86 - 0.87 and therefore have an impressive shelf-life. These are heat processed meat products, however, also intensively dried raw products have even more often an a_w below 0.90. In long ripened hams from pork (Prosciutto di Parma or di San Daniele from Italy, Jabon de Bayonne from France, Jamôn Serrano from Spain or Kraški pršut from Yugoslavia) the a_w may be as low as 0.80, and the same is true for raw hams from beef (Bündnerfleisch of Switzerland and Pastirma of Turkey). Furthermore, there are some fermented sausages which after intensive drying are in the IMF range, and some have an a_w as low as 0.65 (Hard Salami). But as stated before these are just specialities within categories of meat products which generally are high moisture foods (Leistner et al., 1981).

Asia: In that part of the world we can find many IMF based on meat, which have no equivalent in the high moisture range. Most shelf stable meat products of the Orient are derived from technologies developed in China in the course of centuries. In the past the preparation of Chinese meat products was mainly done in the family, but today in China about 1200 processing plants for meat and eggs are in operation (Yang, 1988). The stability of most Chinese meat products is due to a reduced water activity. The a_w of these products is adjusted by the addition of salt and sugar as well as a mild drying process. A heating step during processing or before consumption is important for the hygienic quality of the products. Today pork is the preferred meat in China, however, also beef, lamb and other species are used as raw material. For the microbiological safety and stability of these IMF of major importance is the halotolerant Staphylococcus aureus and xerotolerant moulds of the genera Aspergillus and Penicillium. The pathogenic staphylococci are inactivated by heating the products during processing for several hours at 50°C, and the xerotolerant moulds, including toxigenic species, are inhibited by adjusting the a_w to a proper level. Shin (1984) determined that on Oriental intermediate moisture meats with an a_w of or below 0.69 mould growth does not occur, and therefore such products are stable for several weeks or months without refrigeration. Of the intermediate moisture meats widely appreciated in the Orient for their sensory and nutritional properties, dried meats, raw sausage, bacon and pressed duck should be mentioned. Their origin, technology and stability have been described in detail by Leistner (1988). **Chinese dried meats** (Rou Gan) are easy to prepare and can be processed and stored without refrigeration (Lou et al., 1980; Ho and Koh, 1984; Leistner et al., 1984; Li et al., 1985; Leistner, 1987a). The total consumption of these meats throughout Asia is very large and their popularity is still increasing (Chen, 1987). Most Chinese dried meats are IMF, and some are even in the low moisture range (a_w below 0.6). Many different products are known, depending on the species of meat, the kind of additives and the type of technology used. Three different technologies are distinguishable: dried pork or beef in slices (process I), beef, pork, or chicken in pieces, cubes or strips (process II), and shredded pork or chicken (process III). These processes, especially II and III are readily employed in developing countries. The humectants used, i.e. sugar and salt, are cheap and generally available. In addition, sugar has beneficial effects on the texture and plasticity of dried meats. However, the sweet taste of Chinese dried meats, which is an advantage in the Orient, might not be accepted by consumers in other parts of the world, and therefore modifications of the processes might prove neccessary. From the microbiological point of view Chinese dried meats can be recommended without reservation. **Chinese sausage** (Lup Cheong) is made from pork, but formulas differ with respect to the percentage of meat, fat, sugar, salt, soy sauce and wine used, as well as to the favored spices (Lou et al., 1980; Ho and Koh, 1984; Savić, 1985; Leistner and Dresel, 1986). The technology employed is similar in all Chinese communities. Lup Cheong may be prepared by small manufacturers, because only simple equipment and installations are needed. Traditional Chinese sausage is a raw but non-fermented product with an a_w in the intermediate moisture range (usually 0.75), and therefore this product may be stored for 1 - 3 months without refrigeration. In general, the bacteriological status of Lup Cheong is good and provides no risk. Nevertheless, the product is always warmed before consumption, and often is sliced and fried or steamed with rice, noodles or various vegetables. A few slices of Lup Cheong are sufficient to flavor an entire dish. **Chinese Bacon** (La Rou) is a common meat product made from pork, but sometimes also from beef or lamb (Li et al., 1985). For La Rou the meat is cured (dry or wet) with salt, sugar, spices, wine, nitrate, and thereafter dried by air, in an oven or by light smoke (Leistner, 1988). For the drying process a temperature of 40 - 55°C is recommended (Li et al., 1985), however, it was experimentally demonstrated that Staphylococcus aureus which may occur on the product is only securely inactivated if bacon is dried two days at 50 - 60°C (Wang et al., 1989). The finished product (a_w 0.70) may be stored up to 2 years without refrigeration. Altough Chinese bacon is produced and stored in the raw state, it is always eaten after heating; often cooked in a soup. **Pressed Duck** (Ban Ya) is a traditional and famous meat product of China, storable for several months without refrigeration. The limiting factors for the shelf-life could be rancidity and/or mould growth. Different breeds of ducks are used for Ban Ya or Nan An in different provinces of China, however, the employed technology is similar (Lou et al., 1980; Li et al., 1985; Zhou et al., 1987; Zhou and Ding, 1988; Leistner et al., 1989). By the addition of salt and sugar and the removal of water the a_w of the finished products is adjusted to about 0.85. The salt content of such a product is quite high (9 - 10%), and therefore it is soaked and rehydrated in water before consumption. Pressed duck, which has a delicious flavor, is always consumed in the heated state, often as part of a vegetable dish. However, since it takes more than 20 processing days before the a_w is decreased to a safe level, Staphylococcus aureus could have a chance to grow and to produce heat stable enterotoxines in this product. Experimentally it was determined that this food-poisoning organism is eliminated or inhibited during the usual processing of pressed ducks (Leistner et al., 1989). Therefore, it has been demonstrated again that traditional Chinese processes for meats lead to stable and safe products, if properly done.

Africa: On this large continent only few fermented, but many dried meat products are common, which are prepared with different degrees of sophistication. Most of them are in the intermediate moisture range, or after intensive drying are even low moisture meats. Heinz and Winkelmann (1990) estimated that the a_w of African dried meats ranges from 0.75 - 0.50. The names of these products depend upon the technology used, but also vary with the geographical area in which the meats are produced. Most processes are traditional and empirically employed, probably since centuries. Recently some African scientists have become interested in studies on traditional meat products by using scientific methods (Faparusi, 1981; Igene, 1983; Adesiyun, 1984; Igene and Abulu, 1984; Alonge, 1987; Gailani and Fung, 1989; Igene et al., 1990); and this approach must be encouraged. The following names of African dried meat products should be mentioned: North Africa: Pastirma, Sharmoot; East Africa: Odka, Qwanta; West Africa: Khundi, Kilishi; South Africa: Biltong. From some of these meats detailed information is available to the author of this contribution and could be summarized as follows: **Pastirma** is a sophisticated product made from salted and dried beef. It is known in Egypt, Turkey and other Moslem countries, but also in Armenia (USSR). Pastirma is an example of a meat product processed beyond geographical and religious borders. The meat used for Pastirma originates from the hindquarters of beef cattle, it is cut into long strips, which should have a diameter of not more than 5 cm. These strips are rubbed with salt and nitrate, thereafter they are dried, pressed and covered with a paste containing several ingredients, including 35% garlic (Leistner, 1987a). Pathogenic bacteria and parasites hardly survive the manufacturing process (Berkmen, 1960), and there is no mould growth on the surface of the product, due to the effect of garlic (El-Khateib et al., 1987). Probably also lactic acid bacteria contribute to the preservation of Pastirma, which has in the finished product a salt content of 4.5 - 6.0% and an a_w of 0.85 - 0.90. The product is consumed in the raw state and is storable for about 9 months without refrigeration (Leistner, 1987a). **Sharmoot** is a powdered dried meat product known in Sudan and other parts of North and East Africa, it has an a_w of 0.40 - 0.55 and is storable for at least 4 months without refrigeration. The product is prepared by cutting beef into thin strips, which after sun-drying are grinded into a fine powder. Before consumption Sharmoot is rehydrated, and thereafter is used with vegetable ingredients for various dishes. Gailani and Fung (1989) investigated improved methods for the processing of this product and the microorganisms associated with Sharmoot. **Odka** is a dry-salted and sun-dried meat product made of lean beef, it is of major importance to Somalia and other East African countries. Relatively large meat strips are cut after only 4 - 6 hours of sun-drying into smaller strips and cooked in oil. After this heat treatment drying is continued and finally spices are added. For storage Odka is again covered with oil and, when kept in closed containers, it has a shelf-life of more than 12 months (Heinz and Winkelmann, 1990). **Qwanta** known in Ethiopia and other East African countries is made from long strips of beef muscles which are prior to drying coated with a sauce containing a mixture of salt (25%), hot pepper/chilli (50%) and other spices (25%).

After drying the meat pieces are exposed to a light wood smoke and are then fried in butter fat and dried again to some extent. At this stage the product is ready for consumption or storage (Heinz and Winkelmann, 1990). **Khundi** is produced in Nigeria by smoke-drying fresh beef, camel or horse meat. This meat is cut into pieces, sprinkled with salt and smoked over hardwood on a grill for about 3 days, until it is 'well smoked'. The final product may have a NaCl-content of about 0.5%, however, since the a_w is about 0.80, it is storable for several months without refrigeration. The effects of different smoking methods on phenol and benzo(a)pyrene levels of Khundi were investigated by Alonge (1987), and he observed rather high benzo(a)pyrene levels (average 41 mg/kg) in this product. **Kilishi** are thin slices of meat from lean muscles of beef, goat or lamb. It is produced on a large scale in Nigeria and other arid or semi-arid zones of West Africa, and is sold in the streets or in supermarkets, and even is exported from Nigeria to Saudi Arabia. The sun-drying of Kilishi is a two-stage process. In the first stage of drying the moisture of the meat slices has to be reduced to about 40 - 50%. The slices are then put into an infusion containing 'defatted' wet groundnut cake paste (about 50%), and is further composed of water (30%), garlic (10%), bouillon cubes (5%), salt (2%) and spices such as pepper, ginger and onion. The 'dried' slices of meat should absorb the infusion up to almost three times their weight. After infusion, the wet product is again exposed to the sun to dry. When the moisture content of the slices has been reduced to 20 - 30% the slices are roasted over a glowing fire for about 5 minutes. The roasting process helps to enhance the flavour and to inactivate microorganisms. After roasting, the final moisture content ranges between 10 - 12% (Heinz and Winkelmann, 1990). Kilishi, when packaged in sealed containers, is stable without refrigeration for about one year. Igene et al. (1990) studied the physical, chemical and sensory characteristics of Kilishi and observed a remarkable oxidative lipid stability in this product. **Biltong** is a well-known dried meat product originating from beef or game meat, and is regarded as a delicacy in South Africa. Its use dates back to the early settlers of the Cape (van Wyk, 1980; van der Riet, 1982). Most muscles in the carcass may be used for Biltong, but the largest muscles are most suitable. The meat is cut with the grain into large strips and placed in brine, or frequently salted in the dry state. Common salt is the principal curing agent used, although other ingredients such as sugar, vinegar, pepper, coriander, garlic, or other spices are included in some pickling mixtures. Nitrate and nitrite as well as other preservatives (e.g. potassium sorbate) are sometimes added. Biltong is left in the cure for several hours, then dipped into hot water with vinegar and is now ready for sun-drying for one day. Then the strips are moved into the shade for the rest of the drying period (Heinz and Winkelmann, 1990). The a_w of microbiological stable Biltong should be below 0.70 (van der Riet, 1982), however, a wide variety of a_w is encountered (Shin, 1984), since specific standards for processing of Biltong do not exist. Spoilage is mainly caused by xerotolerant moulds and/or rancidity (van der Riet, 1982), however, some consumers prefer Biltong with a slightly rancid flavor (van Wyk, 1980). Biltong is sold in sticks, slices, and in the ground or pulverized form. These meats may be stored for months without refrigeration, in airtight packages for more than one year. Biltong is not heated during processing or before consumption; and since it is eaten in the raw state, it has caused food-poisoning due to salmonellae (Prior and Badenhorst, 1974). Therefore, care in the selection of meat as well as good hygiene is required in the processing of Biltong (van der Riet, 1982). The introduction of Biltong for general use in developing countries is hampered by these requirements, however, the risk can be minimized if certain guidelines are observed (Leistner, 1987a). Probably, the **drying of meat** under natural temperatures, humidity and circulation of air, including direct influence of sun rays, is the oldest method of meat preservation. Meat used for drying in developing countries is usually derived from unchilled carcasses and rapid ripening processes occur during the first stage of drying as the meat temperature continues to remain relatively high. For that reason the specific flavor of dried meat is quite different from the characteristic flavor of fresh meat (Heinz and Winkelmann, 1990). As a general rule only lean meat is suitable for drying, since an unpleasant rancid flavor is often the limiting factor for the shelf-life of dried meats; even a certain oxidation of meat fats might be considered typical for dried meats. Because meat is always consumed slightly salted, the raw materials may be presalted before drying. The presalting of meat has advantages from the sensory, technological and hygienic point of view, and shortens the time during which a safe a_w-level in dried meats is achieved. Furthermore, presalting is a protection against insects during drying. Additional treatments used for some special dried meat products are smoking, curing and the utilization of spices. These treatments flavor the products and encompass the addition of preservatives, e.g. phenols and formaldehyde (with smoking), nitrite (with curing), and bacteriostatic or fungistatic substances which are contained in certain spices. These additional treatments facilitate the processing of meat to safe and stable products, however, it should be remembered that the main criterion for shelf-stable and wholesome dried meat products is the water activity (a_w), and therefore the a_w should be the leading factor in studies and improvements of intermediate and low moisture meats of Africa.

America: The significance of a_w in the preservation of foods, including meats, has been emphasized in North America (Labuza, 1974; Troller, 1980) as well as in South America (Chirife, 1978; Chirife and Ferro Fontán, 1982). In North America only few intermediate moisture meats are known: **Pemmican** was an old Indian trail and winter storage food made of buffalo meat and berries. Labuza (1974) replaced in this product the buffalo meat with freeze-dried chicken, and called it **Hennican.** This newly developed IMF had an a_w of 0.85 and was used as a model in studies on the fungistatic effects of a number of substances. On the other hand, **Beef Jerky** is a traditional intermediate moisture meat which is actually on the market in the US and Canada. This product consists of lightly salted or marinated, spiced and dried slices of meat (Acton and Dick, 1976; Palumbo and Smith, 1977; DeLong, 1979). The processing, appearance and taste of Beef Jerky is similar to Biltong, and it has the nostalgic appeal too. Historically, Beef Jerky was a very important food commodity in North America, which substituted for fresh beef in areas where refrigeration was not available. Today, this product is a popular snack meat among campers and hikers. Holley (1985) inoculated Beef Jerky with several food-poisoning bacteria and observed that this product of normal retail quality would involve little risk, provided initial drying is done rapidly at temperatures of or above 55 - 60°C to an a_w below 0.86. From a microbiological viewpoint, refrigeration storage of Beef Jerky proved less desirable than storage under ambient temperatures. Intermediate moisture foods are more important in South America than in the North, and a multinational project on this subject is in progress. The project is called '**Development of Intermediate Moisture Foods (IMF) Important for Iberoamerica**' (CYTED-D-AHI), and it is part of a technical co-operation in 'Science and Technology for Development' (CYTED-D), which has been launched by Spain and 10 Iberoamerican countries to commemorate the 5th centennial of the discovery of America (Chirife, 1989; Aguilera et al., 1989). The objectives of this project are (i) to identify, characterize and critically evaluate traditional IMF of the region, and (ii) to determine the basic principles governing the stability (microbial and chemical) of these IMF. The project should lead to improvements in quality and safety of traditional IMF, and to the development of new IMF storable without refrigeration. The foods studied encompass products made of fruit and vegetables, milk, fish, cereals, as well as meat. From the participants 360 potential IMF of Iberoamerica were identified, and after a critical appraisal a total of 266 products remained in the list, and 29 of those were meat products. These meat products (raw ham, charque, cooked ham, salami, mortadella, Bologna-typed sausage and local varieties of sausages) were reported from Argentina, Cuba, Chile, Mexico and Venezuela, and they had the following physiochemical characteristics: a_w 0.67 - 0.95, moisture 22 - 60%, NaCl 3 - 26%, pH 4.5 - 6.4 (Chirife, 1989). All are storable without refrigeration. However, in the frame of CYTED-D-AHI not only IMF are studied but also combined methods (CM) of food preservation (Aguilera et al., 1989). This concept has been called 'Hurdle-Technology' by Leistner (1985b). The combined methods (CM) are considered to be an extension of the IMF-concept, because besides the depression of the a_w also other factors (hurdles), such as low heating, pH, Eh, competitive flora, preservatives, contribute to the stability and safety of the foods (Leistner et al., 1981). IMF/CM are believed to be for developing countries an appropriate alternative to other preservation methods for foods, such as refrigeration, freezing and canning, which need extensive infrastructure and are more costly (Anguilera et al., 1989). Since the a_w-range of IMF/CM based on meats was extented to 0.95, also products such as **Salchichón Viajero** of Costa Rica, which is a dried Bologna-type sausage with an a_w of 0.92 (Flores et al., 1982), are included in this concept. Wellknown traditional meat products of South America are Carne-de-Sol and Charque, which are consumed in large quantities in the remoter and more impoverished regions of Brazil, however, as specialities they are also appreciated by people living in large cities. Carne-de-Sol and Charque are traditionally manufactured from bovine muscle although sheep and goat meat are also used. Pork, which is rich in unsaturated fatty acids is not suitable for Charque, however, due to the shorter storage time it may be used for Carne-de-Sol (Norman and Corte, 1985). **Carne-de-Sol** (meat of the sun), was earlier known as Carne-de-Vento (meat of the wind). The latter name is actually more appropriate since drying is generally accomplished in covered, well ventilated areas without much direct exposure to the sun. This meat product is only lightly salted and partially dehydrated, and thus has a limited shelf-life (3 - 4 days at ambient temperatures), which is comparable to fresh meat held at refrigeration temperatures. Carne-de-Sol usually contains salt levels between 5 - 6% and a moisture content of 65 - 70%. Since the a_w of the final product is approximately 0.94, it is not a real IMF. However, because this product is manufactured by many small processors, in often inadequate facilities and without proper controlled procedures, the physicochemical characteristics of Carne-de-Sol vary considerably. This meat product is usually prepared from meat of the whole carcass which is cut into uniform thickness (2 - 4 cm) and dry salted, thereafter washed and dried in well ventilated areas, protected from insects by netting. Carne-de-Sol due to the lower salt content is more likely than Charque to be attacked by insects. Since the product is lightly and quickly salted, much of the salt remains in the superficial layers of the meat. This excess salt can be removed by soaking the meat for 1 - 2 hours in cold water prior to cooking, thus producing a cooked meat virtually indistinguishable from fresh meat (Norman and Corte, 1985). **Charque** consists of large, flat pieces of meat ('mantas'), mainly from the flank or forequarters of beef, preserved by salting and sun-drying. The raw meat with an uniform thickness of 2 - 4 cm is submerged in a saturated salt solution for about one hour, and thereafter dry-salted in piles. To form a pile, salt is spread evenly over the floor and then a layer of meat is put on the salt. The meat is covered with another (1 cm) layer of salt following by adding another layer of meat, and so on until the alternate layers of salt and meat reach a height of about 1 m. After 8 hours the pile is restacked so that the top meat goes to the bottom of the pile. The restacking process with fresh layers of salt is repeated every day for 5 days. Thereafter, the meat pieces are subjected to rapid washing to remove excess salt adhering to the surface. Now the meat is exposed to direct sun-light on wooden rails ('varales') which are oriented north-south, thus permitting an even solar coverage. To ensure even drying, the meat is placed on the rails during the morning and removed again in the afternoon. The meat pieces are exposed to the sun each day over a period of 4 - 5 days; in Brazil this is known as 4 - 5 'suns' (or 'sois'). Temperatures in excess of 40°C on the meat surface should be avoided. After each exposure the pieces are stacked in piles and covered with an impermeable cloth to protect them against rain and to hold the heat absorbed (Norman and Corte, 1985; Heinz and Winkelmann, 1990). Salt and sun are the most important ingredients for making Charque. The final product contains about 44 - 45% moisture and 12 - 15% salt, and this results in an a_w-range of 0.87 - 0.91. Charque is produced at the industrial scale in factories ('charqueadas'), and plants producing 30 tonnes per day are not uncommon. Since the product is stable for months without refrigeration, it may be transported over long distances. Charque has a typical strong odour and taste. Enzymatic fermentations probably occur to give the meat its typical flavor. However, whether lactic acid bacteria, such as Pediococcus halophilus, contribute to this ripening process is not well understood. On the other hand, it is known that halophilic bacteria might spoil (sour) the product. Charque is eaten always in the cooked state. Full rehydration of the product before consumption is not possible even with prolonged soaking, but excess salt might be removed in this manner. The 'de-salted' product is usually cut up into small pieces and cooked with beans or rice in dishes such as 'feijao', typical for Brazil (Norman and Corte, 1985).

CONCLUSIONS: On a world-wide scale with rapid increasing world-population the supply of meat will become more precious and scarce (Leistner, 1983). This prediction and the therefrom derived recommendation, to make better use of meat when available and at least to prevent spoilage in times of abundance, have proven to be reasonable. One approach to prevent spoilage is to process meat into meat products, and preferably those which don't need refrigeration and thus energy for storage. Fermented and intermediate moisture meats fulfill the latter prerequisite.

Furthermore, in industrialized countries fermented meats have the image of being preserved naturally with little use of chemicals, but are 'bio-preserved' with desirable microorganisms which are employed as starter or protective cultures. Considerable knowledge has been accumulated and the understanding of fermentation processes employed for meats is growing. These data are used in industrialized countries for the standardization and automation of fermetation processes, which lead to improved products. However, the present knowledge could also be used in countries where only recently an interest in the production of fermented sausages has grown, and this is true for a number of developing countries. However, by no means all is already known about the fermentation of meats, and there is still much room for improvements and further research efforts are justified.

Another sound approach for transformation of meat to stable and safe meat products are the intermediate moisture foods. Especially in developing countries it is reasonable to use traditional intermediate moisture foods, instead of taking over western technologies, e.g. refrigeration, freezing or canning, which need much energy and infrastructure. The traditional processes which have grown over centuries should be appreciated, because they inherent much wisdom. Traditional in preference over newly developed intermediate moisture meats should be applied, and if necessary optimized in using up-to-date methodology to study them. Especially gentle preservation methods based on 'Hurdle-Technology' should be studied and encouraged. Use of the HACCP-concept should be made to optimize and control production. In this endeavour a close co-operation between developing and industrialized countries could be of mutual interest, because a better understanding of traditional intermediate moisture meats would not only foster the supply of high quality and wholesome products in developing countries, but also could be an abundant source of innovative ideas for industrialized countries which could be used in food design.

In general, an exchange of efficient technologies for meat preservation between different parts of the world would be beneficial. As this incomplete review on fermented and intermediate moisture meats common in different regions demonstrates, there are similar but also quite different preservation processes used for these foods in Europe, Asia, Africa and America, therefore, indeed we could learn much from each other.

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