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# Food preservation by combined methods

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Foods preserved by combined methods remain stable and safe even without refrigeration, and are high in sensory and nutritive properties due to the gentle processes applied. The concept is gaining ground in industrialized as well as in developing countries. Several topics will be discussed briefly: (1) water activity, (2) hurdle effect, (3) hurdle technology (4) shelf stable products, (5) intermediate moisture foods, and (6) perspectives.

*Keywords:* combined methods, hurdle technology, shelf stable products, intermediate moisture food, water activity.

## 1 WATER ACTIVITY AND FOOD PRESERVATION

As is well known, the stability and safety of food does improve if the water activity ($a_w$) of the products decreases. Common methods for decreasing the $a_w$ of foods are drying, addition of salt, sugar or polyols, and freezing. The $a_w$ of foods influences the multiplication, metabolic activity, resistance and survival of the organisms present (Leistner *et al.*, 1981).

If we want to intelligently influence the $a_w$ of foods, we have to know it. The $a_w$ of foods may be calculated by employing equations (Chirife *et al.*, 1980) or it is measured using suitable instruments. Several reliable instruments are today available, which measure $a_w$ by applying different principles. We devised several years ago a simple hair hygrometer made by Lufft (Stuttgart, Germany) which is reasonably priced and works quite well, if handled with care (Rödel *et al.*, 1975). Widely used are electric hygrometers made by Novasina or Rotronic (both Zürich, Switzerland), for measuring the $a_w$ of foods (Rödel *et al.*, 1979), these are more precise, but also more expensive. Recently our laboratory has introduced a new instrument for the accurate and quick measurement of $a_w$ in meats, which is based on the determination of the freezing point (Rödel *et al.*, 1989). It is remarkable, that with this instrument made by Nagy (Filderstadt, Germany) an $a_w$ measurement is done in about 15 min, and the same instrument can be employed for determining temperature, relative humidity, pH and redox potential, of course, by using different sensors. Such multipurpose instruments are appropriate for quality assurance in food processing.

The stability and safety of many foods is not based soley on $a_w$, but on the combined effects of several factors. Therefore, the $a_w$ of foods should always be viewed in relation to other inherent factors, and this is the topic of this paper. The mode of action of the combined factors used in food preservation should be studied, since they could have an additive or even synergistic effect.

## 2 HURDLE EFFECT AND FOOD STABILITY

The hurdle effect is an illustration of the fact that in most foods several factors (hurdles) contribute to stability and safety. This hurdle effect is of fundamental importance for the preservation of food, since the hurdles in a stable product control microbial spoilage and food poisoning as well as the desirable fermentation.

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There are many processes used for making foods stable and safe, e.g. heating, chilling, freezing, freeze drying, drying, curing, salting, sugar-addition, acidification, fermentation, smoking or oxygen removal. However, these many processes are based on relatively few parameters or hurdles, i.e. high temperature (*F* value), low temperature (*t* value), $a_w$, pH, redox potential ($E_h$), preservatives, and competitive flora. In some of the preservation methods mentioned, these parameters are of major importance, in others they are only secondary hurdles (Leistner *et al.*, 1981).

We introduced the hurdle effect some years ago (Leistner, 1978), and it has since been modified and extended several times (Leistner, 1986*a*, 1987). The present concept is shown in Fig. 1, which gives eight examples. Example 1 illustrates the principle and represents a food which contains six hurdles (i.e. *F*, *t*, $a_w$, pH, $E_h$, and preservatives). The microorganisms present cannot overcome ('overjump') these hurdles, thus the food is microbiologically stable and safe. However, Example 1 is only a theoretical case, because all hurdles are of the same height, i.e. have the same intensity. A more likely situation is presented in Example 2, since the microbial stability of this product is based on hurdles of different intensity. In this product the main hurdles are the $a_w$ and preservatives, while other less important hurdles are storage temperature, pH and redox potential. These five hurdles are sufficient to inhibit the usual types and numbers of organisms associated with such a product. If there are only a few microorganisms present at the start (Example 3), then a few or low hurdles are sufficient for the stability of the product. The aseptic packaging of perishable foods is based on this principle. On the other hand, as in Example 4, if due to bad hygienic conditions too many un-

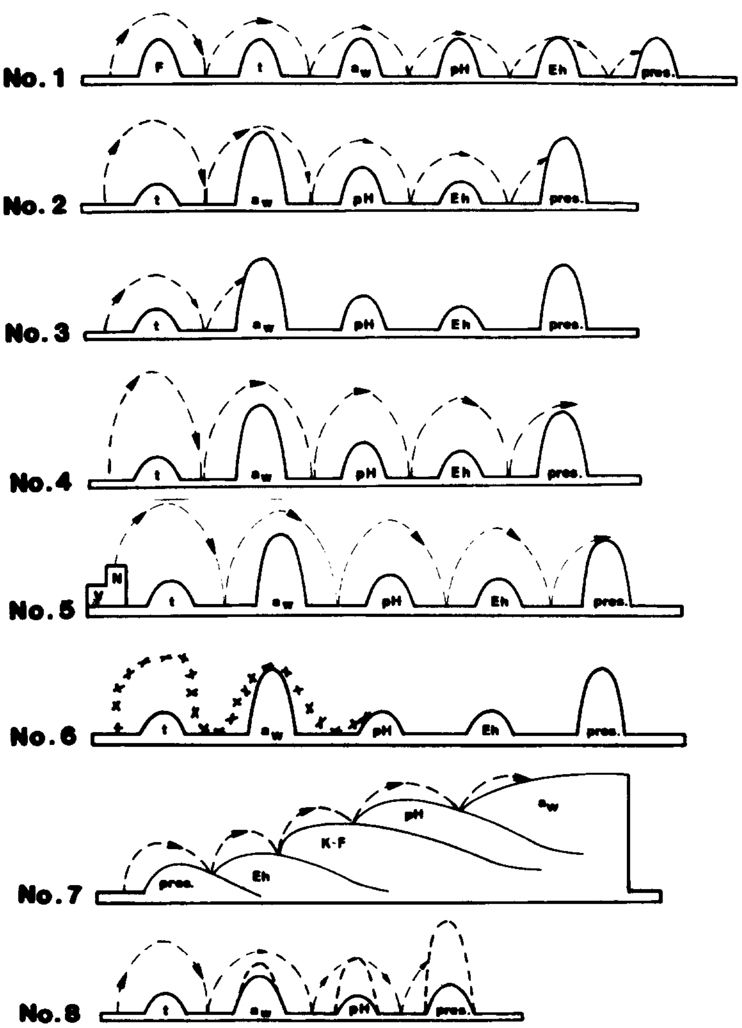


**Fig. 1.** Illustration of the hurdle effect, using eight examples. Symbols have the following meaning: F, heating; t, chilling; $a_w$, water activity; pH, acidification; $E_h$, redox potential; pres., preservatives; K-F, competitive flora; V, vitamins; N, nutrients.

desirable organisms are initially present, even the usual hurdles inherent in a product cannot prevent spoilage or food poisoning.

Examples 5 is a food superior in nutrients and vitamins, which foster the growth of microorganisms ('trampoline effect'), and thus the hurdles in such products must be enhanced, otherwise they will be overcome. Example 6 illustrates the behaviour of sublethally damaged organisms in foods. If, for instance, bacterial spores in meat products are damaged sublethally by heat (as occurs in F-SSP, discussed later), then the vegetative cells derived from such spores lack vitality, and therefore are already inhibited by fewer or lower hurdles. In some foods, such as fermented sausages and raw hams, the microbial stability is achieved during processing by a sequence of hurdles. Example 7 illustrates the sequence of hurdles in fermented sausages, as will be discussed later.

Finally, Example 8 should illustrate an important phenomenon, which deserves particular attention in foods preserved by combined methods, because different hurdles in a food might not just have an additive effect on stability, but could act synergistically. A synergistic effect of hurdles is to be expected if the different factors (e.g. pH, $a_w$, $E_h$, preservatives) have different targets within the microbial cell, and thus disturb the homoeostasis in several respects. This could make it difficult for spoilage or food poisoning organisms to overcome the lag-phase, and if multiplication is delayed the microorganisms eventually die. Therefore, employing different hurdles in the preservation of a particular food should be advantageous, because already with gentle hurdles microbial stability could be achieved. Certainly, the relationship between food preservation and the homeostasis of microorganisms deserves attention.

As Fig. 1 indicates, in fermented sausages we can distinguish five different hurdles which become active and fade out in a sequence (Leistner, 1985, 1986*b*). These hurdles effectively inhibit food poisoning organisms (*Salmonella* ssp., *Listeria monocytogenes, Staphylococcus aureus, Clostridium botulinum*) as well as other bacteria which might cause spoilage. On the other hand, this sequence of hurdles favours the selection of the desired competitive flora (especially lactic acid bacteria), which contribute to the stability of the products. An important hurdle in the early stage of the ripening process of salami is nitrite, added with curing salt, because nitrite inhibits the growth of salmonellae. Nitrite also inhibits some additional bacteria, while others can grow and due to the multiplication of these bacteria the redox potential of the product decreases, and this in turn enhances the $E_h$ hurdle, which inhibits aerobic organisms and favours the selection of the competitive flora, primarily lactic acid bacteria. Their growth and metabolic activity cause acidification of the product and thus an increase of the pH hurdle. This is of particular importance for the microbial stability of quick ripened fermented sausages, which are not properly dried. The hurdles of nitrite, $E_h$, competitive flora and pH diminish with time, because in ripened salami the nitrite level and the count of lactic acid bacteria decrease, while the $E_h$ and pH increase again. Only the $a_w$ is strengthened with time, and this hurdle is mainly responsible for the stability of long ripened fermented sausages. Certainly, also in the processing and storage of some other foods, e.g. cheese, a sequence of hurdles is responsible for microbial stability, and it should be challenging to investigate this phenomenon in various foods.

With fermented sausages we can differentiate in Germany two groups; i.e. quick ripened products and slow ripened products. Quick ripened products amount to about 80% of the production and the slow ripened products to only 20%. In quick ripened products the $a_w$ is rather high, because they still contain much water, and therefore are less expensive. However, to compensate for this high $a_w$ a low pH in such products is necessary for microbial stability. On the other hand, slow ripened products, which are more expensive due to the long drying period, have a low $a_w$, and therefore these products can afford a rather high pH which makes them much more tasty. I mention these differences between quick and slow ripened salami, because they illustrate that the hurdles in a food are somehow interchangeable. Emphasis could be given to different hurdles to achieve stability, with the consequence that the products have different features related to their sensory properties and price.

## 3 HURDLE TECHNOLOGY AND FOOD DESIGN

From the hurdle effect, the hurdle technology has been derived (Leistner, 1985, 1986*a*), since an intelligent combination of hurdles secures the microbial stability as well as the sensory nutritive, toxicological and economic properties of a food. The practical importance of hurdle technology for stable and safe foods has now been recognized by the food industry. In food design as well as food control this principle is increasingly applied and has proved very successful.

Even the pet food industry has made novel and attractive products by applying hurdle technology. A stable pet food was formerly produced with an $a_w$ of 0·85 and this needed addition of much propylene glycol which might have caused health implications in cats. But now based on hurdle technology pet foods are stable with an $a_w$ of 0·94, and they are more healthy, tasty, and economic.

Hurdle technology is now widely used especially in food design, for making new products according to needs. For instance, if energy preservation is the goal, then energy consuming hurdles such as refrigeration are replaced by hurdles ($a_w$, pH or $E_h$) which don't demand energy and still ensure a stable and safe food (Leistner, 1978). Furthermore, it we want to reduce or replace preservatives, such as nitrite in meats, we could emphasize the other hurdles in a food, e.g. $a_w$, pH, refrigeration, or competitive flora, which would stabilize the products (Leistner *et al.*, 1980).

Food control could be based on the physical and chemical measurement of hurdles in a food and computer evalution of the results. This approach could give faster and sometimes more reliable information on the stability and safety of foods than a microbiological investigation. Hurdle technology used for food control may be regarded as a precursor of predictive microbiology.

Hurdle technology is by no means a new process, as has been pointed out by Chirife *et al.* (1991) in their study on mummification in ancient Egypt. In the opinion of these authors the embalmed mummies contained (at least) three hurdles, namely reduced $a_w$ (0·72), increased pH (10·6) and preservatives (spices, aromatic plants). Therefore, the application of combined methods used for preservation has indeed a long history.

## 4 SHELF STABLE PRODUCTS (SSP) STORABLE WITHOUT REFRIGERATION

The term SPP was introduced by our laboratories (Leistner & Rödel, 1979) for high moisture meats ($a_w$ > 0·90), which may be stored for weeks or months without refrigeration, in spite of a mild heat treatment. We predicted (Leistner *et al.*, 1979) that SSP would gain importance. Fox & Loncin (1982) emphasized that in heated foods which contain only viable spores of bacilli and clostridia the microbial stability could be more easily achieved by certain hurdles, than in products where a large range of microorganisms is present.

Stability without refrigeration is an important feature for foods in developing as well as industrialized countries. In developing countries refrigeration is not readily available and in industrialized countries foods which need no refrigeration save costs by saving energy during distribution and storage. Furthermore, mild heat treatment (70–110°C core temperature) is beneficial, because it fosters the sensory and nutritional properties of the products. However, the heat process must be sufficient to inactivate all but sporulated bacteria. Since the containers are sealed, a recontamination of foods after heating is avoided. SSP still contain viable spores of bacteria, but the growth of surviving bacilli and clostridia is inhibited by a sufficient decrease of $a_w$, pH, and $E_h$. A low redox potential favours clostridia, on the other hand some bacilli are more $a_w$-tolerant than clostridia but can be inhibited by a low $E_h$. Therefore a low redox potential overall contributes to the microbial stability of SSP meats (Leistner *et al.*, 1980). For industrialized countries production of SSP is more attractive than intermediate moisture foods, because of the required $a_w$ for SSP is not as low, and thus less humectants and/or less drying of the products are necessary.

Depending on the hurdles which are most important for the stability of a particular product group, we distinguish today between F-SSP, $a_w$-SSP, pH-SSP and Combi-SSP; minor hurdles are also active in these products. The primary reason for stability of F-SSP is the inactivation or sublethal damage of bacterial spores, for $a_w$ the reduction of $a_w$, for pH-SSP an increased acidity, and in Combi-SSP several hurdles are balanced out. Traditional SSP meats (both $a_w$-SSP and pH-SSP) have been on the market for many years, the F-SSP were introduced about 10 years ago, and Combi-SSP are still under development, Hitherto the SPP concept has been mainly applied for meat products, however, certainly it could be useful for other foods too.

SSP are quite sophisticated products, which need reliable control of important critical points during manufacture, therefore, their processes are best defined using the HACCP concept. During processing the temperature and time as well as pH and $a_w$ should be strictly controlled, a microbiological investigation of the products based on suggested guidelines would provide additional information (Hechelmann *et al.*, 1991).

### 4.1 F-SSP

During the last decade German meat processors have introduced a new line of mildly heated meat products, which are sold in huge quantities by discount chains without refrigeration. These products are autoclaved sausages in casings, called F-SSP (Leistner, 1985). The products are given only relatively mild heat treatment ($F$ value 0·4), which inactivates all vegetative microorganisms and sublethally damages spores. Bacteria deriving from such spores have a diminished vitality, and therefore are already inhibited by $a_w$ and pH values that are not detrimental to the sensory properties of the products. A low $E_h$ contributes to stability (Leistner *et al.,* 1980). The four hurdles which are most important for the stability and safely of F-SSP have been called the 'magic square' (Leistner, 1986*a,* 1987), and in some products (Brühwurst) nitrite is also a hurdle.

F-SSP consist of liver, blood and Bologna-type (Brühwurst) sausages (100–500 g), filled in artificial PVDC-casing (30–45 mm diameter), impermeable to water vapour and to air, and closed by clips. These sausages are autoclaved for 20–40 min at 103–108°C under stringently controlled counter pressure (1·8–2·0 bar during heating, 2·0–2·2 bar during chilling). The autoclaved sausages have a shelf-life of at least 6 weeks without refrigeration. Strangely enough the F-SSP might even become sterile during storage. This is due to the fact that bacterial spores are able to germinate under less favourable conditions than where the vegetative cells of bacilli and clostridia are able to multiply. Therefore, during storage of the products some of the viable spores germinate, but the vegetative cells deriving from these spores die. Thus the spore count actually goes down during storage.

Of course, this will only happen if the products are microbiologically stable due to the following hurdles: the sausages must be heated to F values higher than 0·4, and if the initial spore count in the products was low (due to the use of spice extracts instead of natural spices), only relatively few bacterial spores will survive this heat treatment. The $a_w$ of F-SSP must be lower than 0·97 in Bologna-type sausages and lower than 0·96 in liver and blood sausages. The higher $a_w$ in Bologna-type sausages (Brühwurst) is possible, because nitrite is still active in these products, whereas the $a_w$ must be lower in liver and blood sausages, because in these products the nitrite is inactivated by the high iron content. The $E_h$ should be low in order to inhibit $a_w$-tolerant bacilli, and the air tight casings secure a low $E_h$. The pH of F-SSP should be lower than 6·5, but this is only critical in blood sausages, because the other products have a pH close to 6·0. Finally, for F-SSP casings are more advisable than cans (Hechelmann *et al.*, 1985), because during chilling of the cans after autoclaving, some water condensation may occur inside the lid, and if drops of water fall back on the surface of the sausage mix, locally the $a_w$ increases and thus growth of clostridia may start in this portion of the product. If autoclaved sausages fill the casings tightly, water condensation inside the container cannot occur, and therefore F-SSP in casings are more stable than in cans with headspace.

F-SSP have not caused botulism or severe spoilage problems during the decade they have been on the market. The obligatory guidelines for the manufacture of safe and stable F-SSP have been investigated and reported by Hechelmann & Leistner (1984).

### 4.2 $a_w$-SSP

The term $a_w$-SSP was chosen for products stabilized mainly by $a_w$, although other hurdles are important for their stability too (Leistner, 1985). The first experiments into $a_w$-SSP were done by Leistner & Karan-Djurdjić (1970). However, for a long time there have been already traditional $a_w$-SSP meats on the market, such as Italian Mortadella and German Brühdauerwurst, which have been produced empirically with an $a_w$ close to 0·95, but none of the manufacturers measured the $a_w$ of their products or even recognized the significance of water activity. In Italian Mortadella the reduction of the $a_w$ is achieved mainly by the formulation of the sausage and some drying during heating of the product. Whereas German Brühdauerwurst acquires the desired $a_w$ primarily by drying of the finished product. Due to the $a_w$ adjustment both product groups may be stored without refrigeration. Since the lipases are inactivated by heat in $a_w$-SSP meats, they are stable longer than fermented sausages. According to Wirth (1979), fermented sausages can be stored 15 months and German Brühdauerwurst even 18 months without much sensory deterioration.

The processing and stability of both groups of traditional $a_w$-SSP meats have been studied in our laboratories (Leistner *et al.*, 1979). For stable and safe meat products of the $a_w$-SSP type, the following guidelines (Leistner, 1987) must be observed: $a_w$-SSP should be heated to an internal temperature of at least 75°C in a sealed container, preferably casings. The water activity of $a_w$-SSP must be adjusted to or below 0·95. Thus, a lower $a_w$ is more essential than for F-SSP, because with the milder heat treatment of $a_w$-SSP the bacterial spores are damaged less than in F-SSP. The $E_h$ of the product should be low, because a reduced redox potential contributes to the growth inhibition of $a_w$-tolerant bacilli. The growth of moulds on $a_w$-SSP could be troublesome, because the surface $a_w$ of these products (since the casings are penetrated by water vapour) corresponds to the $a_w$ of the interior. Mould growth on the surface of $a_w$-SSP meats could be avoided by smoke or potassium sorbate treatment, or by vacuum packaging of the products. Hechelmann *et al.* (1991) recommended repasteurization of the vacuum packaged $a_w$-SSP for 45 min at 85°C. By this process not only moulds are inactivated but also other organisms, including lactic acid bacteria, which might grow on the vacuum packaged meats during storage. Repasteurized vacuum packaged $a_w$-SSP have a superior shelf-life.

### 4.3 pH-SSP

It is well known that pasteurized fruit and vegetable preserves with a pH <4·5 are bacteriologically stable and safe, in spite of only mild heat treatment. In such products vegetative microorganisms are inactivated by heat, and the multiplication of surviving bacilli and clostridia is inhibited by the low pH. Such foods could be called pH-SSP (Leistner, 1985). Since bacterial spores are able to germinate at lower pH levels than vegetative bacilli and clostridia are able to multiply, in pH-SSP, as in F-SSP and $a_w$-SSP, the number of spores tends to decrease during storage. On the other hand, while the heat resistance of bacteria and their spores is enhanced with decreasing $a_w$, it is diminished with decreasing pH. Thus pH-SSP need less heat treatment for the inactivation of microorganisms than do $a_w$-SSP.

Meat products of the pH-SSP type are brawns and in this jelly sausages are adjusted to an appropriate pH by the addition of acetic acid. Such products are, for example, composed of a brine (pH 4·8) made of water, gelatine, salt, sugar, agar-agar (1%), and spice, and a solid phase, made of Frankfurter-type sausage in cubes with an $a_w$ of 0·98. Both components are mixed (2 parts brine: 3 parts meat), filled in casings and heated to an internal temperature of at least 72°C but not higher than 80°C. If the product is in equilibrium, it should have a final pH below 5·2, and then it is storable for 6 days at 30°C without refrigeration (Hechelmann *et al.*, 1991).

### 4.4 Combi-SSP

Some SSP are stabilized by several hurdles which have to be well balanced with each other. Our experimental work suggests that even small enhancements of the individual hurdles in a food in summation have a definite effect on the microbial stability of a product. Figure 2 illustrates this phenomenon. For instance, for the stability and safety of meat products it is of significance whether the $F$ value is 0·3 or 0·4, the $a_w$ is 0·975 or 0·970, the pH is 6·5 or 6·3, and the $E_h$ value is somewhat higher or lower. Every small improvement or reinforcement of a hurdle brings some weight to the balance, and the sum of these weights determines whether a food is microbiologically unstable, uncertain, or stable (Fig. 2). In other words, all little steps in the direction of stability will finally decide whether or not the balance swings from an unstable into a stable state of a product. The quantification of these influences on the microbial stability of foods is an important research area of food designs. In this endeavour technologists and microbiologists must work together. The technologist must determine which additives are suitable for the enhancement of hurdles in foods by taking technological, toxi-

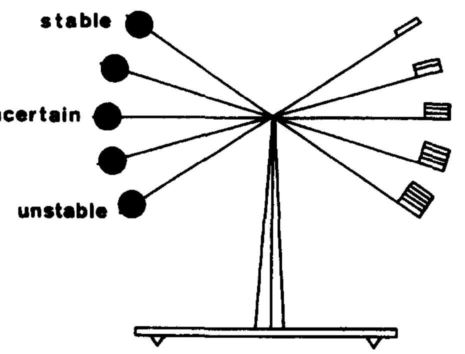


**Fig. 2.** The balance should illustrate that even small enhancements of different hurdles could bring about in summation a substantial improvement of the microbial stability of a food.

cological, sensory, nutritive, and legal limitations into consideration. The microbiologist must determine which intensity of factors or hurdles in a particular food are needed for the desired microbiological stability, and his concept has to be challenged by inoculation studies using relevant microorganisms in feasible numbers. Predictive microbiology could be useful in this respect too.

As an example of a Combi-SSP the Gelderse Rookworst of the Netherlands could be mentioned. This is a Bologna-type sausage (Brühwurst) in which the pH by the addition of glucono-delta-lactone is adjusted to 5·4–5·6. This product is microbiologically stable for several weeks without refrigeration, if vacuum packaged in a pouch and then pasteurized at 80°C. This treatment inactivates vegetative organisms in and on the sausages. Bacterial spores are apparently not of much concern in this product, since their population decreases during the heating process and the surviving spores are inhibited by the low pH. If the product is manufactured with a somewhat higher pH, the sensory properties definitely improve, however, then the $a_w$ of the product has to be lowered in order to obtain the desired stability.

We have followed this line in our product design of Bologna-type sausages as Combi-SSP. Different types of Brühwurst (wieners, bockwurst, fleischwurst, fleischkäse, fleischkäse in slices) were developed which proved stable and safe during 6 days of storage at 30°C. The initial spore load should be low, and these products are heated to a core temperature >72°C, and are adjusted to an $a_w$ and pH of 0.965 and <5·8, respectively. The products are re-pasteurized after vacuum packaging for 45–60 min (depending on the diameter of the products) at 82–85°C (Hechelmann *et al.*, 1991). Combi-SSP offer many opportunities, however, they require strict process control following the HACCP concept.

## 5 NOVEL AND TRADITIONAL INTERMEDIATE MOISTURE FOODS BASED ON MEAT

The intermediate moisture foods (IMF) are stabilized by $a_w$ in the range of 0·90–0·60, although additional hurdles, such as heating, preservatives, pH and $E_h$ might be important too. Many traditional and some novel IMF are known. Such foods need no refrigeration during storage.

### 5.1 Novel IMF

An example of this product group in the meat field is mini-salami. This product is liked by the consumers as a snack and it is produced in large quantities in Germany, also for export. Mini-salami is based on hurdle technology and is produced either as fermented sausage ($a_w$ < 0·82) or as dryed Bologna-type sausage ($a_w$ < 0·85). In the packaging of mini-salami a modified atmosphere is used in order to delay rancidity and to avoid the growth of moulds (Tändler & Rödel, 1983). As the example of mini-salami demonstrates, a modified atmosphere could be another hurdle which contributes to stability, especially if carbon dioxide is used.

### 5.2 Traditional IMF

In different regions of the world, traditional IMF based on meat are known. This is especially true of Asia (e.g. tsusou-gan, njorsou-gan, sou-song of China, or dengdeng giling of Indonesia) as well as for Africa (e.g.biltong, khundi, quanta, pasterma, klich, iamkila). Some IMF meats are also known in America (e.g. charque, carne de sol, beef jerky). The IMF based on meat are nutritious and palatable, and are much liked by the consumers.

In such products hurdle technology is empirically applied, and they are easy to prepare and to store, because only simple equipment is needed, and neither expensive packaging nor refrigeration are required. Furthermore, common humectants (salt and sugar) are employed, and thus no 'chemical over-loading' of these foods results.

Recently, the traditional IMF based on meat have been reviewed (Leistner, 1990, 1991), and thus in this contribution a few remarks should suffice. It is obvious that a thorough study of traditional IMF using up-to-date methodology would be of benefit to developing countries. However, also for industrialized countries such studies are rewarding, because traditional products are an abundant source of innovative ideas which could be used in food design. For instance, we learned from Chinese sausage (lup cheong) that a sausage could be preserved in the raw state even without fermentation, or we realized that in charque of Brazil a fermentation takes place even at an $a_w$ < 0·90, if halophilic pedicocci are involved. Heat inactivation of most pathogenic bacteria, including staphylococci, is achieved in some Chinese IMF meats by just applying 50°C for several hours. Another interesting aspect of traditional IMF meats is the bacteriocidal effect of Maillard products towards food poisoning organisms, because if these recontaminate the product after heating and drying they don't survive long. Apparently the growth inhibition of xerotolerant moulds on unpackaged Chinese dried IMF meats with an $a_w$ of 0·69 is also supported by Maillard reaction products, which therefore probably are important hurdles for traditional IMF.

## 6 CONCLUSIONS AND PERSPECTIVES

Food preservation based on combined methods is applicable for the improvement of traditional products as well as the design of novel foods. Combined methods secure stable and safe foods in spite of a gentle preservation, and thus result in products with high sensory and nutritive properties. Research in combined processes has brought about admirable results in Latin America within the CYTED-D project. Also combined methods for food preservation are currently studied in Europe within a project of the FLAIR-PROGRAM, and eleven countries participate in this project.

Several concepts for improvement of the safety, stability and quality of foods have emerged in recent years and are pursued. Now, taking into consideration Good Manufacturing Practice (i.e. a better defined GMP), Hurdle Technology, the HACCP Concept and Predictive Microbiology, an overall strategy for better foods should be derived, which is applicable in industry as well as in small and medium size enterprises, if possible world-wide.

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