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# PRESERVATION OF RAW MEAT - PRESENT STATUS AND FORESEEN TECHNOLOGIES*

Summary

In the paper an attempt was made to highlight various aspects of present status and foreseen methods, technologies and techniques for fresh meat and processed meat products preservation. Emphasis was made on existing preservation methods categories and the means of preservation within each category used. Prediction for future direction of traditional preservation methods usage is made. Potentiality for use of novel non-conventional methods as tools for slaughter raw material and processed meat product preservation is presented.

## Introduction

The mankind safe existence began not only when the man-like-apes learned to harvest the food raw materials such as: fruits, roots, leaves, corns, nuts, small animals, insects etc., but when attempted to develop and to implement methods for food preservation, so as to be able to overcome periods of extreme shortage and/or scarce food supply due to natural catastrophes or crop failure etc. The commonly used methods for meat preservation by primitive man were: drying and smoking, and thereafter heat treatment (cooking, roasting, frying), salting or curing. Since such an early time, preservation of plant crops is considered of paramount and most important issue for the mankind. This concerns also the animal origin raw materials i.e. carcass meat, wholesale and retail cuts, processed meat products, offals etc. It is generally recognised that the preservation of all kind of food raw materials including meat and processed meat products is accomplished by creating an unfavourable environment for the proliferation of spoilage organisms such as: bacteria, yeast, moulds, parasites etc. aiming at delay or elimination deteriorate changes, which make meat and meat products unusable as a food or which downgrade some quality aspects of them. The effect of preservation

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depends also on controlling the action of certain enzymes within the tissue, and preventing the chemical oxidation of lipids which leads to rancidity.

## The greatest achievements in theory and practice of food conservation during last quarters of XX century - invention of hurdle concept of preservation

According to Chirife [17] the traditional food preservation procedures rely upon the use of "extreme conditions" namely: high temperature (sterilisation), very low temperature (freezing), high acidification, dehydration etc. In that contents it seems justified to present the opinion of Board and Gould [8] who described such situation by saying: „the traditional approach to food preservation is equivalent to stopping a clock by striking it once with a heavy object: the mechanism is broken (microbial growth is stopped) but the case (organoleptic properties of the food) is invariably extensively damaged". Some of the limitations of conventional methods of food preservation are shown below (Tab. 1).

Table 1

Some limitations of traditional food preservation methods based on one hurdle.

| Method | Hurdle | Limitations |
|---|---|---|
| Air drying | $a_w$ | Loss of flavour, shape and colour. Pure texture. Slow/incomplete rehydration |
| Freeze-drying | $a_w$ | Cost |
| Canning | Thermal inactivation | Quality loss. Cost of the can & energy |
| Salting | $a_w$ | Very high salt content, poor texture |
| Acidification | pH | Flavour changes due to high acidity (natural/artificial) |
| Preservatives | Antimicrobial action | Legal and health problems |
| Refrigeration or Freezing | Low temperature | Energy cost. Absence of „cold chains" (also $a_w$ for freezing) |

Chirife, J. [17]

Therefore, combined methods of food preservation, invented and developed by Leistner, gained a world-wide recognition and the concept is known as „hurdle preservation technology". According to the hurdle concept of food preservation each preservation process is based on one or two main hurdles, with additional minor hurdles being required to provide the expected microbial and/or enzymatic stability [17, 65, 71, 72, 73, 74, 77, 94, 126].

Table 2

Techniques and technologies of raw material and food product preservation.

| A. PHYSICAL METHODS (HURDLES) | | | |
|---|---|---|---|
| A. 1. | Heat processing (heat transfer: conductance, convection, radiation) (main means: hot air, water, fat or oil, steam) | A. 4. | Electromagnetic energy (EME) |
| | | A. 4a. | *Microwave energy* |
| | | A. 4b. | *Radiofrequency energy* |
| | | A. 4c. | *Oscillating magnetic field pulsed energy* |
| A. 1a. | *Sterilization* | A. 4d. | *High electric pulses field energy* |
| A. 1b. | *Pasteurization* | A. 5. | Photodynamic inactivation (high energy density pulsed light) |
| A. 1c. | *Cooking* | | |
| A. 1d. | *Scalding* | A. 6. | Ultrahigh pressure (Pascalisation) |
| A. 1e. | *Blanching* | A. 7. | Ultrasonication |
| A. 1f. | *Ohmic heating* | A. 8. | Packaging |
| A. 1g. | *Radiant heating (grilling)* | A. 8a. | *Vacuum packaging* |
| A. 1h. | *Dielectric heating* | A. 8b. | *Moderate vacuum packaging* |
| A. 1i. | *Extrusion cooking* | A. 8c. | *Active packaging* |
| A. 2. | Storage temperature | A. 8d. | *Smart packaging* |
| *A. 2.a.* | *Above the freezing point (cooling, chilling)* | A. 8e. | *Aseptic packaging* |
| | | A. 8f. | *Edible coatings* |
| A. 2b. | *Below the freezing point (freezing)* | A. 9. | Modified atmosphere packaging |
| | | A. 10. | Modified atmosphere storage |
| A. 3. | Radiation | A. 11. | Controlled atmosphere storage |
| A. 3a. | *Ultraviolet (UV)* | A. 12. | Hypobaric storage |
| A. 3b. | *Ionizing (Radappertization, Radicidation, Radurization)* | A. 13. | Microstructure |

| B. PHYSICOCHEMICAL METHODS (HURDLES) | | | |
|---|---|---|---|
| B. 1. | $a_w$ | B. 12. | Sulphite or $SO_2$ |
| B. 2. | pH | B. 13. | Phosphates |
| B. 3. | Redox potential (Rh) | B. 14. | Glucono-delta-Lactone |
| B. 4. | Salt (NaCl) | B. 15. | Phenols |
| B. 5. | Nitrite ($NaNO_2$) | B. 16 | Chelators |
| B. 6. | Nitrate ($NaNO_3$ or $KNO_3$) | B. 17. | Ethanol |
| B. 7. | Carbon dioxide ($CO_2$) | B. 18. | Surface treatment agents |
| B. 8. | Nitrogen ($N_2$) | B. 19. | Propylene glycol |
| B. 9. | Oxygen ($O_2$) | B. 20. | Spices and Herbs |
| B. 10. | Ozone | B. 21. | Lactoperoxidase |
| B. 11. | Organic acids | B. 22. | Antioxidants |
| B. 11a. | *Lactic acid, lactate* | B. 23. | Lysozyme |
| B. 11b. | *Acetic acid, acetate* | B.24. | Curing |
| B. 11c. | *Ascorbic acid ,ascorbate* | B. 25. | Smoking |
| B. 11d. | *Sorbic acid, sorbates* | B. 26. | Maillard reaction products |
| B. 11e. | *Formic acid, formiates* | B. 27. | Carbon monoxide |
| B. 11f. | *Propionic acid, propionates* | | |

| C. MICROBIALLY DERIVED TECHNOLOGIES (HURDLES) | | | |
|---|---|---|---|
| C. 1. | Competitive flora | C. 3. | Bacteriocins |
| C. 2. | Starter cultures | C. 4. | Antibiotics |

| D. MISCELLANEOUS TECHNOLOGIES (HURDLES) | | | |
|---|---|---|---|
| D.1 | Monolaurin | D. 3. | Chitosan |
| D. 2. | Free fatty acids (FFA) | D. 4. | Chlorine |

[Bogh-Sorensen [9] Adapted and modified by Duda, Z.]

According to Bogh-Sorensen [9], the most important hurdles, especially for safety and stability, could be subdivided on: physical, physico-chemical, microbiologically derived and miscellaneous hurdles. The above categorisation of preservative methods could be considered of being appropriate to the contemporary development level of food preservation techniques and technologies. They are summarised in Table 2.

Assuming that different deterioration processes must be under permanent control for maintenance of meat quality, the most dangerous from public health and economic points of view, by no means and undoubtedly, is the microbial spoilage. It will quickly make meat unfit for consumption and by any criterion fresh meat, due to its chemical composition, must be considered a highly perishable product and preserved immediately [68, 57]. Therefore, minimisation and/or limitation, of the initial number of microorganisms that contact and contaminate raw meat, offals and/or processed meat products, will lengthen their shelf life. Simultaneously, it will very considerably influence the potentiality of storage length resulted from amelioration and/or increase of used traditional industrial preservation methods effectiveness [13, 36, 107, 129].

Demand for up-dating knowledge on recent technologies which allow extension of the storage and distribution period without jeopardising public health or the consumer's image of meat, resulted in conducting by the European Consortium for Continuing Education in Advanced Meat Science and Technology (ECCEAMST) advanced training course in „Shelf life of meat and meat products: quality aspects, chemistry and microbiology". Published proceedings of this course could be recommended as a manual assisting in acquaintance with contemporary developments in meat and meat products preservation and their shelf life extension [4].

## Improvement of carcasses, sides and cuts preservation methods effectiveness through reduction of initial surface microbial (bacterial) contamination

The investigations oriented toward identification of the sources and levels of after slaughter and dressing invasion and proliferation of bacteria and other sorts of microflora, resulting in surface bacterial contamination of beef, pork and/or sheep carcasses, sides, cuts, etc., which seriously limits the shelf life and refrigerated (chilling) storage

period, and thereafter invention of the processes or procedures: physical, chemical and/or biological, focused on minimisation and/or elimination of the initial, carcasses and/or sides surfaces bacterial contamination are subjects of numerous recent publications. This reflects and indicates the great importance of the problem for the meat industry [21, 22, 27, 30, 42, 43, 44, 46, 48, 67, 102, 112]. Excellent review paper illustrating and summarising the research achievements, developments and progress in technologies and techniques used for diminishing the initial bacterial contamination of meat and meat products was recently published by Sofos and Smith [115]. The paper deals with non-acid meat decontamination technologies and their commercial applications. In order to complement the problem presented and discussed in the above mentioned review paper and other publications, it is worthwhile to mention of the promising effects of chitozan and urea in meat preservation [24, 95].

Having in mind the data presented in the above selectively cited literature sources, it could be concluded that any approach oriented toward diminishing initial bacterial contamination of the raw materials used in meat processing and culinary meat supply is fully justified. It results from increased consumer awareness and concern about microbial foodborne diseases and simultaneously resulted in enhancement and intensification of the efforts to reduce contamination of raw meat. This is evidenced by new meat and poultry inspection regulation being implemented in the USA. Accordingly, these regulations as well as the implementation of the principles of the hazard analysis critical control point (HACCP) system, renewed and intensified interest of meat and poultry slaughtering and processing plants, in the development and commercial application of meat and poultry surfaces decontamination procedures. Technologies and techniques developed and evaluated for initial surface of carcasses microbial decontamination and recommended for hampering bacterial proliferation in raw semi-processed meats (meat), presented and discussed in numerous recent publications, as well as in the above mentioned review paper include: live animal cleaning /washing, chemical dehairing, steam/hot water vacuuming for spot-cleaning/decontamination of carcasses, spraying/washing/rinsing of carcasses with water of low or high temperatures and pressures or chemical solutions, side of carcasses exposure to pressurised steam etc. Some of them are already employed in commercial applications. One of several recently invented facilities for carcasses surface bacterial decontamination is presented below (Fig. 1).

Use of the non acid chemicals: chlorine, chlorine dioxide, trisodium phosphate, hydrogen peroxide, ozonised water, potassium sorbate, nisin and commercial decontaminating agents for microbial decontamination of carcasses are mentioned. Physical decontamination treatments are also briefly discussed by Sofos and Smith, as well as, by numerous other authors [15, 16, 18, 20, 35, 47, 50, 55, 69, 70, 79, 86, 93, 99, 105, 106, 119, 121, 122, 123, 125, 131].

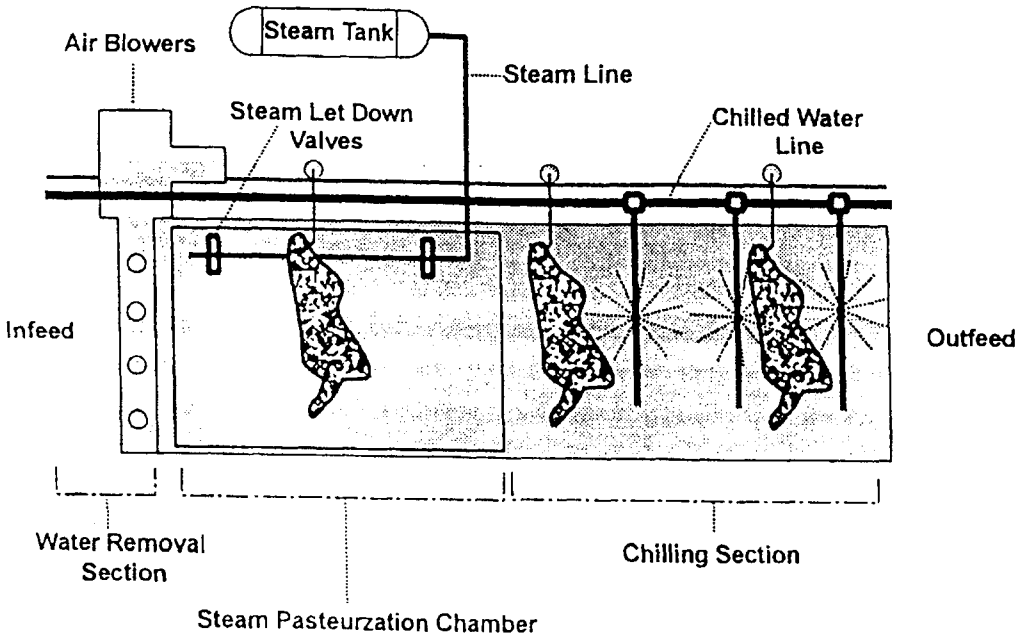


Fig. 1. Schematic diagram of commercial pasteurisation system. (Phebus, at. all., 1997).

Biopreservation of selected raw materials and food commodities, including fermented processed meat products, refers to extended storage life and enhanced safety of foods using the natural microflora and /or their antibacterial products. Lactic acid bacteria are considered of having a major potential for use in biopreservation. Their preservation effect is demonstrated by reduction the putrefactive bacteria population, as well as pathogenic microflora. Preservative effectiveness in meat by bacteriocins, nisin alone and/or as different joint treatments is presented in many papers [22, 49, 108]. Bacteriocins, other than nisin, are also considered of being effective preservatives for raw meat, semi-products like ground meat (beef, pork), fermented sausages etc. [1, 3, 19, 40, 53, 56, 62, 117, 120].

Research findings on use of diluted solutions of organic acids (acetic, lactic, fumaric, gluconic, propionic, ascorbic) as a very effective surface of carcasses, subprimal and retail cuts bacterial decontaminates are summarised in recent review paper by Smulders and Greer [114]. The results of relevant investigations that are presented and critically discussed there, are indicating that the reduction of initial bacterial contamination of slaughter raw materials is strongly influencing the applied preservative methods effectiveness, and consequently the shelf life of culinary meat, raw semi-products and processed meat products. Favourable and efficient decontamination of carcasses,

sides, subprimals, cuts surface and/or ground meat, as well as, processed products (sausage, cooked ham), by diluted organic acids treatments and/or treatment by diluted acids in combination with other bactericidal or bacteriostatic agents [electricity, extracts of spices (ginger, garlic, onion), nisin, etc], are also presented in several other publications [5, 7, 28, 90, 97, 104, 109, 127, 132].

**Envisaged perspectives for traditional slaughter raw materials and processed meat product preservation technologies**

Practically, preservation effectiveness for all sorts of food raw materials, both plant and animal origin, of known and commonly used preservation methods and/or techniques, to the great extend depends on kind and chemical composition of raw materials used for food commodities manufacturing. Consequently, effectiveness of used methods of preservation of food products, manufactured from relevant raw materials, depends mainly on selected features, namely: the amount of water, particularly of biologically available, initial microbial contamination which reflects the hygienic standard of handling and/or processing, applied method of preservation, conditions and period of storage, etc. All above concerns mainly such commonly used methods of preservation like: chilling, scalding, cooking and pasteurisation. Heavy (massive) initial contamination of raw materials greatly diminish probability of sufficient level of destruction by the above mentioned methods of preservation, the vegetative form of microorganisms, particularly of bacteria. Therefore, the hygienic processing and/or so called good manufacture practice and particularly the implementations and observation of the HACCP concept in handling of animal origin raw materials, mainly culinary meat and meat products, is considered of being of paramount importance for effectiveness of used preservation technologies, and consequently the wholesomeness point of view of animal origin food products processing.

It could be predicted that in the near future shelf-life of a great assortment of culinary meat cuts such as for example pork and lamb chops, t-bone steaks and the like, as well as, semi-processed mainly ground meat products (hamburgers, meat balls etc.) will be substantially extended using novel physical methods and techniques of preservation. Raw ground meat, mainly beef, used for preparation many different dishes in household, is in many countries a popular commodity available in retail meat shops and/or in supermarkets. Being very perishable product it requires special care i.e. to maintain chilling chain throughout whole handling and distribution and/or to apply appropriate food preservatives, physical treatment like irradiation (ionising, ultraviolet) and/or other supplementing methods for extension of its shelf life. Nowadays, applied food preservation and processing methods, techniques and/or technologies are generally considered to secure the supply of a wholesome, nutritious and tasty food, including meat and processed meat products [91, 92]. However, it should be stressed that

even slightly destructive preservation methods can not be acceptable and should be substituted by the methods which negative effects are negligible or the negative effects do not exists at all. Simultaneously, commonly used preservation methods must be trustworthy, reliable and economically justified.

Recently, professionals envisaged **renaissance of the refrigeration** methods for food preservation, particularly of **chilling**, although with reservation of simultaneously extended shelf live. Such an opinion is based on that the refrigeration technologies and techniques of food preservation, among other attributes, are more environmentally friendly, creating less waste, commodities are stored more easily and taking up much less vital space for inventory and are easier to use. It is also predicted that in coming years advances in packaging will have a major impact on the industry manufacturing refrigerated i.e. chilled and frozen foods, aiming at fulfilling consumer demand for foods preserved by refrigeration [88]. Increasingly, consumers are demanding minimally-processed foods including animal origin (meat, poultry, fish, etc.) that are high in quality, nutritionally superior, tasty, easy to prepare and economic [26, 99]. According to Marth [85], extended shelf life refrigerated foods are those that have received minimal processing or pre-cooking and have an enhanced but limited shelf life. For such foods the refrigeration is a key preservation measure. These food include: luncheon meats and cured meats, as well as, partially processed refrigerated foods such as different sorts of salads, soups, entries, complete meals, uncured meat and poultry items. However, effectiveness of chilling as a preservation method of fresh meat and processed raw and cooked meat products is nowadays linked with simultaneously applied other conservation methods. Among other it is advisable or recommended to use such complementary methods as for example: vacuum, controlled and/or modified atmosphere packaging, if possible and preferentially in edible and/or biodegradable polymer films packing materials and/or coatings. Use of oxygen and free radicals quenchers, metal scavengers, retarders, antioxidants, bacteriocins, irradiation, etc. is also considered and envisaged and partially already implemented [2, 10, 29, 39, 41, 45, 58, 64, 66, 80, 82, 89, 103, 116, 124].

However, applying refrigeration for food preservation (mainly chilling) particular attention should be focused on maintaining the required, stable temperature during whole period of refrigerated food storage. It is strongly recommended to avoid abusive temperature, i.e. above 10°C, at which many psychrotrophic bacteria and nonproteolitic pathogens such as *Clostridium botulinum* and *Listeria monocytogenes* can grow, albeit slowly [31].

Regarding pork, lamb and beef carcasses, chilling technology and methods, numerous different technologies have been investigated and are recommended and considered for industrial use. Symptomatically enough, according to selected publications,

ultra-rapid and spray-chilling, cryogenic, and other non-traditional refrigeration (chilling) technologies are recommended [11, 14, 59, 60, 63, 78, 83, 84, 111, 118, 130].

It could be also predicted with a great probability, that as at present and still for many coming decades freezing will remain most commonly used preservation and long storage method for raw meat, edible offal's, and selected raw processed meat products. Recommended and already selectively applied decrease of frozen storage temperature to around -40°C or even lower, will considerably lengthen storage time of large assortments of food products, including meats, without deterioration effects on stored products, mainly on the texture. In the above contents it seems worthwhile to focus the readers attention on that, that already in 1963, Dalhoff, E. and Jul, M. presented their results of investigation showing great influence of freeze storage temperature lowering on substantial lengthening of keeping times for frozen meat products (pork chops). The so called TTT (The Time Temperature) concept of meat item frozen storage, illustrated by Fig. 2. shows, that time and temperature of storage are equally important factors for frozen food (meat) storage from the quality point of view.

For preservation of selected assortments of processed meat commodities (hamburgers, meat balls, steaks, chops etc.), very rapid freezing techniques and technologies (fluidised bed freezing, brine, cryogenic and impingement freezing), using tunnel, spiral and/or cryogenic freezers, preventing the formation of large ice crystals that can damage cells and allow loss of moisture („drip loss") and subsequent loss of texture upon thawing, could be envisaged [87, 100, 113]. In order to reduce damage resulted from frozen storage of meat, preslaughter administration of antifreeze proteins was examined and their use positively assessed [101]. Use of cryoprotectants for frozen red meats is also suggested Tomaniak A, et all. [128].

It could also be envisaged that with observed developments in construction of the controlling and/or steering devices, allowing precise maintenance of required temperature in refrigerated chambers, still neglected method of raw meat preservation at it cryoscopic temperature will be given due consideration. Research findings showed possibility of raw meat storage at -1.5 to -2.5°C without water crystallisation, i.e. of the ice crystals forming in meat tissue. Meat, at cryscopic temperature, could be stored over 4 weeks and thereafter will be as fresh as stored at 4°C [34].

Heat treatment, as at present, will be also in coming future the most commonly used preservation method for food products consisted with the great variety of heat applied technologies. All known and used methods of heat treatment of meat and processed meat product such as: cooking, scalding, frying, roasting, pasteurisation and tyndalisation, but particularly sterilisation, are considered of very trustful and effective methods of food preservation, although their effectiveness depends on the amount of heat energy absorbed. Sterilisation applied by the food caning industry and commonly used at present, will continue to be popular preservation technology also for the fore-

seen future. It allows long term storage of food (meat) products at ambient temperature and to maintain strategic (emergency) reserve deposition, particularly those of animal origin. Drying jointly with fermentation will be also in future used by the meat industry to manufacture the fermented meat products i.e. long ripening assortments such as salami type sausage, prosciuto or Iberian type hams etc.

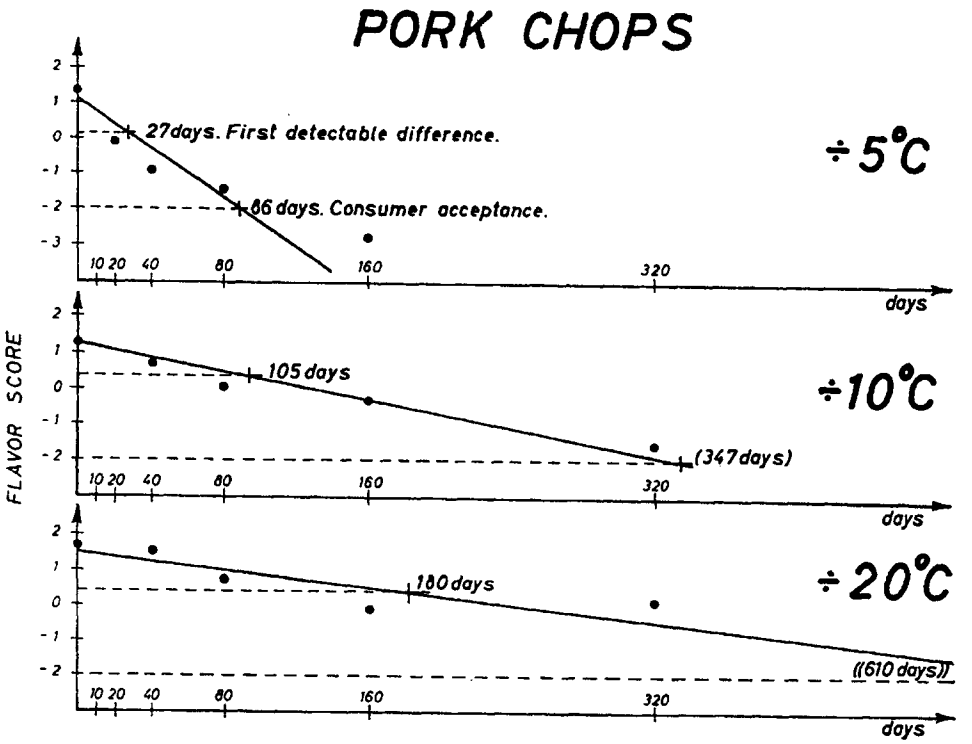


Fig. 2. The TTT concept illustrated by determining flavour „ first detectable difference" and „consumer acceptance limit" for frozen stored pork chops. ([23] adapted by Duda Z.).

Curing and smoking has had lost their preservation significance for already many years. According to commonly accepted and approved opinion, at present, as well as, in the future those technologies, although still having restricted, albeit important, preservation effects and functions, namely antibotulinal and antioxidative, respectively, are and will be mainly considered as technologies allowing to create: colour, aroma and taste (flavour) as well as wholesomeness of cured meat products [6, 12, 32, 37, 38, 51, 52, 54, 65, 76, 81, 96, 110, 129].

## Conclusions

1. Preservation of perishable foods particularly of proteinaceus animal origin is a formidable task.
2. Still in several regions of the world: energy-, capital-, and technology intensive processes are not within the financial and managerial possibilities of many countries.
3. Traditional low energy preservation processes still assume importance and deserve due consideration.
4. In selecting and implementation of preservation technologies, dietary and religious habits, requirements and preferences, need to be obligatory observed.
5. In the industrial countries great impact of high technologies on food preservation techniques and technologies should be forecasted and novel and newly discovered preservation technologies will be applied and in common use.
6. The greatest preservation potentiality is for selected physical (non-thermal) methods: gamma-irradiation, pascalisation, microwaves, ultrasonication, high density pulsed light energy, high voltage pulsed electric fields, etc.

## REFERENCES

[1] Abee T., Krockel L., Hill C.: Bacteriocins: Modes of action and potentials in food preservation and control of food poisoning. Int. J. Food Microbiol., **28**, 2, 1995, 169-185.

[2] Ahvenainen, R.: Trends and applications of modified atmosphere and active packaging system; safety and acceptability. In: New shelf-life technologies and safety assessments. Ahvenainen, R., Mattila-Sandholm T., Ohlsson T. Eds. VTT Symposium, **148**, 1995, 85-102.

[3] Aymerich, M. T., Hugas, M., Monfort, J.M.: Review: Bacteriocinogenic lactic acid bacteria associated with meat products. Food Science and Technology International, **4**, 1998, 141-158.

[4] Bauer F., Burt S.A.: Proc. ECCEAMST course: „Shelf life of meat and meat products: quality aspects, chemistry, microbiology, technology. ECCEAMST, Utrecht, The Netherlands, 1995.

[5] Bell K.Y., Cutter C.N., Sumner S.S.: Reduction of foodborne micro-organisms on beef carcass tissue using acetic acid, sodium bicarbonate, and hydrogen peroxide spray washes. Food Microbiology, 14, 1997, 439-448.

[6] Bertola N.C., Bevilacqua A.E., Zaritzky N.E.: Heat treatment effect on texture changes and thermal denaturation of proteins in beef muscle. J. Food Processing & Preservation, **18**, 1994, 31-46.

[7] Blom H., Nerbrik E., Dainty R., Hagtvedt T., Borch E., Nissen H., Nesbakken T.: Addition of 2.5% lactate and O.25% acetate controls growth of Listeria monocytogenes in vacuum-packed, sensory-acceptable servelat sausage and cooked ham stored at 4° C. Int. J. Food Microbiol., **38**, 1997, 71-76.

[8] Board R.G., Gould G.W.: Future prospects. In: Food Preservatives, (Ed. Russell N.J. and Gould G.W.) Blackie and Sons, Glasgow, 1991, 267-284.

[9] Bogh-Sorensen L.: Description of hurdles. In: Food preservation by combined processes. Ed. Leistner L. and Gorris L.G.M. Final Report. FLAIR Concerted Action No. 7, Subgroup B, EUR 15776 EN. 1994, 7- 24.

[10] Brody A.L.: Integrating aseptic and modified atmosphere packaging to fulfil a vision of tomorrow. Food Technol., **50**, 4, 1996, 56-66.
[11] Brown T., Chourouzidis K.N., Gigiel A.J.: Spray chilling of lamb carcasses. Meat. Sci., **34**, 3, 1993, 311-325
[12] Cambell-Platt G.: Fermented foods - a world perspective. Food Res. Int., **27**, 1994, 253-257.
[13] Cassens R.G.: Meat preservation. Preventing losses and assuring safety. Food & Nutrition Press, Inc. Trumbull, Connecticut 06611, USA, 1994.
[14] Chadderton T.: Non-traditional refrigeration technologies for efficient meat processing. Proc. 43rd Int. Congress Meat Sci. Technol. Auckland, New Zealand. Plenary session, 1997, 28-35.
[15] Cheftel J.C.: Review: High-pressure, microbial inactivation and food preservation. Food Sci. Technol. Int., **1**, 1995, 75-90.
[16] Cheftel J.C., Culioli J.: Effect of high pressure on meat: A review. Meat. Sci., **46**, 3, 1997, 211-236.
[17] Chirife J.: Physicochemical aspects of food preservation by combined factors. Food Control, **4**, 4, 1993, 210-214.
[18] Collins C.I., Murano E.A., Wesley I.V.: Survival of Arcobacter butzleri and Campylobacter jejuni after irradiation treatment in vacuum-packaged ground pork. J. Food Prot., **59**, 11, 1996, 1164-1166.
[19] Coventry M.J., Muirhead K., Hickey M.W.: Partial characterization of pediocin PO2 and comparison with nisin for biopreservation of meat products. Int. J. Food Microbiol., **26**, 2, 1995, 133-145.
[20] Crawford L.M., Ruff E.H.: A review of the safety of cold pasteurization through irradiation. Food Control, **2**, 2, 1996, 87-97.
[21] Cutter C.N., Dorsa W.J., Siragusa G.R.: Rapid desiccation with heat in combination with water washing for reducing bacteria on beef carcass surfaces, 1997.
[22] Cutter C.N., Siragusa G.R.: Incorporation of nisin into a meat binding system to ihibit bacteria on beef surfaces. Letters in Applied Microbiology, **27**, 1998, 19-23.
[23] Dalhoff E., Jul M.: Factors affecting the keeping quality of frozen foods. Proc. Xth Int. Congress of Refrigeration. Munich, Germany, P-9, 1963, 57-66.
[24] Darmadji P., Izumimoto M.: Effect of chitozan in meat preservation. Meat Sci., **38**, 1994, 243-254.
[25] Deatherage F.E.: Man and his food and nitrite. National Livestock and Meat Board., 1978, 1-12.
[26] Dedaza M.S.T., Alzamora S.M., Chanes J.W.: Combination of preservation factors applied to minimal processing of foods. Crit. Rev. Food Sci. & Nutr., **36**, 6, 1996, 629-659.
[27] Delmore L.R.G., Sofos J.N., Schmidt G.R., Smith G.C.: Decontamination of inoculated beef with sequential spraying treatments. J. Food Sci., **63**, 5, 1998, 890-893.
[28] Dickson J.S., Hardin M.D., Acuff G.R.: Organic acid rinses. Proc. Annual Rec. Meat Conf. AMSA, **49**, 1996, 129-131.
[29] Doherty A.M., Allen P.: The effect of oxygen scavengers on the color stability and shelf-life of $CO_2$ master packaged pork. J. Muscle Foods, **9**, 1998, 351-363.
[30] Dorsa W.J.: Decontamination of beef carcasses by commercial steam-vacuum. Proc. Rec. Meat Conf. AMSA, **49**, 1996, 114.
[31] Doyle M.P.: Extending the shelf life of refrigerated foods: for better or worse? Food Technol., **52**, 2, 1998, 20.
[32] Duda Z.: Non-conventional methods for determination of the heating endpoint temperature of thermally processed meat and poultry meat products. Tehnologija Mesa, **XXXIX**, 3, 1998, 113-117.
[33] Duda Z.: Selected problems of nitrite use in meat processing. (In Polish). Żywność Technologia Jakość, **5**, 3(16), 1998, 5-42.
[34] Eustace I.J., Bill B.A.: Investigation of temperature minima for the storage of chilled meats. Proc. 34th Int. Congress Meat Sci. Technol. Part A. Brisbane, Australia, 1998, 228-230.

[35] Farkas J.: Irradiation as a method for decontaminating food. A review. Int. J. Food Microbiol., **44**, 3, 1998, 171-178.

[36] Fellows P.: Food processing technology. Principles and practice. Woodhead Publishing limited, Cambridge, England, 1996.

[37] Fessmann K.D.: Smoking technology at time of change. Fleischwirtsch., **75**, 9, 1995, 1124-1126.

[38] Fillion L., Henry C.J.K.: Nutrient losses and gains during frying: a review. Int. J. Food Sci. Nutr., **49**, 1998, 157-168.

[39] Fung D.Y.C., Lin C.C.S., Gailani M.B.: Effect of phenolic antioxidants on microbial growth. CRC Crit. Rev. Microbiol., **12**, 2, 1985, 153-183.

[40] Ganzle M.G., Hertel C., Hammes W.P.: Antimicrobial activity of bacteriocin-producing cultures in meat products - Modelling of the effect of pH, NaCl, and nitrite on the antimicrobial activity of sakacin P against *Listeria ivanovii* DSM20750. Fleischwirtschaft, **76**, 4, 1996, 409-412.

[41] Gennadios A., Hanna M.A., Kurth L.B.: Application of edible coatings on meat, poultry and seafoods: A review. Lebensm. -Wiss. u.- Technol., **30**, 1997, 337-350.

[42] Gill C.O., Badoni M.: The hygienic and organoleptic qualities of ground beef prepared from manufacturing beef pasteurized by immersion in hot water. Meat Sci., **46**, 1, 1997, 67-75.

[43] Gill C.O., Bryant J.: Decontamination of carcasses by vacuum-hot water cleaning and steam pasteurization during routine operations at a beef packing plant. Meat Sci., **47**, 3/4, 1997, 267-276.

[44] Gill C.O., Deslandes B., Rahn K., Houde A., Bryant J.: Evaluation of the hygienic performances of the process for beef carcass dressing at 10 packing plants. J. Applied Microbiology, **84**, 1998, 1050-1058.

[45] Gill C.O., McGinnis J.C.: The use of oxygen scavengers to prevent the transient discoloration of ground beef packaged under controlled, oxygen-depleted atmospheres. Meat Sci., **41**, 1, 1995, 19-27.

[46] Gill C.O., McGinnis J.C., Bryant J.: Microbial contamination of meat during the skinning of beef carcass hindquarters at three slaughtering plants. Int. J. Food Microbiol., **42**, 1998, 175-184.

[47] Giroux M., Laroix M.: Nutritional adequacy of irradiated meat - a review. Food Research Int., **31**, 4, 1998, 257-264.

[48] Gould G.W.: Industry perspectives on the natural antimicrobials and inhibitors for food applications. J. Food Prot. Supplement, 1996, 82-86.

[49] Hague M.A., Kastner C.L., Fung D.Y.C., Kone K., Schwenke J.R.: Use of nisin and microwave treatment reduces Clostridium sporogenes outgrowth in precooked vacuum-packaged beef. J. Food Prot., **60**, 9, 1997, 1072-1074.

[50] Haire D.L., Chen G., Janzen E.G., Fraser L., Lynch J.A.: Identification of irradiated foodstuffs: a review of recent literature. Food Res. Int., **30**, 3/4, 1997, 249-264.

[51] Hammes W.P., Tichaczek P.S.: The potential of lactic acid bacteria for the production of safe and wholesome food. Z. Lebensm Unters Forsch., **198**, 1994, 193-201.

[52] Hanson R.E.: Reducing process variation in the cooking and smoking process. Proc. Rec. Meat Conf. AMSA, **50**, 1997, 33-41.

[53] Hastings J.W., Stiles M.E., Vonholy A.: Bacteriocins of Leuconostocs isolated from meat. Int. J. Food Microbiol., **24**, 1-2, 1994, 75-81.

[54] Hermey B., Patzelt H.: Using liquid smoke. Fleischwirtsch., **75**, 4, 1995, 445-447

[55] Houben J.H., Vanroon P.S., Krol B.: Continuous radio-frequency pasteurization in sausage manufacturing lines. Fleischwirtsch., **73**, 10, 1993, 1146-1149.

[56] Hugas M.: Bacteriocinogenic lactic acid bacteria for the biopreservation of meat and meat products. Meat Sci., **49**, Suppl., 1998, S139-S150.

[57] Huis-in't-Veld J.H.J.: Microbial and biochemical spoilage of foods: an overview. Int. J. Food Microbiol., **33**, 1, 1996, 1-18.

[58] Hurme,E., Vaari A., Ahvenainen R.: Active and smart packaging of food. In: Minimal processing of food. Proc. VTT Symp., **142**, 1994, 149-178.

[59] James S.J., Bailey C.: Process design data for beef chilling. Int. J. Refrig., **12**, 1, 1989, 4249.

[60] Jones S.D.M., Grrer G.G, Jeremiah L.E., Muray A.C., Robertson W.M.: Cryogenic chilling of pork carcasses: effect on muscle quality, bacterial population and palatability. Meat. Sci., **29**, 1, 1991, 1-16.

[61] Kelly W.J., Asmundson R.V., Huang A.C.M.: Isolation and characterization of bacteriocin-producing lactic acid bacteria from ready-to-eat food products. Int. J. Food Microbiol., **33**, 2-3, 1996, 209-218.

[62] Kim, W. J. 1993. Bacteriocins of lactic acid bacteria: their potentials as food biopreservative. Food Reviews Int., **9**, 2, 299-313.

[63] Klettner P.G.: Cooling and freezing of carcasses. Fleischwirtsch., **76**, 7, 1996, 679.

[64] Krochta J.M., De Mulder-Johnston C.: Edible and biodegradable polymer films: challenges and opportunities. Scientific status summary. Food Technology, **51**, 2, 1997, 61-74.

[65] Laack van R.L.J.M.: Spoilage and preservation of muscle foods. In: Muscle Foods - Meat, Poultry and Seafood Technology. Ed. Kinsman D.N., Kotula A.W., Breidenstein B.C. Chapman and Hall. New York-London 1994, 378-405.

[66] Labuza T.P.: An introduction to active packaging for food. Food Technol., **50**, 4, 1996, 68-71.

[67] Lahr J.A.: Beef carcass microbial contamination - post slaughter numbers of bacteria, sources of contamination and variability of data. Proc. Annual Rec. Meat Conf. AMSA, **49**, 1996, 132-137.

[68] Lambert A.D., Smith J.P., Dodds K.L.: Shelf life extension and microbiological safety of fresh meat - a review. Food Microbiology, **8**, 1991, 267-297.

[69] Lee M., Sebranek J.G., Olson D.G., Dickson J.S.: Irradiation and packaging of fresh meat and poultry. J. Food Prot., **59**, 1, 1996, 62-72.

[70] Lefebvre N., Thibault R., Charbonneau R., Piette J-P.G.: Improvement of shelf-life and wholesomeness of ground beef by irradiation.- 2. Chemical analysis and sensory evaluation. Meat Sci., **36**, 3, 1994, 371-380.

[71] Leistner L.: Food preservation by combined methods. Food Res. Int., **25**, 1992, 151-158.

[72] Leistner L.: Introduction to hurdle technology. In: Food preservation by combined processes. Ed. Leistner, L. and Gorris, L. G. M. Final report FLAIR concerted Action No. 7, Subgroup B. EUR 15776 En. 1-6, 1994.

[73] Leistner L.: Further development in the utilization of hurdle technology for food preservation. J. Food Eng., **22**, 1994, 421-432.

[74] Leistner L.: Principles and applications of hurdle technology. In: New methods of food preservation. Ed. Gould, G. W. Blackie Academic and Professional. An Imprint of Chapman and Hall. Chapman and Hall. London, Glasgow, Weinheim, New York, Tokyo, Melbourne, Madras 1995, 1-21

[75] Leistner L.: Microbial stability and safety of healthy meat, poultry and fish products. In: Advances in Meat Research - vol. 11. Production and processing of healthy meat, poultry and fish products. Ed. Pearson, A. M. and Dutson, T. R. Blackie Academic and Professional. An Imprint of Chapman and Hall. Chapman and Hall. London, Weinheim, New York, Tokyo, Melbourne, Madras 1997, 347- 360.

[76] Leistner L.: Mild and effective thermal treatment on meat products by application of hurdle technology. Tehnologija Mesa, **XXXIX**, 3, 1998, 95-100.

[77] Leistner L., Gorris L.G.M.: Review. Food preservation by hurdle technology. Trends in Food Sci. and Technol., **6**, 2, 1995, 41-46

[78] Lucas T., Raoult-Wack A.L.: Immersion chilling and freezing in aqueous refrigerating media: review and future trends. In. J. Refrig., **21**, 6, 1998, 419-429.

[79] Luchsinger S.E., Kropf D.H., Chambers IV E., Zepeda C.M.G., Hunt M.C., Stroda S.L., Hollingsworth M.E., Marsden J.L., Kastner C.L.: Sensory analysis of irradiated beef patties and whole muscle beef. J. Sensory Studies, **12**, 1997, 105-126.

[80] Luck E.: Food applications of sorbic acid and its salts. Food Additives &. Contaminants, **7**, 5, 1990, 711-715.

[81] Lucke F-K.: Fermented meat products. Food Res. Int., **27**, 1994, 299-307.

[82] Madsen H.L., Bertelsen G.: Spices as antioxidants. Trends Food Sci. Technol., **6**, 8, 1995, 271-277.

[83] Mallikarjuman P., Mittal G.S.: Optimum conditions for beef carcass chilling. Meat Sci., **39**, 2, 1995, 215-223.

[84] Mallikarjunan P., Mittal G.S.: Selection criteria for beef carcass chilling. Food Res. Int., **29**, 7, 1996, 661-666.

[85] Marth E.H.: Extended shelf life refrigerated foods: microbiological quality and safety. Food Technol., **52**, 2, 1998, 57-62.

[86] McClemens D.J.: Advances in the application of ultrasound in food analysis and processing. Trends Food Sci. Technol., 6, 9, 1995, 293-299.

[87] Mermelstein N.H.: Freezing seafood. Food Technology, **52**, 2, 1998, 72-73.

[88] Mermelstein N.H.: Food Technology's 50th anniversary: looking ahead. Food Technology, **51**, 12, 1997, 49-54.

[89] Meyer A.S., Isaksen A.: Application of enzymes as food antioxidants. Trends in Food Sci. Technol., **6**, 9, 287-319

[90] Miller R.K.: Effect of non-meat ingredients as aid to shelf-life. Proc. Annual Rec. Meat Conf. AMSA, **45**, 1992, 85-95.

[91] Miller S.: Developing a new food wholesomeness science to ensure food safety. Food Technol., **51**, 12, 1997, 62-65.

[92] Miyagishima K., Moy G., Miyagawa S., Motarjemi Y., Kaferstein F.K.: Food safety and public health. Food Control., 6, 5, 1995, 253-259.

[93] Murano E.A.: Irradiation of fresh meats. Food Technol., **49**, 12, 1995, 52-54.

[94] Nair R.B.: Preservation. Stabilised meat products. Meat Focus Int., **1**, 12, 1992, 374-377.

[95] Narasimha-Rao D., Sreenivasamurthy V.: A preliminary study on the effect of urea in the preservation of meat. Meat Sci., **17**, 4, 1986, 251-265.

[96] Nout M.J.R.: Fermented foods and food safety. Food Res. Int., **27**, 1994, 291-298.

[97] Ogden S.K., Taylor A.J., Dood Ch.E.R., Guerrero I., Buendia H.E., Gallardo F.: The effect of combining propionic and ascorbic acid on the keeping qualities of fresh minced pork during storage. Lebensm. -Wiss. u-Technol., **29**, 1996, 227-233.

[98] Ohlsson T.: Minimal processing - preservation methods of future: an overview. Trends Food Sci. & Technol., **5**, 11, 1994, 341-344.

[99] Olson D.G.: Irradiation of food. Food Technology, **52**, 1, 1998, 56-62.

[100] Ovadia D.Z., Walker C.E.: Impingement in food processing. Food Technol., **52**, 4, 1998, 46-50.

[101] Payne S.R., Young O.A.: Effects of pre-slaughter administration of antifreeze proteins on frozen meat quality. Meat Sci., **41**, 2, 1995, 147-155.

[102] Phebus R.K., Nutch A.L., Schafer D.E.: Laboratory and commercial evaluation of a steam pasteurization process for reduction of bacterial population on beef carcass surface. Proc. Annual Rec. Meat Conf. AMSA, **49**, 1996, 121-124.

[103] Phillips C.A.: Review: Modified atmosphere packaging and its effects on the microbiological quality and safety of produce. Int. J. Food Sci. Technol., **31**, 1996, 463-479.

[104] Podolak R.K., Zayas J.F., Kastner C.L., Fung D.Y.C.: Reduction of bacterial populations on vacuum-packed ground beef patties with fumaric and lactic acids. J. Food Prot., **59**, 10, 1996, 1037-1040.

[105] Pushpa P., Chawla S.P., Thomas P., Kesavan P.C.: Effect of high hydrostatic pressure, gama-irradiation, and combination treatments on the microbiological quality of lamb meat during chilled storage. J. Food Safety, **16**, 1997, 263-271.

[106] Radomyski T., Murano E.A., Olson D.G., Murano P.S.: Elimination of pathogens of significance in food by low-dose irradiation: A review. J. Food Prot., **57**, 1994, 73-86.

[107] Romans J.R., Costello W.J., Carlson C.W., Greaser M.L., Jones K.W.: The meat we eat. Interstate Publishers, Inc. / Danville, Illinois 1994.

[108] Rozbeh M., Kalchayanand N., Field R.A., Johnson M.C., Ray B.: The influence of biopreservatives on the bacterial level of refrigerated vacuum packed beef. J. Food Safety, **13**, 1993, 99-111.

[109] Scannell A.G.M., Hill C., Buckley D.J., Arendt E.K.: Determination of the influence of organic acids and nisin on shelf-life and microbiological safety aspects of fresh pork sausage. J. Appl. Microbiol., **83**, 1997, 407-412.

[110] Seideman S.C., Durland P.R.: The effect of cookery on muscle proteins and meat palatability. J. Food Quality, **6**, 1984, 291-314.

[111] Sheridan J.J.: The ultra-rapid chilling of lamb carcasses. Meat Sci., **28**, 1, 1990, 31-50.

[112] Sheridan J.J.: Sources of contamination during slaughter and measures for control. J. Food Safety, **18**, 4, 1998, 321-339.

[113] Shewfelt R.L., Erickson M.C., Hung Y.-C., Malundo T.M.M.: Applying quality concepts in frozen food development. Food Technol., **51**, 2, 1997, 56-59.

[114] Smulders F.J.M., Greer G.G.: Integrating microbial decontamination with organic acids in HACCP programmes for muscle foods: prospects and controversies. Intern. J. of Food Microbiol., **44**, 1998, 149-169.

[115] Sofos J.N., Smith G.C.: Nonacid meat decontamination technologies: Model studies and commercial applications. Int. J Food Microbiology, **44**, 1998, 171-178.

[116] Sorheim O, Nissen H., Nesbakken T.: The storage life of beef and pork packaged in an atmosphere with low carbon monoxide and high carbon dioxide. Meat Sci., **52**, 2, 1999, 157-172.

[117] Stiles M.E.: Biopreservation by lactic acid bacteria. Proc. Fifth Symp. on Lactic Acid Bacteria: Genetics, Metabolism and Applications. Venema M., Veld J.H.J.H., Hugenholz J. Eds. 1996, 331-345.

[118] Strydom P.E., Buys E.M.: Effect of spray-chilling on carcass mass loss and associated bacteriology. Meat Sci., **39**, 2, 1995, 265-276.

[119] Suzuki A., Homma N., Fukuda A., Hirao K., Uryu T., Ikeuchi Y.: Effect of high pressure treatment on the flavour-related compounds in meat. Meat. Sci., **37**, 1994, 369-379.

[120] Tain M-X., Weber G. H., Ayres J.W., Sandine W.E.: Bacteriocins applied to food packaging materials to inhibit *Listeria monocytogenes* on meats. J. Food Sci., **62**, 2, 1997, 413-415.

[121] Tarkowski J.A., Beumer R.R., Kampelmacher E.H.: Low gamma irradiation of raw meat. II. Bacteriological effects on samples from butcheries. Int. J. Food Microbiol., **1**, 1, 1984, 25-31.

[122] Tarkowski J.A., Stoffer S.C.C., Beumer R.R., Kampelmacher E.H.: Low dose gamma irradiation of raw meat. I. Bacteriological and sensory quality effects in artificially contaminated samples. Int. J. Food Microbiol., **1**, 1, 1984, 13-23.

[123] Thakur B.R., Nelson P.E.: High-pressure processing and preservation of food. Food Rev. Int., **14**, 4, 1998, 427-447.

[124] Thakur B.R., Singh R.K., Arya S.S.: Chemistry of sorbates - a basic perspective, Food Rev. Int., **10**, 1, 1994, 71-91.

[125] Thayer D.W.: Extending shelf life of poultry and red meat by irradiation processing. J. Food Prot., **56**, 10, 1993, 831-833.

[126] Thumel H.: Preserving meat and meat products. Possibilities and methods. Fleischwirtsch., **75**, 5, 1995, 674-678.

[127] Tinney K.S., Miller M.F., Ramsey C.B., Thompson L.D., Carr M.A.: Reduction of microorganisms on beef surfaces with electricity and acetic acid. J. Food Prot., **60**, 6, 1997, 625-628.

[128] Tomaniak A., Tyszkiewicz I., Komosa J.: Cryoprotectants for frozen red meats. Meat Sci., **50**, 3, 1998, 365-371.

[129] Varnam A.H., Sutherland J.P.: Meat and meat products. Technology, chemistry and microbiology. Chappman & Hall. London, Glasgow, Weinheim, New York, Tokyo, Melbourne, Madras 1995.

[130] Wal van der P.G., Engel B., Beek van G., Veerkamp C.H.: Chilling pig carcasses: Effects on temperature, weight loss and ultimate meat quality. Meat. Sci., **40**, 2, 1995, 193-202.

[131] Wouters P.C., Smelt J.P.P.M.: Inactivation of microorganisms with pulsed electric fields: potential for food preservation. Food Biotechnology, **11**, 3, 1997, 193-229.

[132] Ziauddin K.S., Rao H.S., Nadeem-Fairoze: Effect of organic acids and spices on quality and shelf-life of meats at ambient temperature. J. Food Sci. Technol.- Mysore, **33**, 3, 1996, 255-258.

## UTRWALANIE MIĘSA - STAN AKTUALNY I PRZEWIDYWANE TECHNOLOGIE

Streszczenie

W przeglądowym opracowaniu podjęto próbę przedstawienia współczesnych i przyszłościowych metod, technologii i technik utrwalania mięsa i przetworów mięsnych. Zaprezentowano poglądy na podział i kategoryzowanie metod i technik utrwalania surowców rzeźnych i finalnych wyrobów. Omówiono przewidywane kierunki rozwoju i postępu tradycyjnych metod utrwalania oraz potencjalne możliwości wykorzystania do tego celu technologii niekonwencjonalnych.