Some Aspects of Research at the Institute of Meat Technology, The University of Helsinki

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History

Research in meat technology has a surprisingly long tradition in Finland. As early as 1940, the Finnish meat industry founded a research laboratory to carry out scientific research on meat and meat products. Although the operations of the research laboratory were rather modest in the beginning, one must respect the farsightedness of the people who started this work. In Europe there were no models for meat research at that time. The author was the head of this research laboratory from 1947 to 1961.

In 1961 an institute of meat technology and a professorship in meat technology were set up in the Faculty of Agriculture and Forestry with the financial support of the meat industry.

As an Institute in the university, the most important duty of the Institute of Meat Technology is to train people to be technical managers in the meat industry. Scientific research, which is an essential part of the program at every university, has been carried out since the foundation of the Institute. I will now briefly discuss some aspects of Finnish meat research.

Cooked Sausage Technology

As early as the beginning of the 1950s, I and my co-workers, Pohja and Ryynänen, focused attention on the water-binding capacity of meat and its significance to the quality of meat products and the economy of production. Development of a method for determination of water-binding capacity was found to be of fundamental importance. In 1952 I participated in the development of the filter paper-compress method of Grau and Hamm (1957) in Kulmbach, Germany.

Using this commonly known method, we considered the effect of sodium chloride on the water-binding capacity of meat. The increase in water-binding effected by salt is, according to our research, due to the fact that adding salt to the meat emulsion changes the isoelectric point of the meat from a pH value of 5.7 to a pH value of 4.9. This value will be reached in a salt concentration of approximately 4%. In this salt concentration the meat has the best water-binding capacity. If the salt concentration increases, the isoelectric point begins to rise toward higher pH value (Figure 1). As a result, the water-binding capacity decreases. The water-binding capacity is of course lowest at the isoelectric point of meat, circa in pH value 5.7.

Figure 1

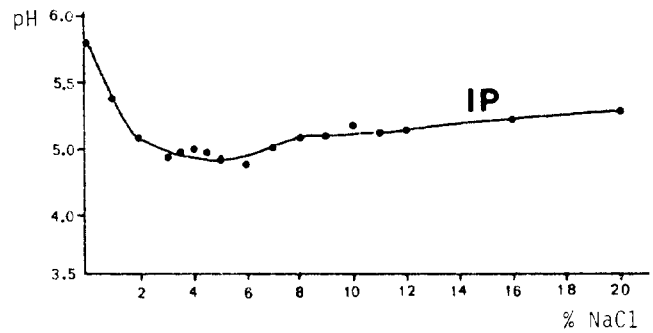

Figure 1. Effect of salt concentration on the change in the isoelectric point (Niinivaara and Pohja 1954).

Although our first research on water-binding capacity was done nearly 30 years ago, the problem is still current. Research of this kind is still being carried out in many meat research institutes, and also in the Institute of Meat Technology at Helsinki University.

At our Institute, Doctor Puolanne and his co-workers have developed a method for determining the water-binding capacity of cooked sausage. We have called this method the "laboratory sausage method", because it is based on measurements performed on small laboratory sausages. (Figure 2).

This method lends itself better to determining the water-

Figure 2

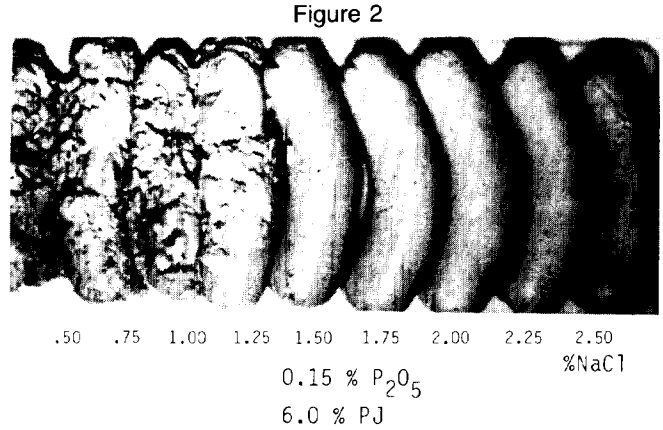

Figure 2. Effect of salt on the consistency of sausage emulsion.

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binding capacity of sausage emulsion than Grau and Hamm's (1957) compress method, which is excellent for determining the water-binding capacity of meat.

Our method permits comparison of the effect of other ingredients besides meat on the properties of sausage. In Figure 3 we can see the effect of salt concentration.

The maximum water-binding capacity is about 4% both with added phosphate (upper diagram) and without added phosphate (lower diagram). The steepest rise with phosphate is in the 1-2% range, and without phosphate an equally steep rise does not occur. More accurate research in the 0.5-2.5% range shows that the critical salt concentration with phosphate is 1.5% NaCl.

In lower salt concentrations the sausage does not remain solid. (Figure 4).

The optimal final salt concentration of the cooked sausage is approximately 1.6-1.8%. Raising the salt concentration above this level has little effect on either the water-binding capacity or the consistency.

With this method we have done some investigations on the water-binding capacity and linear programming of meat assortments and other raw materials.

Figure 5 shows the water-binding capacity of some beef assortments in cooked sausage as a function of their concentration.

In Figure 5 we can observe that when one assortment in a sausage is replaced by another, the diagram is no longer linear. Likewise the diagram of water-binding capacity with milk powder is also non-linear. On the basis of this and our other research, we have come to the conclusion that even in theory linear programming is only an approximate method.

Figure 3

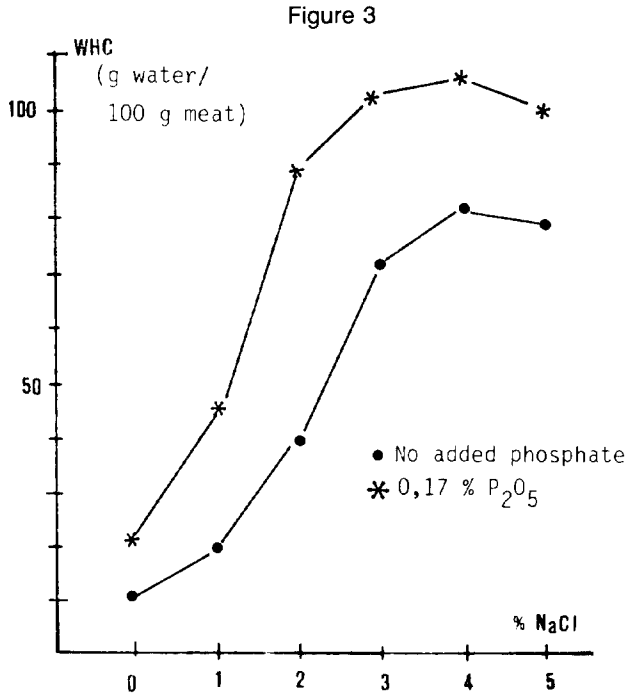

Figure 3. Effect of salt concentration on the water-binding capacity of sausage emulsion (Puolanne and Ruusunen 1980).

Figure 4

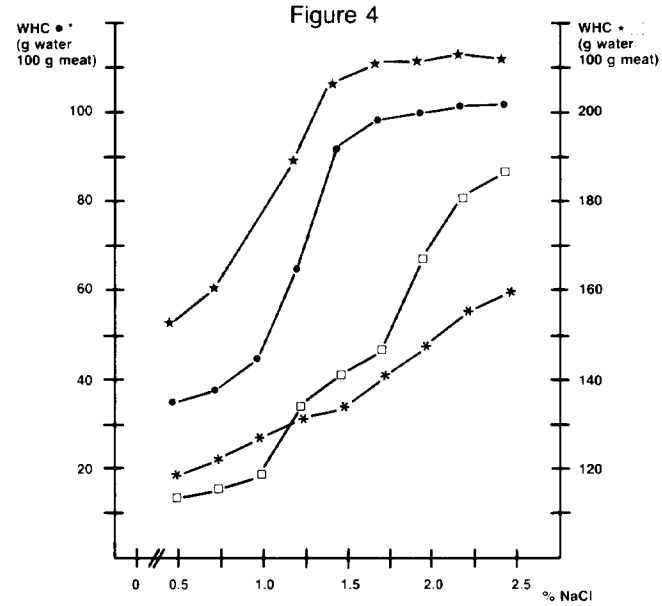

Figure 4. Effect of salt concentration on the water-binding capacity of cooked sausage. The effect of salt, salt + starch (potato flour), salt + starch (potato flour) + phosphate. (Puolanne and Ruusunen 1982).

*Salt □ Salt + Potato Flour
• Salt & Phosphate ✱ Salt + Phosphate + Potato Flour

Figure 5

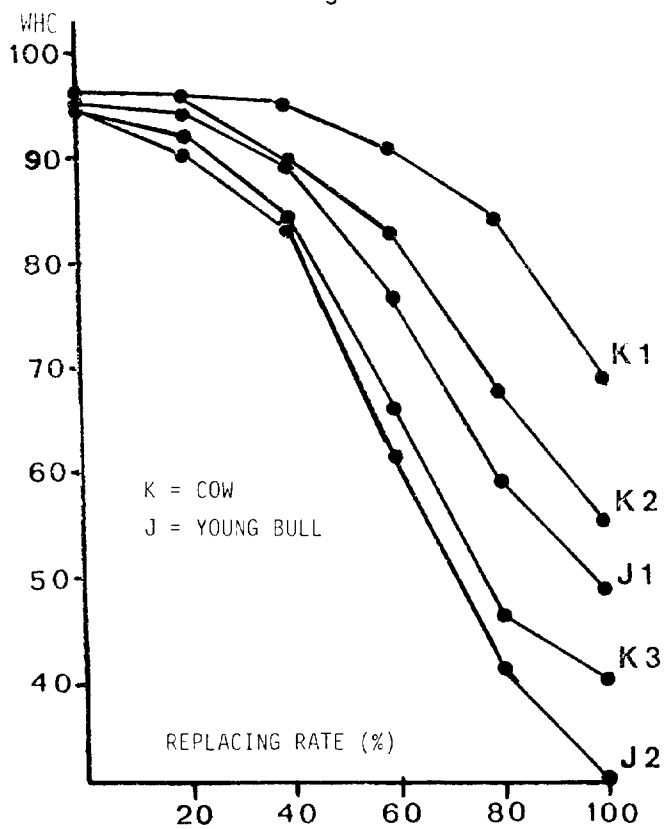

Figure 5. Water-binding capacity of cooked sausage when one beef cut is replaced by others. (Puolanne and Kukkonen 1982).

This is because the binding value of the ingredients depends on their mass concentration, and e.g., the amount of water added, salt concentration, etc. Thus a single value cannot be given for linear programming, e.g. lb, water/lb meat assortment, the value of which would be constant in all concentrations and in all sausages in which the assortment in question is used.

The Technology of Fermented Meat Products

The essential problems of the processing technology for cooked sausage are the water-binding capacity and colloid chemistry of meat. With dry sausage the essential problem field is microbiological. In the 1950s there was a lot of mysticism about dry sausage and because of a lack of knowledge, the product was often spoiled during manufacturing process. Air conditioning equipment was unknown and therefore the manufacturing of dry sausage was possible only during the winter months. This was why we started doing research on microbiological phenomena and on the development of the processing technology for dry sausage and other fermented products.

It was known that certain microbes play an important role in the ripening process, but it was not known what organisms were needed and for what purpose. It was felt that the milk industry had progressed much further in this respect, because there was more scientific research in the milk industry (dairy science) than in the meat industry. Meat science was a virtually unknown concept. This was the case in spite of the fact that the meat industry in many countries played a more important economic role than the milk industry.

In 1953 we started investigations of the role of microorganisms in the processing of fermented meat products. Our special interest was to improve the production technology by adding to the meat emulsion pure cultures of the microorganisms that could have beneficial effect on the ripening process of the sausage.

The research findings were published in my dissertation in 1955 (Niinivaara 1955). The best pure culture among the many strains (about 700) (Pohja 1960) of bacteria studied was a strain of *Micrococcus aurantiacus* M_{53}, according to present nomenclature in Bergeys Manual, *Staphylococcus sp.* By inoculating this strain into the sausage emulsion, we were able to speed up and ensure the success of the manufacturing process and improve the quality of the final product.

This research gained wider significance for two reasons: The U.S. Department of Agriculture was interested in financing its continuation, and it was thus possible to start a new project in 1959 and continue research with USDA grants until 1967. The research was concerned with the role of lactobacilli in the ripening process, and a practical application of new pure culture of micrococci and lactobacilli was introduced. The results were published in Nurmi's dissertation (Nurmi 1966).

Another important point for the use of starter cultures was the fact that a German company, Rudolf Müller & Co., in cooperation with Finnish meat research, developed an industrial method of production of bacterial pure cultures and introduced the use of starter cultures to the meat industry. This was extremely important, as the findings might otherwise have been left to gather dust on the shelves of the library. After persisting for ten years in supplying information about the advantages of the starter cultures, we succeeded in breaking the conservative attitudes of the European meat industry. Starter cultures became an integral part of the manufacture of fermented meat products. In the USA, the use of starter cultures is commonly accepted, Niven's *Pediococcus* has been used as a starter culture since 1955 (Niven et al 1955).

In the 1960s it was generally believed that lactobacilli caused the spoilage of dry sausage. This view was proved correct for the first time by inoculating a *Lactobacillus plantarum* strain into dry sausage. The dry sausage was readily discolored and its taste became unpleasant. The consistency of inoculated sausages developed faster and the pH value fell faster than in non-inoculated sausage or sausage with micrococcal culture alone. If both micrococci and lactobacilli were inoculated at the same time, discoloring and formation of off flavor could be avoided (Nurmi 1966).

The effect of the combined inoculation of micrococci/lactobacilli could be explained as follows: The lactic acid bacteria produce hydrogen peroxide, which oxidizes the fat. This is the reason for the off flavor caused by lactobacilli. Micrococci — as catalase-positive organisms — immediately decompose the hydrogen peroxide formed by lactic acid bacteria and oxidation of fat is thus prevented.

Determination of the Activity of Starter Cultures

Until recently the activity of starter cultures, as well as the activity of microbes in general, has been measured by determining the amount of bacteria, or to be more accurate, the number of units that form colonies. During the last few years, bacterial activity, which is of fundamental importance, has become the subject of considerable interest.

In processing dry sausage it has been discovered that there are differences between starter culture preparates which are not caused by differences between the amounts of bacteria. The activity of starter cultures from the same manufacturer varies from one production charge to another due to the age of preparate. In a study carried out at our Institute, Kuusela et al (1978) published a method which can measure the activity of lactic acid production of lactobacilli and the nitrate reduction activity of staphylococci. The determination is made in a tube within 1-2 hours using only the substrates needed in the reaction (glucose or nitrate and formiate). This ensures that the bacteria do not multiply very much during determination. The method can be successfully used in both searching for new, more efficient bacteria strains and in quick testing of starter culture preparates (quality control).

In the 1950s we showed that starter cultures have an antagonist effect against spoiling and also against pathogenic bacteria (Niinivaara and Pohja 1957).

Niskanen and Nurmi (1976) demonstrated that starter cultures prevent growth of *Staphylococcus aureus*. Sirviö et al (1977) also found that salmonellas can be prevented by using starter cultures (Figure 6).

There are similar results in American sausage processing, in which pH value decreases faster and falls lower than in European sausage processing (Smith et al 1975).

Figure 6

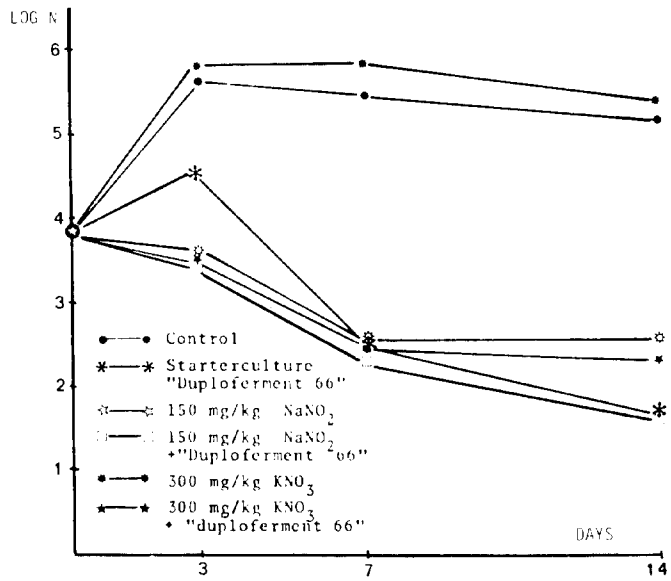

Figure 6. The effect of starter culture "Duploferment 66" on the growth of *Salmonella senftenberg*.

Gram-negative Microorganisms as Starter Cultures

Present rapid production methods make the dry sausage taste flat. One of the reasons put forward is that nitrite, together with a rapid drop in pH, inhibits the action of the mainly gram-negative bacteria, which produce the aroma. Dr. Petäjä (1977) has carried out research on this problem at our Institute. Findings show that addition of gram-negative bacteria has a favorable effect on taste and aroma, but only when lactic acid bacteria are added. This may help us find ways of preventing deterioration in taste. The gram-negative strains isolated and studied by Petäjä belonged to the family *Aeromonas*. They have been successfully used in industrial production of dry sausage.

Enzymes

Many investigators have unsuccessfully tried to replace starter cultures with enzymes such as lactic acid producing enzymes, nitrate reductase, peroxidase, etc. Many of these enzymes are endoenzymes. In the first place, it is difficult on an industrial scale to break down the microbes without destroying the enzymes. Secondly, the enzymes usually belong to bigger, particle-bound systems. In a living cell, these act effectively, but far less effectively in sausage. Enzymes do not increase in sausage, have not been observed to have antagonistic properties and do not produce flavor and aroma as bacteria do. For these reasons attempts to replace starter cultures with enzymes have apparently been abandoned.

The Importance of Fermented Meat Products

Today meat preservation is no problem in industrialized countries. Still, dry sausage production has persisted in civilized society. The methods are roughly the same as those of Stone Age man. The difference is that modern industry has precise control over the process and knows what the method is based on.

Well-ripened salami is still the king of sausage. It is valued as a good wine is valued. To produce both, a lot of know-how and patience is needed. Only the right kind of bacteria produce the right flavor.

According to the FAO, the production and consumption of meat and meat products will increase markedly during the next few years. Growth is expected in industrialized and especially in developing countries. Fermented meat products will certainly play an important part in this development. This is a very good way to use meat: the products keep without refrigeration and initial nutritive value is retained well. Manufacturing requires only rather modest equipment.

Research in this field has brought many new improvements in process technology. Therefore, it is highly desirable to promote and extend research into phenomena which are essential in forming optimal flavor, aroma, color and keeping properties of fermented meat products.

DFD Meat, a Serious Problem in Beef and Reindeer Meat

When the aging of beef for wholesale purposes by vacuum packing began, it was discovered that spoilage readily occurred if meat was DFD (dark, firm, dry). This meant substantial losses to the meat industry and meat dealers. Before packing, it was unknown whether the meat would be DFD meat or normal meat. The reasons for the formation of DFD meat were also unknown. Therefore a thorough study was made to determine why DFD meat forms and how to predict if meat would develop to DFD meat or normal meat (Puolanne et al 1981).

Approximately 15,000 head of cattle in different parts of the country were examined both ante mortem and post mortem. Special attention was paid to conditions before slaughter.

On the basis of this research, improvements were made in treating animals, e.g. common pens were replaced by individual pens. As a result, the amount of DFD meat has decreased considerably. By measuring pH value 24 hours after slaughter, we are able to predict if meat will be DFD or not.

Reindeer meat accounts for only about 0.5% of Finnish meat production. But it is an important product and is processed into fine delicacies. Reindeer meat, however, contains a lot of DFD meat, which is not suitable for processing. We have done research in Lapland from October to March and found a surprisingly clear correlation between slaughtering time and meat quality. The earlier in the autumn the reindeer are slaughtered, the better the chances to obtain normal meat. The later in the autumn the slaughtering takes place, the greater the chances that the meat will become DFD. The meat of animals slaughtered in March is 100% DFD.

The condition of the animals deteriorates during the winter months because of low temperatures (– 40°C and colder) and difficulties in finding fodder. The glycogen supplies decrease and normal lactic acid formation is not possible. The pH value of meat remains at 6.5 or higher. The research findings have been of great significance, and we now aim at slaughtering reindeer before December, so that all the meat can be processed into valuable products.

Figure 7

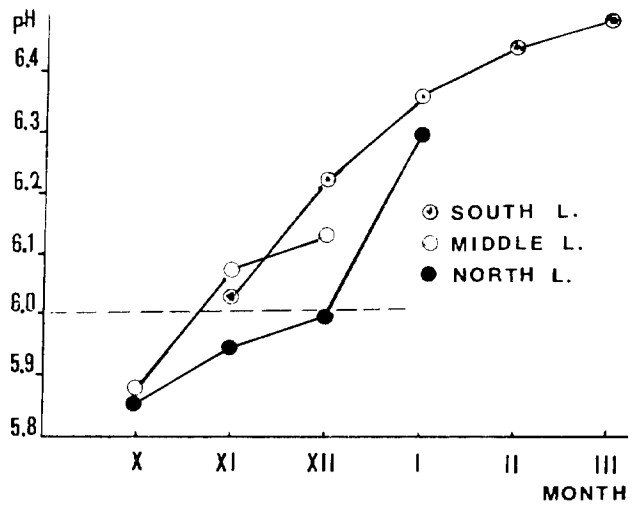

Figure 7. The effect of slaughtering month on the pH-value of reindeer meat.

The International Influence of Finnish Meat Research

In evaluating the international influence of Finnish meat research, the following conclusions may be justified:

The focus of Finnish meat research is on starter cultures for production of fermented meat products. This research has been the basis for the use of starter cultures in Europe in the 1950s and 1960s. Results achieved inspired starter culture research in many meat research laboratories. The International Starter Culture Symposium was held in Finland in 1972.

On the author's initiative, the first International Meeting of Meat Research Workers was held in Finland in 1955. The idea proved to be an important one, since the meeting has been held every year since 1955. The 28th Congress will be held in Madrid this year. In 1980 the USA was an excellent host of the international congress, and it was held in Colorado Springs, Colorado.

The European Meeting of Meat Research Workers, in which research workers from all continents have participated for decades, has inspired meat research in all countries. It has made people aware of the significance of meat research and created new resources for its development. The host country of the congress changes each year. It has often been possible to make the authorities take a more favorable attitude towards financing meat research in a country after it has hosted the congress. It is a pleasure to note that the Finnish initiative 27 years ago has led to remarkable international activity in this field.

The University of Helsinki has offered meat technology as a main branch of study for 21 years. There are still only a few universities in Europe where meat technology can be studied at university level. The study of meat technology at academic level in Finland has catalyzed the higher education in meat technology in several European countries.

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