

# *Global Meat Research Initiatives*

R. B. Sleeth

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## Introduction

I believe it is imperative that all scientists foster worldwide cooperation in meat science and technology research to become better informed and to minimize duplication. One purpose of the International Congress of Meat Science and Technology (IcoMST) is to provide a global forum for discussing research concepts and accomplishments. However, proceedings are not readily available to many in the scientific community. This presentation will briefly highlight selected meat research projects from several countries, which hopefully will provide the impetus to develop a plan of implementation in an effort to encourage greater worldwide exchange of meat science and technology information.

To assist in the preparation of this paper, the following survey information concerning the meat (or related) research activities at institutions in 24 countries was requested. Nineteen countries representing 22 research institutions responded.

- Major research emphasis
  - Basic research, processing, food safety, etc.
- Previous research completed
- Major current research project
  - Significance/anticipated impact
  - Selected data
  - Conclusions

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## Argentina

Instituto Tecnologia de Tecnologia Agropeduaría, INTA  
Dr. H. Ricardo Rodriguez

### Major Research Emphasis

**Food Safety.** Development of technologies to generate knowledge, on the presence, metabolism and transformation of agricultural and industrial chemical compounds, and the

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study of biological and chemical contaminants in raw materials, processes and finished products.

**Biochemistry.** To characterize or improve food quality throughout the study of biochemical composition and stability of raw materials and processed products.

**Physical Analysis.** To study physical, physiological and psychological aspects that contributes to food quality (sensory attributes that determines food acceptance by consumers) of raw materials and processed food.

**Food Processing.** To acquire knowledge and develop processing technologies in order to formulate and manufacture food products with added value, following the national and international marketing demands and the Argentine food industry requirements to include design and optimization of processes and formulation of fresh beef products.

## Previous Research

- Chemical and sensory characterization of red meat produced under different rearing conditions.
- Compositional studies of fatty acids and cholesterol in different meats.
- Enzymatic profile of different enzymes and isoenzymes in bovine muscles from different breeds.
- Determination of optimal level of bos indicus blood and British type crossbreeds to avoid reduction of meat quality under Argentine rearing conditions.
- Tenderness evaluation (population data) of Argentine beef from different origin and breeds.
- Adipocyte size/enzymatic activity profiles for different bovine breeds.
- Development of a procedure to count bacteria on whole beef carcasses area.
- Development of methodologies to control anabolic and pesticide residues in meat to be applied by official authorities.
- Development of a meat product stable for eight months at room temperature.
- Development of models to assure food safety in shelf stable meat based products.
- Development of processes (long time-low temperature - LT-LT processing) to improve quality of biologically safe meat products.

- Patent on combined treatment (curing, thermal treatment, irradiation) for inactivation of foot and mouth disease virus, *Listeria monocytogenes* and *Clostridium botulinum*.
- Thermally stabilized ready-to-eat meals formulated with vegetables and meat.

## Current Major Research

### *Food Safety*

Predictive microbiology in foods, use of mathematical models to predict behavior of pathogen and spoilage microorganisms in food models and actual food, and development of analytical procedures for detecting - adrenergic in different biological matrix.

### *Biochemistry*

Investigation of factor influencing tenderness to improve meat quality, influence of ambient factors (rearing conditions, crossbreed, climate) on enzyme systems involved in tenderization of meat, study of collagen phenotype in crossbreeds, investigation of the relationship between animal stress reactivity and tenderness of meat, determination of level and rate of oxidative, hydrolytic and ketonic process, determination of activity level of enzymes involved in oxidative processes, natural antioxidants, and determination of compounds with beneficial health properties (functional foods).

### *Physical Analysis*

Physical and rheological properties of food; new product development and the improvement of existing ones require the knowledge of raw material and food components, physical properties that are important to stabilize or to improve certain desired properties. Prediction of beef tenderness; obtain population data of meat tenderness regarding production variables (crossbreed, age, weight, etc.), study the effect of different meat tenderization methods to reduce meat tenderness variability, aroma profiles of meat from different production systems (pasture, grain, new supplements, etc.) to predict flavor acceptance. Minimally processed food; develop minimally processed food to obtain "ready-to-eat" products with longer shelf life and determine the conditions to obtain an adequate shelf-life with minimum deterioration of sensory properties.

### *Food Processing*

Cook-in packaging and processing of beef to manufacture products such as corned beef and canned meat due to their low tenderness values, process cuts combining LT-LT process and additives in order to obtain a finished or a semi-finished vacuum-packed product with adequate organoleptic properties and yield, and formulation of fresh beef products. Fresh beef products have a market in expansion due to increasing activity in fast foods and supermarket. The formula optimization of this kind of product will improve its quality and eventually customer demand. Attention is focused on manufac-

ture of fresh beef products by adding soy protein and enzymes as binders.

## Australia

Brisbane Laboratory of Food Science Australia (previously CSIRO Meat Research Laboratory)

Dr. Robin Shorthose

## Major Research Emphases

The laboratory, with a staff of approximately 70, is one of five in Food Science Australia. Current research is a reasonable blend of strategic and applied research, with less than 50% of funds coming direct from government.

### *Equipment Innovation and Automation*

Ultra-sound, laser and video image analysis are currently being combined effectively with robots to automate repetitive abattoir tasks. A number of spin-offs from the semi-automatic beef slaughter system "Fututech" are being developed. In the Fututech system, stunning (electric), exsanguination, dehorning, brisket and pelvis sawing, evisceration and sawing carcasses into sides were automatic; opening the hide and removing hocks were manual operations and dehiding was semi-automatic. A commercial prototype was built in 1993. A number of customized sub-units of Fututech have been installed in abattoirs since. The spin-offs include a semi-automatic rib deboning system and a rectum sealing system.

### *Co-Products*

A system to deodorize, decolorize, and defat mutton was developed to a commercial pilot plant stage to produce "mutton surimi." Extraction of pharmaceuticals from the waste stream of this system was also investigated.

### *Factors Influencing the Appearance and Eating Quality of Meats*

The retail display life of meat after packaging, aging and transport to sometimes remote markets is a very important quality trait. Research is continuing into factors that influence initial meat color and the rate of metmyoglobin formation during retail display. Presently, the benefits of natural antioxidants are being assessed.

The research has shown that the contribution of connective tissue (CT) to toughness increases with animal age, but that the rate varies markedly between muscles of carcasses processed to avoid muscle shortening. For example, the CT contribution in the tenderloin (*M. psoas major*) is low, and remains low, even in old animals; it increases slowly in the loin (*M. longissimus dorsi*) (LD) and rump (*M. gluteus medius*), and increases rapidly with increasing animal age in the eye-round (*M. semitendinosus*) (ST). As the proportions of known cross-links of intramuscular collagen are similar within

muscles of the one carcass, the CT contributions to toughness will vary with the CT contents of the muscles. Between-muscle differences in the rate of increase of the CT contribution with increased animal age probably reflect differences in the number and nature of the more heat-stable, and uncharacterized, cross-links formed.

The *post mortem* rate of glycolysis is known to influence the color, color stability, water-holding capacity, cooking loss and tenderness of muscles. The influences of small differences in the rate are being reinvestigated to see if they can account for differences in meat quality of muscles of carcasses that have been processed optimally.

The rates of disappearance of unaged, striploin steaks, sold at three prices and differed in size, meat color, subcutaneous fat trim and amount of intramuscular fat, from supermarket displays in three cities that were monitored. The average urban Australian shopper preferred large steaks with no subcutaneous fat and little marbling. Marbling accounted for less than 1% of the variation in the tenderness scores of the consumers (66% return).

### *Microbiology and Production Hygiene*

In a country that exports the majority of the meat it produces, pathogens, hygiene and storage have always been important areas of study. Pathogens that have been investigated include *Salmonella* and *Listeria*. The ecology of pathogenic *E. coli* is presently under intensive investigation. A national study of the hygienic status of Australian beef and sheep carcasses and frozen meat was completed recently. The beef and sheep carcasses had similar bacterial loads to those in other countries. Loads were greater on carcasses chilled for three days rather than one and sheep carcasses had more *Salmonella* and fewer *E. coli* O157H7 than beef carcasses. It was concluded that improvements in chilling procedures, particularly in domestic abattoirs could reduce bacterial loads. The survival of pathogens in salamis has also been studied. Hygiene studies have been facilitated by both modeling bacterial growth and risk assessment studies.

A hot water carcass decontamination unit that reduces bacterial numbers by at least 2.5 logs has been developed and commercialized.

The microbiology of vacuum packaged meats has been of continuing interest. Recently, a method of modified atmosphere packaging has been developed which allows retail-ready packs of beef to be exported to overseas markets.

## **Current Major Research**

### *Factors Influencing Carcass Characteristics and the Appearance and Eating Quality of Beef*

In 1993, the organization together with the New South Wales and Queensland Departments of Agriculture, the universities of New England, Queensland and Central Queensland, and with support of many sectors of industry, entered into a Cooperative Research Center (CRC) (Meat Quality) agreement. The aim was to develop cost-effective ways of

producing desired carcasses for any market and to understand, particularly, genetic influences on the efficiency of production and carcass and meat quality. Approximately 8,000 animals (straight-bred offspring of four British [Angus, Hereford, Murray Grey and Shorthorn] and three tropically adapted breeds [Belmont Red, Brahman and Santa Gertrudis] and cross-bred offspring of terminal sires from most of these breeds, plus Charolais, Limousin and Charbray, over Brahman females) were used in the first stage (1993 - 2000) of the CRC. One-half of the animals were finished off pasture and half through feedlots. Animals were slaughtered at carcass weights of either 220, 280 or 340 kg. carcass weight. It was demonstrated that, with careful pre-slaughter handling and effective electrical stimulation, tender meat (*M. longissimus dorsi* (LD) and *semitendinosus* (ST)) could be produced at one day *post mortem*; mean LD Warner-Bratzler peak shear force value of samples cooked at 70 degrees C for an hour was 4.29 kg and mean LD compression value 1.69 kg.

Heritabilities and genetic correlations were obtained for live weight gain, lean yield, subcutaneous fat depth, fat color, meat color, intramuscular fat, ultimate pH, cooking loss, Warner-Bratzler peak shear force and compression values of the LD and ST. The heritability of tenderness varied from 4 to 25% in the British breeds and 17 to 44% in the tropically adapted breeds and that of intramuscular fat content was 43%. Genes for particular carcass and meat quality traits were identified and EBVs (EPDs) were supplied to the relevant breed societies for use in future breeding programs. They were distributed through the genome, with concentrations on chromosomes 5, 6, and 14. Stage II of the CRC runs from 2000.

Data from the CRC and studies on the effects of variations in rates of glycolysis on quality led to a strong relationship with those developing the Australian beef grading system, Meat Standards Australia (MSA). The system is unique in that it prescribes animal type, pre-slaughter treatment, carcass processing and meat aging procedures, rather than just describing the attributes of the animal and carcass, and considers the quality of all major cuts on the carcass, rather than only those of the loin (LD).

## **Belgium**

Department of Animal Production of Ghent University  
Prof. Dr. Daniel Demeyer

### **Major Research Emphasis**

The department is responsible for graduate and post-graduate level teaching on general and animal nutrition, animal science, meat science and technology and aquaculture. Teaching is supported by research projects involving about 40 academic staff members and centered around five main subject area's:

- Digestive physiology of both ruminants and pigs.
- Beef and pork carcass quality.
- Beef nutritive value and sensory quality.

- Meat fermentation.
- The rearing biology of the brine shrimp *Artemia* and its use in aquaculture.

### Previous Research

- The quantification of the relation between *post mortem* proteolytic changes and tenderness in beef, using SDS-PAGE.
- The demonstration of the lower myofibrillar tenderness in beef from double muscled animals, associated with lower proteolysis and changes in calpain and calpastatin activity.
- The dominant importance of endogenous, non-microbial protease and lipase activities in the initial metabolic changes leading to flavor development during dry sausage fermentation.
- The further elucidation of the relation meat quality-carcass quality in pork.
- The relationship between fat content and fat composition in double muscled beef, as affected by breed and feeding.

### Current Major Research

The main meat related research effort started in 2001 deals with the optimization of meat fatty acid composition. The effort is again supported by both European and national sponsoring. It is aimed at an improvement of the functional food value of meat with particular interest in the presence of conjugated linoleic acids in meat from double muscled bulls, as affected by both breed and feeding. The impact of the expected results on the nutritive value of beef for the consumer is evident. Besides effects of nutrition, evidence for animal effects on n-3 poly-unsaturated fatty acid metabolism has already been obtained (Table 1).

## Brazil

Instituto de Tecnologia de Carnes – CTC  
Dr. Nelson Jose Berequet

## Major Research Emphasis

The Centro de Tecnologia de Carnes (CTC) (Meat Technology Center) is part of the Instituto de Tecnologia de Alimentos (ITAL) (Food Technology Institute) of the Secretariat of Agriculture of the State of Sao Paulo. CTC was established in 1976 as the first infrastructure in Brazil geared to technological research in meat processing with emphasis on:

- Meat quality as affected by slaughter technology techniques stunning electrical stimulation, handling of animals before slaughter.
- Shelf-life extension of fresh meat (acid sprays, modified atmosphere irradiation).
- Meat safety (occurrence of *E. coli*, bacteriocins).
- Product development (battered/breaded fish and poultry meat, use of non-conventional meats like fermented cooked sausages).
- Breeding and nutrition effects on meat quality (pigs).

### Previous Research

- Stunning and electrical stimulation on poultry meat quality.
- Use of acetic acid spray for decontamination of meat and meat products.
- Use of organic acid spray for extending shelf-life of chicken breast meat.
- Use of modified atmosphere to extend poultry carcasses and cuts shelf-life.
- Use of modified atmosphere to extend the shelf-life of beef steaks.
- Storage temperature and aging of meat.
- Irradiation of poultry carcasses and cuts.
- Occurrence of *E. coli* 015:H7 in hamburgers in Brazil.
- Slaughter techniques and its effects on pig meat quality.
- On-line methods to evaluate water holding capacity, intramuscular fat and total pigments on pig carcasses.
- Modified atmosphere and its effects on sliced cooked ham.

### Current Major Research

Seventy-five percent of the pork meat in Brazil is driven for further processing. There is an interest of the meat companies to increase the market share for the fresh meat. To achieve this, the quality of the fresh meat has to be assured using the best slaughtering practices. In this direction CTC carried a large study on stunning, bleeding techniques, skinning, types of scalding and boning (hot/cold) regarding its effects on quality characteristics of pork meat. It was expected that the results obtained would help industry to choose the best slaughtering techniques. Shown in Table 1 are selected data from the experiments comparing automated high voltage vs. low voltage manual stunning for male and female pigs. Manual stunning had a negative effect on meat quality: higher blood splashing; WHC values indicative of PSE meat; increased drip loss, boiling loss and firmness.

**TABLE 1.** Amount of conjugated linoleic acids (CLA), polyunsaturated (PUFA)/saturated fatty acid (SFA) and n-6/n-3 PUFA ratios in meat of Belgian Blue bulls depending on the double-muscling genotype (mh = double muscled allele; + = normal allele) (Raes et al., 2000).

	Mh/mh	mh/+	+/+
CLA (% of total fatty acids)	0.45 <sup>a,b</sup>	0.39 <sup>a</sup>	0.51 <sup>b</sup>
PUFA/SFA	0.56 <sup>a</sup>	0.40 <sup>b</sup>	0.19 <sup>c</sup>
n-6/n-3	5.53 <sup>a</sup>	5.17 <sup>a</sup>	6.32 <sup>b</sup>

<sup>a,b,c</sup> Means with different superscripts are significantly different (p < 0.05)

**TABLE 1.** Mean Values for the Meat Quality Characteristics.

Variable	Muscle	Treatments			
		A	B	C	D
R-Value	LD	0.9242 <sup>a</sup>	0.9286 <sup>a</sup>	0.9743 <sup>b</sup>	0.9885 <sup>b</sup>
pH <sub>1</sub>	LD	5.91 <sup>a</sup>	5.87 <sup>a</sup>	5.68 <sup>b</sup>	5.59 <sup>b</sup>
pH <sub>2</sub>	SM	5.93 <sup>a</sup>	5.84 <sup>a</sup>	5.64 <sup>b</sup>	5.66 <sup>b</sup>
Blood splashing	LD, SM, BF e Q	2.17 <sup>a</sup>	2.50 <sup>ab</sup>	2.67 <sup>ab</sup>	2.84 <sup>b</sup>
WHC, G value	SM	0.5421 <sup>b</sup>	0.5336 <sup>b</sup>	0.3988 <sup>b</sup>	0.39309 <sup>a</sup>
Drip loss, %	LD	4.40 <sup>a</sup>	5.94 <sup>b</sup>	5.66 <sup>b</sup>	6.58 <sup>c</sup>
Boiling loss, %	LD	21.17 <sup>a</sup>	27.66 <sup>a</sup>	36.51 <sup>b</sup>	35.62 <sup>b</sup>
Firmness, Kgf	LD	2.31 <sup>a</sup>	2.24 <sup>a</sup>	3.01 <sup>c</sup>	2.83 <sup>b</sup>

A = automated high voltage, male

B = automated high voltage, female

C = manual low voltage, male

D = manual low voltage, female

<sup>a, b, c</sup>Means within a row with different superscripts are significantly different (p<0.05)

The study indicated that high voltage electrical stunning should be recommended although CO<sub>2</sub> stunning gave similar results. The meat of skinned/hot boned carcasses had better quality characteristics than those from scalded/cold/hot/boned ones.

tests, and 5) fiber-optic spectrophotometry. Impedance was the best method. It is also the simplest. On the basic side, some unusual relationships between electrical capacitance and optical properties were detected. These are now being re-investigated, looking at the effect of frequency, electrode placement and time change post-mortem.

## Canada

University of Guelph  
Dr. Howard Swatland

### Major Research Emphasis

- Meat processing and poultry.
- Beef and meat quality research.
- Instrumentation for meat research.

### Previous Research

- Incidence of PSE in turkeys.
- Whey protein gelation.
- On-line sensors used in meat processing.
- Effect of breed on beef tenderness and taste.
- Dietary effects on beef tenderness and taste.
- Development of polarized light probe for meat.
- Development of UV fluorescence probe for connective tissue.

### Current Major Research

A local turkey breeder (Hybrid Turkeys, Kitchener, Ontario) was interested in finding the heritability of meat quality in their various lines of turkeys. Customers identified fluid losses as the meat quality trait with the greatest economic importance. A battery of different methods were applied to find the strongest correlations with fluid losses: 1) pH, 2) Minolta colorimeter paleness, 3) electrical impedance, 4) polarized light

## Canada

Lacombe Research Center  
Dr. L. E. Jeremiah

### Major Research Emphasis

- Meat quality and safety.

### Previous Research

- Fat, marbling and PSE in pork.
- Objective pork carcass grading.
- Pasteurization of beef and pork carcasses.
- Beef tenderness prediction.
- Physiological maturity indicators and quality classification of sheep and lamb.
- Sex-taint compounds in pork.
- Early disease detection with infrared thermography.
- Radio-frequency thermal antimicrobial treatment of meats.

### Current Major Research

- Extension of meat storage life with preservative packagings.
- Based upon visual and olfactory perceptions controlled atmosphere, CO<sub>2</sub>, packaging and vacuum packaging provide a storage life for chilled pork of 15 and 12 weeks, respectively, under commercial conditions.

- Each six-week interval of chilled storage in controlled atmosphere, CO<sub>2</sub> packaging results in a one-day reduction in subsequent aerobic, retail display life.
- Pork undergoes relatively slow autolytic deterioration in controlled atmosphere, CO<sub>2</sub> and vacuum packaging.
- Ingress of oxygen into vacuum packages during storage results primarily in deterioration of visual properties after relatively long storage times.
- The optimum CO<sub>2</sub> concentration for use in controlled atmosphere CO<sub>2</sub> packaging of chilled pork is two liters per kilogram of product.
- The pH of pork with PSE characteristics tended to normalize with extended storage in controlled atmosphere, CO<sub>2</sub> packaging, and the color of pork with extremely aberrant quality approval to normalize by approximately one level of quality after 15 weeks of controlled atmospheres, CO<sub>2</sub> storage.
- The limiting factor for extension of chilled pork storage life is early development of off flavors, which coincides with lactic acid bacteria approaching maximum numbers and a shift in the lactic microflora from non-aciduric to aciduric and renders product with commercial contamination undesirable after six weeks of anoxic stability.
- The color stability and subsequent aerobic, retail display-life of display-ready beef and pork stored in controlled atmosphere, CO<sub>2</sub> and vacuum packaging is maximized by storage at below zero temperature (-1 to -1.5° C).
- A storage life of at least three weeks should be attainable with display-ready packs of pork.
- Retail-ready beef steaks stored, in controlled atmosphere, CO<sub>2</sub> retained an aerobic display-life of 30 hours after 13 weeks or less of storage, while retail-ready beef steaks stored in vacuum retained an aerobic display-life of 30 hours after only eight weeks or less of storage.
- The storage life of display-ready packs of beef and pork, masterpackaged in controlled atmosphere, CO<sub>2</sub> and stored at -1.5° C could be extended to 10 weeks by including oxygen scavengers in the retail packs.

## China

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Nanjing Agriculture University  
Dr. Guanghong Zhou

### Major Research Emphasis

#### Meat Standard

- Beef quality grading standard (System): to be recognized by Ministry of Agriculture as the national standard.
- Pork quality measurement: WHC, color and darkness measurement standard and relevant instruments development.

#### Processing Technology

- Improving traditional Chinese style meat products: quality control, standardization of production techniques.
- Development of new meat products.

- Meat preservation: chilled meat, nature ingredient used for extension of meat products' shelf-life.

#### Meat Production and Meat Quality

- Effects of aging and ES on beef, WHC and pH of Pork.
- Comparison of muscle components of major livestock and poultry.
- Carcass studies: beef, pigs and ducks, effects of breeds, nutrition and growth regulation on their carcass composition.
- Growth regulation: use of growth hormone and beta agonist to improve livestock and poultry meat productivity.

#### Meat Safety

- Microbiology studies and residue detection (Clenbuterol)

## Denmark

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Danish Meat Research Institute (DMRI)  
Dr. K. B. Madsen

### Major Research Emphasis

- Food safety.
- Product quality.
- Production efficiency and working environment.
- External environment.
- Measuring technology.

#### Food Safety

The main concern is the microbial food safety. The chemical food safety is monitored, but results show that in Danish pig production residues such as medicine, antibiotics, toxic chemical (dioxin, PCB etc.) are always detected in extremely small amounts.

In microbial food safety, emphasis has been and still is on *Salmonella* and *Listeria*.

#### *L. Monocytogenes* Projects

*L. Monocytogenes* can be a troublesome organism in chilled retail meat packages. The organism can grow at low temperature and may persist in the production environment for years. DMRI has implemented a number of projects to minimize the risk:

- Contamination routes of *L. monocytogenes* in meat processing plants.
- Elimination of *L. monocytogenes* in biofilm on processing equipment.
- Growth inhibition of *L. monocytogenes* by use of hurdle technology.
- Growth inhibition of *L. monocytogenes* by use of biopreservative cultures.

#### *Salmonella* Projects

Via a number of action plans, the Danish slaughter industry and the authorities have agreed to reach a *Salmonella* level less than 0.5% in fresh pork by year 2002. By the end of

1999 the level already was less than 1% in fresh pork. DMRI has participated in reaching the goal via the projects:

- Decontamination of pig carcasses.
- Implementation of double fat-end loosener.
- Automatic evisceration.
- Optimization of slaughter line hygiene.

#### *Product Quality*

Product quality comprises animal welfare, slaughter quality, meat quality and eating quality.

- Development of an automatic lairage system without use of electric goads ensuring animal welfare and improving meat quality.
- Development of an automatic classification center for measuring of slaughter quality of pigs.
- Development of equipment for group driving and stunning of pigs.
- Development of equipment for automatic classification of beef.

#### *Production Efficiency*

DMRI has, in close cooperation with machine manufacturers SFK Danfotech, Stork and Attec, developed and designed a number of equipments for the automation of the slaughter line. The latest development is the world's first automatic pig carcass - evisceration equipment. It has been used in daily production in a slaughterhouse for more than a year. Other important developments carried out and implemented in the production are equipment for automatic back scoring and finning as well as for splitting of carcasses.

#### *Measuring Technology*

A range of equipment for measuring different meat quality parameters has been developed by DMRI. For the moment DMRI is cooperating with Purdue University, USA in a project with the aim to predict the final meat quality in pig carcasses based on measurements carried out on the day of slaughter.

### **Current Major Research**

- Automation of the slaughter line.

By the end of 2005, the goal is to have machines available which makes it possible to automate slaughter lines with only a few manual process and surveillance functions left. By the end of 2007, the goal is to have automatic equipment also available for the major processes in the boning and trimming of cuts.

Danish slaughterhouses expect difficulties in the recruitment of personnel due to a significant reduction in the number of young people entering the labor force. Development of automatic equipment reduces the need for labor, and it eliminates arduous operations and improves the working environment. Introduction of automation must under all circumstances maintain the quality and safety of the final product.

Among the new machines to be launched, one will automatically remove the surface bones riblet and neck bone from fore-ends. Also, automatic equipment for sawing of rib-top and splitting of middles in loins and bellies will expectedly be approved for daily production in short time.

Ongoing developments are automatic cutting of pluck and automatic removal of internal bones in fore-ends.

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## **Finland**

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University of Helsinki  
Professor Eero Puolanne

### **Major Research Emphasis**

Stress and animal welfare, and meat quality (basic research)

- Carbohydrate metabolism and oxidative capacity of porcine muscles, related to the animal growth rate.
  - fiber types, oxidative/glycolytic enzymes, glycogen break-down.
  - strength of bones.
  - meat quality.
- Beef glycogen levels.
  - effect of residual glycogen level on the keepability.

Fermented Meat Products (applied research)

- Probiotic bacteria in fermented meat products.

Water-binding in cooked meat products (applied research)

- Reduction of the sodium content in meat products.
- Water-binding capacity of different meat items for linear programming in multicomponent sausage batters.

### **Previous Research**

Stress and animal welfare, and meat quality (basic research)

- The effect of muscle types, storage and food additives buffer on capacity of meat.
- Glycogen levels in beef muscles, related to stress and feeding.
- Poultry meat tenderness in relation to stunning.

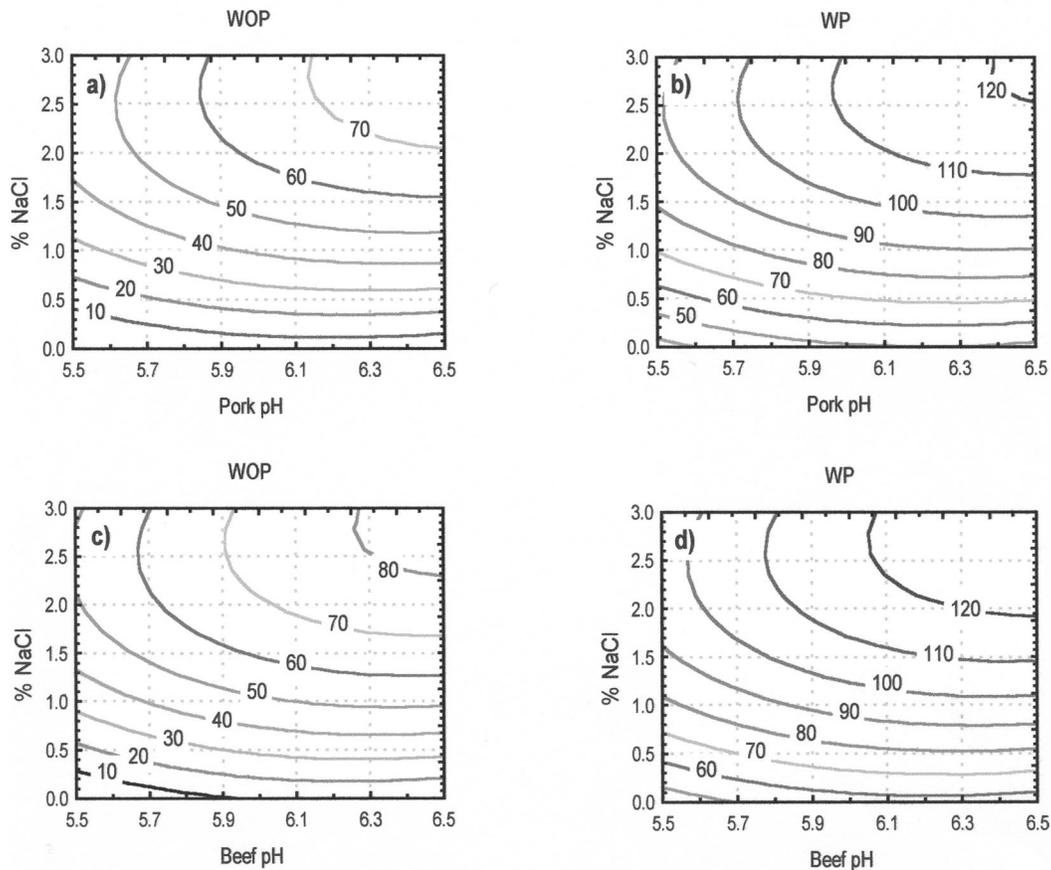
Microbiology and fermented meat products (applied research)

- Spoilage of coarsely ground, cooked ham.
- Starter cultures in fermented fish.

Water-binding in cooked meat products (applied research)

- Production control of integrated meat plant from the animal transport to the delivery of processed products. A combination of process simulation and linear optimization.

WHC,  $R^2 = 0.923$



The effect of the pH of the raw batter and salt content on water holding capacity (WHC, g water/100 g meat) in cooked sausage. (WOP = without added phosphate and WP = with added phosphate).

(Puolanne et al. Meat Science, 58: 1-7; 2001)

## Current Major Research

### Reduction of Sodium Content in Meat Foods and Meat Products

The sodium content in many Western human populations should be reduced for health reasons. Meat foods and meat products are important sources of sodium in the diet. The reduction of the sodium content causes, however, technological problems in manufacturing and keepability, as well as a weakening of taste and flavor. The purpose of the study was to develop new procedures to produce low-sodium meat products that are accepted by consumers.

In the figures below the most important variables on water-binding in meat products, pH-value and salt content, are presented. It can be seen that a same water-binding can be obtained by different salt-pH combinations, with and without added phosphates, depending on the product and on the expectations of the consumers. When lowering the salt content, the pH of the batter should be raised and/or phosphate added in order to obtain the desirable water-binding (gelling). (Please observe that this has been made by experimental sau-

sages, where the amount of added water is larger than in industrial applications.)

Salt is involved in water-holding, firmness, and taste and flavor, as well as microbiological safety of the products. The salt content of cooked sausages can be reduced to 1.0-1.2% and of whole meat products to ca 1.4% NaCl. Depending on the formulation of the product and accustomed salt levels in each particular population, each of the traits mentioned above can become critical for commercially acceptable product, when sodium is reduced. Instead of only reducing NaCl, salt mixtures containing other salts than NaCl provide also a feasible way to reduce sodium content.

## France

Station de Recherche sur la Viande INRA de Theix  
Dr. Eric Draisfield, Prof. J. Labadie

### Major Research Emphasis

- Mechanism of Tenderization of Meat

To better understand the mechanism of tenderization of meat, the problem of variable meat texture was studied where

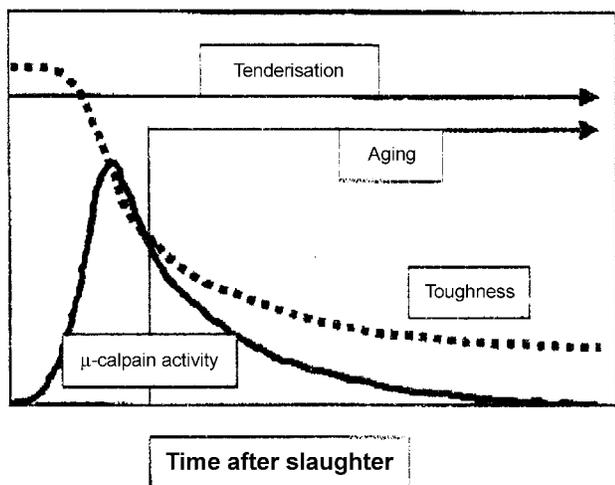
a multidisciplinary project was conducted at the Meat Research Station at Theix in collaboration with the French 'Meat and Livestock Commission' (INTERBEV).

Although it had been suggested as long ago as the mid-1970s that calpains played a role in tenderization, in the early 1990s, there were still strong arguments being put forward that other proteases and even non-enzymatic mechanisms could still be important.

A project was started in which the disciplines of biochemistry, theology, physico-chemistry, and modeling were brought together to give a new insight into the mechanism of tenderization. The project was studied over four years using homogeneous 26 month-old Charolais cattle. With facilities for slaughtering, controlled handling and ability to work on isolated muscles with accurate temperature control, measurements were able to be taken from death to storage up to three weeks. Biochemical measurements, included calpains, calpastatin, cathepsins and their inhibitors, were based on extracts of muscle and meat. Early on in the project it was realized that it was impossible to measure directly the enzyme activities in situ and that a modeling approach would have to be developed. The problem for the modelers was to try to predict the calpain activity in situ from the measurements made *in vitro*. Both empirical statistical expressions and fundamentally- derived equations were developed and compared.

Tenderization was found to be mainly due to the activity of calpains; the key being the demonstration of the relative effect of temperature on the rates of activation and inactivation of  $\mu$ -calpain. Furthermore, the equations developed helped them understand the importance of rigor development to enzyme activity and tenderization and separated tenderization and aging (see Figure 1) helping to resolve much of the confusion in the literature about myofibrillar tenderness. This also helped to rationalize differences between species, temperatures and rigor development as in the case of thaw rigor, PSE and DFD conditions.

No doubt, refinements to the model will be made, but it has already helped in practice for beef in France and for lamb in New Zealand.



The figure shows throughout storage the calculated changes in the activity of  $\mu$ -calpain in raw meat and the toughness of the cooked meat. Soon after death the enzyme activity increases and toughness decreases. With instability of the enzyme, its activity decreases eventually approaching zero when the tenderization stops. The time scale depends particularly on the species. Aging is that part of tenderization which occurs in post rigor meat and is routinely measured.

### Management of Microbial Ecology

In product manufacture in both the dairy and meat products industries, microbiological similarities exist in that the quality of the products depends on the type and quantity of flora.

On one hand, the development of certain microbial species in the chain and/or in the raw materials could be the source of contamination during the stages of fabrication and storage of products particularly if the regulations regarding hygiene are not adhered to. On the other hand, certain types of micro-organisms are necessary for production starting from raw materials in the agro-food industry. The study of such micro-organisms identified the desirable flora, pathogenic flora and those technologically useful as in fermentation.

Identifying the development of different types of flora would guarantee the hygienic quality of products, which must be exempt from all unwanted flora and yet allow the development of specific flora, which give the desirable properties.

Hygiene safety is a fundamental objective for the agro-food industry, which uses drastic and often non-selective measures aimed at the total elimination of micro-colonies colonizing the fabrication plants. However there are limits to such an approach:

- The total elimination of undesirable flora in plants is impossible.
- Too drastic a procedure could decrease the organoleptic qualities of numerous traditional fermented products as well as their specific characteristics and their authenticity.

To solve these difficulties, a task force of ten major French agro-food companies proposed the following research projects, which are currently being studied:

- An ecological study of micro-organisms in production sites (dairy and meat chains).
- Stress in adaptation of micro-organisms in plants.
- Improving hygiene on surfaces by the development and maintenance of biofilms.
- Managed ecology by application of an environmental model.

### Germany

Federal Center for Meat Research  
Dr. Karl O. Honikel

## Major Research Emphasis

- Quality and quantity of meat and meat products.

The goal of enhancing the amounts of meat for consumption continued in the 1950's when the Institute again became a governmental research center. The major emphasis has been on the quality aspects of meat, improvements in processing techniques, more sensitive analytical procedures and studies about animal welfare during transport and slaughtering.

## Previous Research

In the area of production, questions about the impact of intensive, extensive and organic farming on the quality of meat were investigated. The objective grading of pig, cattle, lamb and turkey carcasses was developed.

The ante- and intra- mortem influence of treatment on quality (PSE/DFD meat) was investigated. *Post mortem*, the influence of chilling on microbial and sensory quality aspects and economical problems was studied and methods for detecting of quality characteristics were developed or adapted to carcasses and cuts. The slaughter process was studied with regard to animal welfare especially during stunning and sticking, the hygienic aspects of scalding of pigs, dehiding and evisceration were subject of research.

After a year the splitting of carcasses in order to avoid spreading of SRM (specific risk material) on the carcass became the center of scientific interest in this field. Contamination of carcasses by *salmonellae* and other pathogens were studied in a nationwide survey.

Food safety aspects during processing into meat products especially of raw meat products were topics of high interest. Finally the processing and the stability of mixed foods (e.g. cooked ham on frozen pizza) with regard to microbial and sensorial deviations were studied.

In microbiology starter cultures, bioconservation techniques and predictive microbiology were topics of great interest. Microbial tests for detecting toxins in exchange for animal experiments were started.

In analytical procedures, the sensitivity of analytical techniques for contaminants, residues and other unwanted substances (see below) in meat were enhanced by developing more efficient extraction techniques.

## Current Major Research

The introduction of genetically modified organisms (GMO) in feed and meat products led us to develop and adapt molecular biological methods (PCR, ELISA and others) to feed, raw meat up to highly heated meat products.

Carry-over of contaminants from the environment to feed and meat and representative surveys of contaminants in meat (products) in Germany led to recommended governmental measures for risks assessment and management.

The oxidation of cholesterol to cholesterooloxides (CO) can be toxic, carcinogenic, mutagenic, and have many other negative aspects like the real culprits for forming plaques.

As is known from other oxidative aspects in meat, e.g. the warmed over flavor, oxidation of cholesterol also takes place on chilled meat after a heating process has occurred. Several of the many cholesterol oxides could be detected. The finer the grinding or comminution was, and with increasing level of PUFA in the meat, the concentration of oxides increased. The use of the often-blamed nitrite prevents oxidation as it also retards rancidity. With these experiments we want to show that CO do not have to be formed during storage and nitrate to show positive effects.

## Hungary

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Hungarian Meat Research Institute  
Dr. Kálmán Incze

## Major Research Emphasis

- Basic and applied research
- Food safety
- Healthy nutrition

The research activities of the Hungarian Meat Research Institute involve mainly applied research. These research commissions are coming from the meat companies, including development of new products, analytical, microbiological, sensory examinations or testing of packaging materials. The limited basic research activities are financially supported by the government or by the EU. The most important fields are food safety and healthy nutrition. Food safety research on mycotoxins, nitrosamines, survival of *Listeria monocytogenes*, and EHEC in dry sausages has been studied. With healthy nutrition, the main aim is to supply dieticians as well as consumers with reliable data on the composition and the role of meat, meat products and fat in the healthy nutrition. These data are partially collected from scientific literature and partially from results of own analyses. Another aim is to develop meat products with lowered fat, sodium content, enrichment with important fatty acid, etc.

## Previous Research

The improvement of the quality, naturalness and shelf-life of food products by the use of selected bacteriocins from lactic acid bacteria involved the exploitation of bacteriocins from lactic acid bacteria (LAB) to maintain and enhance the quality, nutritional value, naturalness, freshness and shelf-life of food. Bacteriocins were isolated and characterized and their physiochemical properties were examined under specific environmental conditions of the food products under study. Finally, the bacteriocins and the LAB strains were applied on a pilot scale in meat products. Since the tested *Lb. sakei*, and *Leu. gelidum* strains did not influence the organoleptic properties of Hungarian-style fermented sausage, these strains can be used in combination with the *Lb. jensenii* starter culture, used in Hungary, to produce microbiologically safe and organoleptically stable fermented meat products.

*The Safety of Fermented Meat Products*

The low pH and/or low water activity developing during ripening of fermented meat products are inhibitory to most spoilage and pathogenic bacteria. The acid tolerant *E. coli* 0157:H7 can survive fermentation and storage, and may cause outbreak of often lethal gastroenteritis.

Survival, growth and loss of viability of *E. coli* 0157:H7 in Hungarian fermented sausages have been studied. It was established that the decrease of water activity and the durable action of this lowered  $a_w$  reliably reduces the number of *E. coli* 0157 viable cells by five log units during fermentation. (This rate of reduction meets the USDA and FSIS regulations.)

#### *"Heart-Friendly" Meat Products*

A national program, called "Heart-friendly Foods," related the unhealthy nutritional habits of the Hungarian population, was introduced with the support of the World Bank. Any food product that meets the expected criteria and the relevant national requirements can wear the logo of the program. Cooked ham was chosen for this purpose because of its low fat content. Selection of raw material, curing technology and packaging were important steps in the development of the "heart-friendly" product. Adverse effects of salt reduction on sensory characteristics were eliminated by the use of potassium lactate, potassium chloride and dextrose. The new product called "VITAL ham", meets the requirements of the Hungarian "Heart-friendly Program."

The assessment and enhancement of fermentation and ripening of dry-cured sausages is related to sensory quality and wholesomeness. The aim of the project was to reduce processing time of dry-cured sausages, while maintaining a good texture and reproducible flavor. Special attention has been paid to the influence of micro-organisms and enzymes on processing time, pH and flavor. Dry-cured sausages were manufactured on an industrial scale in Hungary and in the Netherlands, applying the same starter cultures in parallel experiments. The manufacturing technology, the type of starter cultures, and the type of raw materials in the product formulation appeared to be the major factors in determining the flavor and texture of end-product. Addition of proteolytic enzymes showed generally confusing and sometimes even conflicting results on flavor development.

#### *Probiotics*

The possibility of the use of probiotic bacteria alone or in combination in Hungarian-type, raw, fermented sausages has been investigated. Technological, microbiological and sensory evaluations are currently carried out with clinical tests to follow.

### **Current Major Research**

#### *Development of Complex Analytical Systems for Determining the Chemical Composition of Meats.*

In the quality control of meats, the substitution of standard analytical methods with simpler and faster ones is an important task for meat analysts. The theoretical bases of compara-

tive evaluation of methods are thoroughly discussed. The distinction made between deterministic and stochastic relations has primary importance in comparing methods.

For determining moisture content in meats, the microwave drying appropriately substitutes the lengthy standard method. Similarly, the measurement of density of fresh meat can adequately replace the laborious Soxhlet method. For the measurement of nitrate content, the method using hydrazine-sulfate reduction can replace the standard Cd-column in procedure.

Owing to various interfering factors, neither the determination of fat content with the CW-NBMR and P-NMR techniques in fresh meat, nor the determination of phosphorus content with partial digestion of samples was completely successful. Likewise, substitution of the standard Kjeldahl method with trinitro-benzene-sulfonic acid spectrophotometry or with the combustion technique of Dumas cannot be recommended for all types of meat. The latter method gave different results from the Kjeldahl one with raw materials of high connective tissue content.

#### *Mycotoxin-Research*

Traditional Hungarian salami is a long ripened dry sausage with mold cover. Molds developing on the surface come traditionally from the special "house-flora" of the salami factories, in operation for more than 100 years. It has been proven by chemical and biological analyses that this product manufactured under traditional circumstances contains no detectable amount of mycotoxins.

#### *Nitrosamines*

Several Hungarian meat products were tested for occurrence of NA-s and no health hazard levels have been found. Frying of meat products, e.g. bacon, is not commonly eaten in Hungary.

#### *Starter Cultures*

Traditional dry sausage technology, known for more than 100 years in the country, uses no additives, neither starter cultures nor chemical acidulants, to enhance ripening/drying. For this reason, starter culture technology was not known in Hungary since the late 70's. The Institute introduced this technology in the home meat industry, where also new isolates have been tested, approved and put into practice.

## **Ireland**

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The National Food Center  
Dr. Vivian Tarrant

### **Major Research Emphasis**

#### *Food Safety*

Food safety will continue to be the top priority with a strong research, training and consultancy drive aimed at assisting food companies to implement appropriate food safety systems, in compliance with the new food safety regulation. Research will concentrate on developing systems to reduce con-

tamination of foods by pathogenic bacteria and other organisms, and on quantifying the risks to consumer health from pathogens in meats and other food. These systems will provide industry with mechanisms to prevent contamination and so reduce risk to the consumer.

#### *Chemical Residues in Meat and Other Foods*

Studies on chemical residues in meats and other food will prioritize the areas of mycotoxins, antibiotics and antiparasitics. Irish food products will be supported in the marketplace through the availability of timely, focused and high quality data and information on chemical food safety. A Cooperation Agreement with the Food Safety Authority of Ireland will be implemented covering the program of research and training in food safety.

#### *Fresh Beef Products*

Meat research will support the production of fresh beef products of consistent quality and high nutritional value and processed products that meet consumer needs. Information about the future needs of consumers will be provided by the new Food Related Lifestyles model being developed with the Danish MAPP Institute. This will guide industrial innovation and new product development by Irish food companies. Research will continue on the nutritional content of beef produced from grass-based systems with particular regard to beneficial fatty acids. The application of biotechnology as a tool to identify important quality traits in beef will commence. Innovative developments in meat processing and the development of on-line tests for quality will be pursued. Much emphasis will be placed on technology transfer of innovative systems, processes and protocols, to increase the competitiveness of the Irish meat industry.

#### *Product Innovation*

Information on consumer trends and market segmentation will be generated by research into consumer food-related lifestyles. Secondly, technical research will evaluate novel processes and functional ingredients for the improvement of existing products and the development of new products. This will include freeze-chill technology for application to ready meals and fish fillets, *sous vide* cooking with freezing for ready meal components and screening techniques for ingredient authentication.

## **Previous Research**

#### *Mechanical Grading*

Machines that can automatically classify carcasses would be more acceptable than visual grading as a basis of realistic quality-based payments. Such machines should command the confidence of farmers and factories provided that they can be shown to be at least as accurate as the present visual grading system.

The first comparative trial of mechanical beef grading systems was carried out using the Danish BCC 2 system, the German E + V System, and the Australian VIAscan System to

test the accuracy for predicting EUROP classification scores and saleable meat yield. This was the first time anywhere that more than one system was tested in the same trial and the first time that any system was tested on Irish carcasses. The results showed that:

- All three machines agreed closely with the Irish Department of Agriculture's grading panel for conformation class.
- Agreement was not as good for fat class.
- All three machines predicted saleable meat yield with a high degree of accuracy.
- Differences in accuracy between the three machines were small.

The main conclusion was that none of the systems would pass the suggested EU authorization criteria, mainly due to lack of agreement between the machines and the graders on fat class.

#### *Producing Tender and Flavorsome Beef with Enhanced Nutritional Characteristics*

Research examined the effects of modern beef production practices on the eating quality and perceived healthiness of beef. Farm production factors appeared to have a smaller impact on beef tenderness than carcass handling technologies, such as slow chilling and electrical stimulation, and the tenderstretch method of hanging beef.

In contrast with the negative results on tenderness, the diet of cattle had a major positive effect on the nutritional value of beef. An increased proportion of grass in the diet and a corresponding decrease in concentrates produced beef with higher conjugated linoleic acid (CLA) in the lean meat. CLA has anticarcinogenic properties. Furthermore, increasing the proportion of grass in the diet produced lean meat with less fat and a fatty acid profile more compatible with the current human dietary recommendations.

There are marketing opportunities for grass-fed beef on the basis of these results. Furthermore, the finding that forage or concentrate diets did not significantly modify tenderness refutes the common claim that grain-fed cattle produce a superior eating quality.

A rapid test for aged or tender meat was developed, using antibodies that bind to specific fragments of proteins, which appear in meat as it conditions.

#### *New Beef Retail Pack*

Conventional packaging systems using a high-oxygen atmosphere do not provide a sufficiently long storage life to allow retail cuts packaged in Ireland to reach supermarkets in the United Kingdom (UK) or continental Europe. A prototype bulk packaging system for retail ready cuts of beef that will give a storage life of at least three weeks and a display life of at least three days was developed.

#### *Commercial Systems for Rapid Chilling of Lamb*

The technology underwent a factory and market trial in 1999. It reduces weight loss in the chiller, reduces carcass

storage time and allows a faster throughput of product. The results indicate that the ultra-rapid chilling system will be commercially acceptable in the Irish industry, but some fine-tuning of the system is required to maintain carcass appearance in lambs with low fat cover.

#### *A HACCP Plan for Beef Slaughter*

It is anticipated that the new EU hygiene directive will legally mandate HACCP in all food processing operations, including beef plants. However, there are major difficulties with HACCP implementation in abattoirs.

In contrast with other food processes, there is a general lack of validated critical control points in meat slaughter operations. Plans produced in different countries do not provide the details required for the implementation of HACCP in abattoirs, due to the diversity in slaughter operations.

A technical manual was published for the implementation of HACCP in beef export plants. The plan identifies six critical control points (CCPs) on the slaughter line and provides the necessary information to enable beef processors to establish critical limits for each CCP and develop monitoring procedures and corrective actions for use when a CCP deviates from the critical limits.

#### *The Food Residue Database*

The aim of the database is to provide industry with comprehensive information on the residue content of the following Irish food products:

- Third report on nitrates and nitrites in dairy powders.
- Dioxins in cheese.
- Dioxins in pork, beef, sheep and poultry fats.
- Polycyclic Aromatic Hydrocarbons (PAH) in meat products.
- Mycotoxin (ochratoxin A) in pork.
- Antiparasitics (dichlorvos and ivermectin) in farmed salmon.
- Antiparasitics (pyrethroid anthelmintics) in beef and sheep fats.
- Antibiotics in pork, beef, sheep and poultry meats.
- Coccidiostats in poultry meat.

## Italy

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Universita di Parma  
Dr. Roberto Chizzolini

### Major Research Emphasis

- Meat quality and processing meat and meat products.
- Objective evaluation of pork quality.

Various instrumental techniques (electrical conductivity, dielectric loss factor, lightscattering, color, and pH 45 and 24h *post mortem*) have been tested to evaluate the possibility of finding objective quality measurements. The measurement of color parameters, and of "L" and "Hue" in particular, of the CIE-L\*a\*b\* system was found to be useful for a quality classification of fresh pork. Quality was mainly seen as the sum of

those attributes that make pork suitable for processing (technological quality) since in the north of Italy pig production is 90% directed toward heavy pigs (150 - 170 live weight) for traditional products (parma ham, fermented sausages and others). The effect on pork quality of the treatment with salbutamol, a  $\beta$ -agonist, was studied in a specific investigation.

#### *Fresh pork safety*

Bacterial contamination of pork during slaughter was studied in relation with hot and cold cutting of carcasses and with the aim of defining the most significant carcass areas to be subjected to regular controls (HACCP).

#### *Identification of the volatile compounds extractable from Italian raw fermented and cooked pork products*

The relative importance of spices derived molecules and of compounds produced from lipid oxidation, protein/amino acid degradation and bacterial metabolism has been studied in *salame Milano* and Mortadella.

#### *Low-fat pork products*

The research involved the technology for the reduction of fat content in fermented sausages and in Mortadella and on the effects on sensory quality (including the volatiles of the previous point).

#### *Investigation on the oxidative processes of lipids and cholesterol in pork*

Oxidative processes in biological systems are key factors in the physiology of living organisms. They appear to play also very important roles in a number of pathologies, although the link between oxidation and pathology is mostly not a direct cause-effect relationship. Chronic cardiovascular diseases, aging, cancer and degenerative pathologies in general are among the many diseases that have been linked with oxidative stress. Indeed, it has been stated that the discovery of the role of antioxidants and reactive oxygen species (ROS) in chronic degenerative diseases is as important as the discovery of the role of antibiotics and microorganisms in infectious diseases.

Oxidation of lipid moieties can be responsible for the appearance of negative changes in the quality of foods (e.g. rancidity and warmed over flavor), can lead to the loss of some nutritional elements (e.g. some vitamins) and can bring about the formation of toxic molecules (e.g. cholesterol oxides and some aldehydes). The pathological mechanisms of action of lipid oxidation products, acting as free radicals, are not fully understood. There is a general consensus that free radicals can impair the functional integrity of cellular and mitochondrial membranes, damage proteins and nucleic acids, disrupt gene expression and various enzymatic pathways.

Atherosclerosis, being the single most important chronic disease in developed countries, has been widely studied and can be taken as a significant example of the metabolic damages that can be induced or mediated by oxidative stress and lipid oxidation products. Atherosclerotic lesions not only contain cholesterol but also a series of cholesterol oxidation

products (COPs). Recently, the importance of COPs in the development of atherosclerotic lesions was underlined in a clinical study where the serum 7 $\beta$ -hydroxycholesterol concentration was identified as the strongest predictor of a rapid progression of carotid atherosclerosis in humans.

On the wake of such findings the roles of cholesterol as such in the pathogenesis of chronic vascular diseases has been reduced. Factors other than cholesterol intake and serum cholesterol levels are thought to be important, genetics and antioxidant dietary intakes in particular. The notion that cholesterol is toxic or a toxin *per se* seems questionable given the preponderance of data on the contrary. Oxysterols, instead, should be viewed as toxic, particularly with regard to coronary heart disease, since they, not pure cholesterol, cause dysfunction of vascular endothelial cells.

Several studies in rats, rabbits and monkeys have shown that different COPs can be absorbed from the intestine and found in chylomicrons and other lipoproteins and a recent investigation has shown that COPs from ordinary foodstuff were absorbed in the human intestinal tract.

Meat processing procedures could affect lipid oxidation in various ways. Heat treatment has negative effects on cellular structure, inactivates enzymes (including those with reducing activity) and releases oxygen from oxymyoglobin, creating in this way the conditions for hydrogen peroxide production. Cooking, especially at low temperatures for long times, has the effect of releasing iron ions from heme groups as well. Shedding, mincing and mixing disrupt muscle structure and, in this way, increase the surface exposed to oxygen and other oxidation catalysts. Sodium chloride has pro-oxidant effects with still unclear mechanisms. Dry fermented sausages make up a significant part of meat products in many parts of the world and their production technology entails phases (mincing, mixing with salt and additives, maturing), which could promote or facilitate oxidation. Processing times can be as short as two days for cooked hams and longer than one year in dry-cured hams. Processed products can be marketed and consumed rapidly or stored for months. Moreover, raw materials can be used fresh or frozen and in the latter case storage times and conditions can be diverse. Such an ample variety of conditions could have significant effects on fat oxidative stability and, therefore, on the quality and safety of such products.

### Previous Research

The research group formerly belonging to the Istituto di Scienza e Tecnologia degli Alimenti of the University of Parma has been carrying out for a few years a wide investigation on lipids oxidative stability in representative Italian pork products with research projects funded by the European Commission. The projects were:

- New technologies in the manufacture of low fat meat products.
- Dietary treatment and oxidative stability of muscle and meat products: nutritive value, sensory quality and safety.

- Control of bioflavor and safety in northern and Mediterranean fermented meat products.

Such projects have given the opportunity to study fresh pork (chops) and some representative pork products (salame, coppa, parma ham, mortadella) under various production conditions (standard technology, low fat, fresh or frozen raw materials, antioxidants, without nitrites/nitrates, exposure to fluorescent light).

As a general picture, only 7 $\beta$ -hydroxycholesterol, 5, 6 $\alpha$ -epoxycholesterol and 7-ketocholesterol were constantly observed in all products studied. Other oxides considered to be the most dangerous, such as 20 $\alpha$ -hydroxycholesterol, 5, 6 $\alpha$ -epoxycholesterol and 7-ketocholesterol were constantly observed in all products studied. Other oxides considered to be the most dangerous, such as 20 $\alpha$ -hydroxycholesterol, 25-hydroxycholesterol and triol, have been detected only rarely. Cholesterol oxidation was found to vary normally around 0.1% or lower, of total cholesterol in all the types of meat tested with values somewhat higher only in a few cases.

The results obtained on the effect of antioxidants have not always given clear answers due to the variability of analytical data, but there seems to be room for improving the oxidative stability of pork products by an increase in the antioxidant status of the raw materials.

Nitrates and nitrites, as already mentioned, have remarkable effects on the oxidation/reduction equilibrium in fermented meat products directly or via microbial activity. Nitrites, in particular, have a clear antioxidant activity that counteracts the oxidative effects of sodium chloride. The use of other antioxidants, such as ascorbic acid or ascorbates, strengthens such action. The process of mincing and mixing the raw materials with additives and ingredients is responsible for a moderate level of cholesterol oxidation, which does not increase during the following phases of processing.

### Current Major Research

The research line on lipid oxidation is at present focusing on the determination of 4-hydroxy nonenal (4-HNE) in pork products. Such a molecule belongs to a group of aldehydes, characterized by a trans-double bond between C2 and C3 and by an OH group in position 4, considered to be toxic. 4-HNE is produced from oxidation of  $\omega$ -y polyunsaturated fatty acids and is deemed to be the most toxic of lipid oxidation products. The work conducted so far has allowed set up of the analytical method that needed to be adapted to the meat products matrix. The determination of 4-HNE in various pork products is under way.

### Japan

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Hokkaido University  
Prof. Koai Takahashi

### Major Research Emphasis

- Mechanism of Meat Tenderization.
- Basic Research.

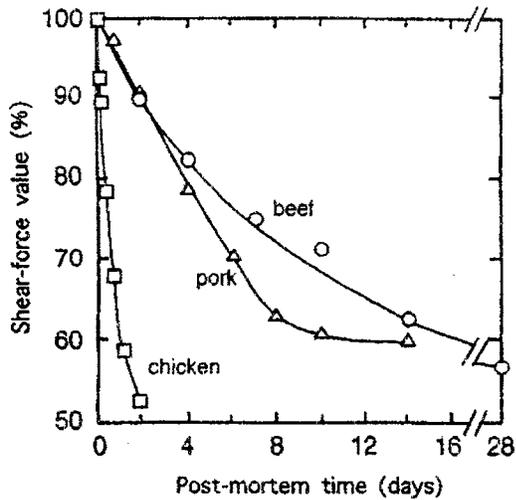


Fig. 1. Tenderization of raw meat during postmortem ageing. Bovine, porcine and chicken *semitendinosus* muscles were aged at 4°C.

### Current Major Research

- Mechanism of meat tenderization during *post mortem* aging: the calcium theory of meat tenderization.

### Current Major Research

- The calcium theory is supported by many experimental facts and seems to be revolutionary.
- Most consumers consider tenderness to be the most important eating quality of meat. To improve meat tenderness, *post mortem* aging at 3 - 5° is required. Again periods are 2 - 4 weeks for beef, 6 - 10 days for pork, and 0.5 - 1 day for chicken (Fig. 1). The toughness is

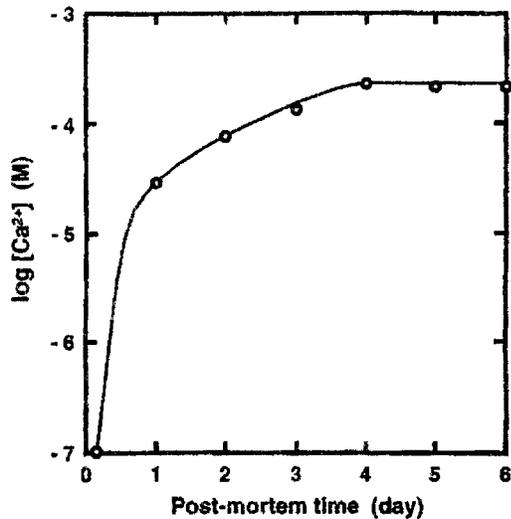


Fig. 2. Increase in sarcoplasmic calcium-ion concentrations during post-mortem ageing of beef. Bovine *semitendinosus* muscle was aged at 4°C, and samples were homogenized with deionized water containing 2mM ATP. Calcium-ion concentrations were determined by atomic absorption analysis.

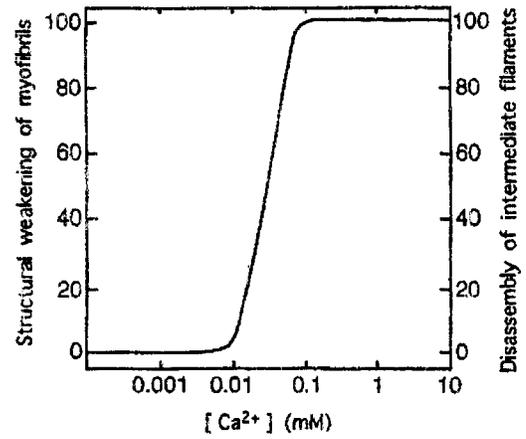


Fig. 3. Dependence of the structural weakening of myofibrils and the disassembly of desmin intermediate-filaments on calcium-ion concentrations. The structural weakening of myofibrils includes four classes of weakening described in the text.

reduced to 50 - 60% of the initial value in all meats. The rapid decrease in toughness is mainly due to the structural weakening of myofibrils and desmin intermediate-filaments, and the structural weakening of the intramuscular connective tissue occurs after 10 days in beef, 5 days in pork and 12 hours in chicken.

- During *post mortem* aging of meat, the sarcoplasmic calcium-ion concentration increases ultimately to 0.2 mM (Fig. 2), which is about 2,000 times higher than the initial value. It has been proposed that the calcium theory of meat tenderization on the basis of the following facts: weakenings of Z-disks and of rigor linkages formed between actin and myosin are specific to calcium ions at 0.1 mM regardless of proteolysis, the same changes in connectin (titin) and nebulin filaments as those observed in aged meat can be induced non-enzymatically by 0.1 mM calcium ions in vitro, and desmin intermediate filaments are disassembled by 0.1 mM calcium ions. These results are summarized in Fig. 3. On the other hand, it has been proven that endogenous proteases, lysosomal cathepsins and sarcoplasmic calpains, do not take part in meat tenderization.
- Proteolysis does not contribute to the tenderization of meat during *post mortem* aging. Rather the *post mortem* increase in the sarcoplasmic calcium-ion concentration to 0.1 mM weakens the structures of myofibrils and desmin intermediate-filaments, resulting in tenderization of meat, i.e. the calcium theory.

## Norway

Norwegian Food Research Institute  
Dr. Einar Risvik

### Major Research Emphasis

The research during the last decade has been focused on trust in meat and willingness to consume as expressed in fac-

tors affecting perceived meat quality. The number one influence on food choice is still quality or freshness, which is rated to be more important than price, taste or healthy eating. The most important quality factors are therefore tenderness and flavor, while color is the most important attribute at point of purchase. The major problem in meat quality is the variability between carcasses.

In close relationship with the Norwegian meat industry, three main topics have been focused at MATFORSK. These are meat tenderness, product and process optimization in the meat industry, and packaging of meat. In addition, generic research with strong relevance for meat has been conducted in several areas. Examples are: consumer attitudes among female adolescents to meat, sensory perception of meat quality, bacterial resistance towards detergents and disinfectants, the use of protective cultures towards contaminating bacteria, and accelerated maturation of fermented meat products.

### Previous Research

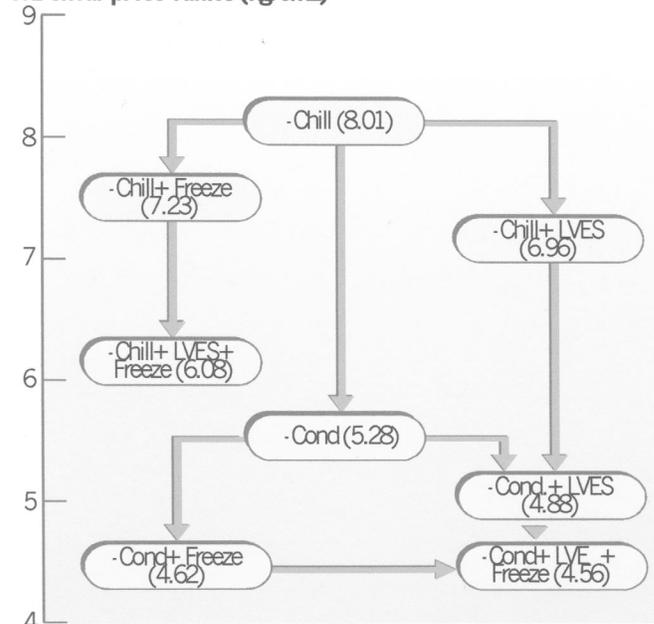
During the last decade research has focused on the effects of modified atmosphere packaging on color and microbiological shelf life. This has been of major interest for the Norwegian meat industry, a country with sparse population. About 60T of retail meat in Norway are currently pre-packaged in modified atmospheres.

Statistical techniques used in product and process optimization have long been a core activity. For a long time the technology gave restrictions as to how many variables could be optimized simultaneously. Recent developments in computers and multivariate statistics makes it now possible to optimize both product and process, with target values for sensory perception and with economically optimal use of a varying raw material quality. Presently, global models across product lines for further improvement of the optimization process are being studied.

The strong focus on meat tenderness started with the use of chemometric and spectroscopic techniques, in order to be able to measure meat tenderness. With reasonable precision this is now possible, using Near Infrared Reflectance and Transmittance as the main principles. Predictive models for tenderness have been tested, and these are now in the process of being validated and evaluated for commercial use.

The most dramatic changes in meat quality occur early *post mortem*, during the first five to ten hours after slaughtering. This period is also when it still is possible to most influence quality parameters. Research has therefore shifted from techniques used for measuring tenderness, to research used to explain what happens during the early *post mortem* period (enzymology, energy depletion and glycolysis rate, and changes in the morphonology of the collagen fibrils). Early *post mortem* cooling regimes have been evaluated, together with pre- and post-rigor temperatures. Stimulation techniques and early *post mortem* deboning and processing are all contributors to tenderness if used correctly together with mechanical and physical restraints.

WB shear press values (kg/cm<sup>2</sup>)



**Figure.** Individual and combined effects of chilling, conditioning, electrical stimulation (LVES) and freezing on tenderness levels of bovine *M. longissimus dorsi* muscles, –measured by Warner Bratzler shear press values after 7 days of conditioning at 4C.

15 - 20% of Norwegian beef carcasses are currently hot-boned. Recent research showed that yield of beef patties increased with pre-salting on direct use of pre-rigor meat.

Findings related to early *post mortem* effects on tenderness are summarized in the following figure. In this figure all the main effects are comparable. Consumer studies have shown that meat with a tenderness/WB shear value of 5.5 or less are considered tender.

The impact of this study is the close relationship between researchers at the Institute and the meat industry to work with implementation concurrent with ongoing research. The slaughtering routines, conditioning, and distribution have been modified continuously as researchers have progressed. At present, knowledge is still ahead of the implementation process, but large modifications in the meat production system have already taken place.

## Poland

Meat and Fat Research Institute  
Dr. Andrzej Borys

### Major Research Emphasis

The research works in the Institute have been performed according to the following main research and development programs: control and evaluation of the dead value of slaughtered animals; forming the desired quality of cuisine (cooking)

meat; theoretical principles and application of unit technological operations in slaughter industry and meat processing with special attention paid to the health, quality and economic aspects, to the decrease of toilsome and harsh influence of food processing on the environment and especially with consideration of improvement of raw material consumption, of the decreasing of water consumption, of the limitation of waste disposal, of the methods of improvement of hygiene conditions of meat production, of the quality and health condition of raw materials and products as well as analytic methods applicable in monitoring, standardization and quality control.

### Previous Research

The after-slaughter (dead) classification of pork and beef carcasses in EUROP system has been developed. As far as pork carcasses are concerned, the regression equations (based on dissection of half-carcasses) for calibration of various kinds of classification appliances are being determined and currently corrected. The Institute has developed a type-series of measuring appliances for the evaluation of flesh class (meat class) based on the principle of an "electronic rule." The classification of beef carcasses consists of personal evaluation of muscle and fat development, while the innovative system of the computerized classification is based on the computerized system interfaced to a video camera. The research has been performed on the influence of chosen survival factors like genotype, feeding level, and rest time before slaughter on the quality and contents of meat in a carcass. While studying the unit meat corning process, research has been carried out on nitrites and nitrates diffusion in the meat environment during injection corning. Simultaneously, the effects of modification of the marinate (flood) corning process of haslets raw material have been monitored. The kinetic tests of influence of particular elements of corning mixtures, sole and in multi-element compositions, on the development of pathogenic and saprophytic microflora of meat have been performed, successfully contributing to the new branch of science, the so-called microbiologic forecasting. The long-term research work was aimed at the determination of the links between the state of order or disorder of the meat structure caused by the unit processes of meat plasticization (softening) and mechanical properties of the products. The research work consisted of the monitoring of changes caused by those processes in the ultrastructure of meat, changes of protein solubility and composition of dissolved fractions, changes in the meat preolytic activity and fragmentation of myofibrils in relation to the changes of the meat sorption capacity and mechanical properties of meat products. In continuation of the search for mechanisms of development of rheological properties of meat products by means of monitoring changes in protein fractions and their swelling abilities, the research work on the influence of high pressure on the processes of disintegration of protein structures as well as on mechanisms of cryoprotection of proteins against denaturing changes in freezing processes have been performed. The structure-forming interactions of proteins and lipides in the model unit process of creating of

dispersion systems typical for highly diminished (cut) meat stuffing have also been examined. The smoking process is the unit process being a long-term research specialization. The research work focused on ensuring healthy products by means of reduction of number (volume) of noxious and undesirable substances penetrating inside the smoked products, on reduction of emission of noxious compounds to the atmosphere and on reduction of energy consumption. Following the current nutrition trends of reducing total fat consumption and especially animal fat consumption, the principles of substitution of animal fats in meat products with low-energetic substances have been developed, especially those enabling achievement of proper texture properties like hardness, elasticity, consistency, adhesion, etc. The oxidation processes have also been tested as well as other quality effects in the meat-stuffing environment, where the animal fats had been replaced with plant oils.

### Current Major Research

At present the Institute performs the works in the following fields: optimization of meat production with consideration of survival and after-slaughter factors, studies on unit processes in meat technology with consideration of optimization, quality and environmental protection aspects, research on restructuring of meat products assortments with consideration of new nutrition trends, research on quality of animal products with consideration of technological, nutrition, health quality and environmental protection aspects, studies on appearance and bio-accumulation of environmental pollution in particular elements of the nutrition chain and on the possibilities of minimization of food. The program of improvement of partition of carcasses into trade and retail portions is carried on as well as the programs of development of meat identification and marking system in production processes and trade, of pre-slaughter handling meat fatteners, of testing of chosen elements of smoke against the oxidation stability of chosen food products, of studies on development of functional food, of studies on generation and occurrence of cholesterol and sterols oxidation products in the chosen groups of meat products, on utilization of structure-forming properties of transglutaminase of microbiological origin in the processing of meat of low physical and chemical value.

### Sweden

Department of Food Science, Swedish University of Agricultural Sciences

Prof. Kerstin Lundstrom; Prof. Leif Anderson

### Major Research Emphasis

- Basic research, general meat science.

### Previous Research

- Systems for assessment and grading of carcasses.
- Carcass composition and meat quality in reindeer and game.

- Beef and pork quality.
- Fish and poultry quality.

### Current Major Research

The RN- allele was first identified in France as causing a reduction in the yield of cured, cooked hams from composite lines containing the Hampshire breed. The effect was determined by "Napole yield" (*Rendement Napole* in France), a standardized method for estimating yield. The dominant allele decreasing the yield was called RN- and was due to an increase in muscle glycogen content. The RN locus has been mapped to chromosome 15, and has recently been identified as a mutation in the PRKAG3 gene, which encodes a muscle-specific isoform of the regulatory sub-unit of adenosine monophosphate-activated protein kinase (AMPK).

The RN- allele has a great effect on technological meat quality, leading to a decrease in ultimate pH and water holding capacity, and an increase in reflectance value. The chemical composition of meat is also altered with an increase of glycogen and water content and a reduction of protein content. These changes lead to a reduction in the yield of cooked, cured ham. On the other hand, the eating quality is enhanced. In several Swedish studies, pork from animals carrying the gene had higher juiciness, meat taste, acidulous taste and usually a higher tenderness. Also Swedish consumers preferred pork from carriers of the RN- allele in comparison with non-carriers. Processed meat from RN- carriers also showed a higher juiciness and tenderness in sensory tests with a trained panel. In contrast, French results showed a negative effect on eating quality. Also, the production traits are altered as an effect of the RN- allele, leading to a higher growth rate and a higher proportion of lean meat in the carcass.

The gene frequency of RN- allele has been around 0.6 in Swedish Hampshire. Due to the negative effect of the RN- allele on a technological meat quality, most countries and breeding companies would like to eliminate the mutation. With the mutation identified, this could be easily achieved. However, the positive effects of the RN- allele on eating quality should be taken into consideration.

Swedish Meat Research Institute  
Dr. Jan Brattstrom

The Swedish Meat Research will close the summer of 2001. It was indicated that a research contribution for the survey would not be appropriate.

## Switzerland

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Swiss Veterinary Office  
Dr. Herbert Koch

### Major Research Emphasis

- Veterinary drug residues in meat and meat products.
- Additives in meat and meat products.

- Contaminants in meat and meat products.
- Meat composition.

### Previous Research

- Similar fields as above.

### Current Major Research

*Comparison of Heavy Metal Concentrations in Tissues of Red Foxes from Adjacent Urban, Suburban, and Rural Areas*

The increasing utilization of urbanized habitats by red foxes prompted us to test whether this species may be used to monitor the presence of anthropogenic pollutants in cities or suburbs (comparison of the concentrations of heavy metals like Cd, Pb, Cu, Zn). Do animals from separate environmental compartments contain different patterns of tissue residues?

## United Kingdom

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University of Bristol  
Prof. Jeff Wood; Dr. Allen J. Bailey

### Major Research Emphasis

The Division of Food Animal Science (DFAS) is the successor to the Meat Research Institute. As part of Bristol University's School of Veterinary Science, it has a teaching role (BVSc and MSc Meat Science and Technology) although its main role is research in 3 main areas:

- Food science and processing.
- Animal welfare on the farm and at slaughter.
- Food safety and public health.

These three areas form a comprehensive program in support of the livestock industry. For future success, the UK industry must focus on areas of public concern such as animal welfare and food safety, but it must simultaneously improve the quality of products rather than simply yield. It is also important to develop a "food chain" approach to problems which recognizes that changes in one part of the chain, from production to retail, has implications at other stages and for the success of the whole operation. This conclusion has been reinforced following the BSE and foot and mouth outbreaks.

### Previous Research

Most research is strategic, i.e. midway between basic and applied, but basic research is also conducted on underlying science issues and applied research directly for industry. In Britain, funding for these three comes from different sources, but it is always important for industry groups to provide some of the funding. For success a balance between basic, strategic, and applied is important.

**TABLE 1.** Fatty acid composition of total lipid (g/100g fatty acids) and sensory scores in grilled chops (0 - 100) from Suffolk lambs fed grass or concentrate diets.

	Grass	Concentrates	
C18:2 n-6	6.8	9.7	***
C18:3 n-3	2.3	0.7	***
C20:5 n-3	1.3	0.4	***
Lamb flavor	27.2	14.9	***

Fisher et al. (2000) Meat Science 55: 141-147

#### Basic Research

- Understanding the physiological and genetic control of meat quality traits e.g. boar taint and calpains.
- Factors influencing colonization with *E. coli* 0157 H:7 in cattle.
- Neurophysiological aspects of stunning.

#### Strategic Research

- How does diet affect meat quality, e.g. flavor?
- Develop more effective stunning systems.
- Define effects of transportation on animal stress.

#### Applied Research

- Effect of genotype on meat tenderness.
- Effect of "new" antioxidant on shelf-life.
- Test company's HACCP scheme for hygiene control.

### Current Major Research

#### Aim and Significance

To improve the healthiness of beef by increasing the ratio of polyunsaturated to saturated fatty acids (P:S) and the n-3 PUFA content and to determine the effects of changes in fatty acid composition on product shelf-life and flavor after cooking.

The significance is related to the need to restore public confidence in beef following BSE. It has been shown that ruminant meats are potentially an important source of n-3

**TABLE 2.** Composition of *m. longissimus* neutral lipid (g/100g fatty acids) in cattle fed a protected lipid supplement (PLS) containing 2:1 linoleic: - linolenic acid

	Control	PLS	
C18:2 n-6	1.1	4.4	***
C18:3 n-3	0.4	1.7	***
P:S	0.1	0.3	***
n-6: n-3	2.7	3.6	*

Enser et al. (2001). Procs. 47<sup>th</sup> Int. Congr. Meat Sci. Technol.

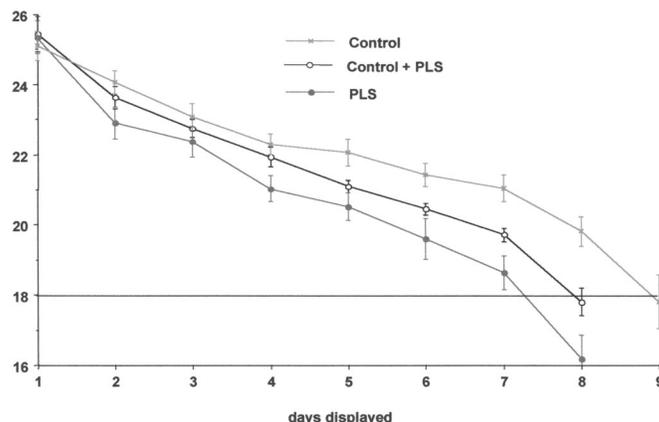
**TABLE 3.** Content of cis-9, trans-11 conjugated linoleic acid (CLA, mg/100g muscle) in beef *m. longissimus* after consumption of diets containing different lipid sources.

	Megalac	Linseed	Fish Oil	Fish Oil + Linseed	
CLA	11	36	24	29	*
C18:3 n-3	22	43	26	30	***

Enser et al. (1999) Animal Science 69: 143-146

PUFA and conjugated linoleic acid (CLA), which is a "good news" story to offset the negative publicity. The industry supports this research with funding to complement that from MAFF (Ministry of Agriculture, Fisheries and Food).

#### Results



**Figure 1.** Effect of a protected lipid supplement (PLS) on color saturation in beef loin steaks.

- Grass feeding rather than grain (concentrate) feeding increases n-3 PUFA and reduces n-6 PUFA levels in beef and lamb. In lamb, the grass-fed product has a more intense lamb flavor (Table 1).
- The P:S ratio can be significantly raised and n-6:n-3 lowered (i.e. the required dietary changes) by feeding concentrates based on linseed (flax), particularly if the PUFA are "protected" from rumen breakdown (Table 2).
- CLA levels in muscle are increased when the level of dietary oil is raised. Different oils have different effects on CLA, either because of rumen effects or effects on the <sup>9</sup> desaturase enzyme system in fat tissue (Table 3).
- Increasing n-3 PUFA levels in muscle increases lipid oxidation during retail display and accelerates the appearance of brown metmyoglobin. However, these effects are difficult to detect at retail (Fig. 1).

Dr. Allen J. Bailey

## Major Research Emphasis

- Basic Research.
- Meat Texture and Collagen.

Although meat texture is still a major concern, the subject has not advanced much since 1988. Collagen plays a major role in deciding texture changes with age.

The Japanese have suggested that the glycoproteins (eg. Decorin) are seen attached to the collagen fibers in the EM determine texture, but we have done some preliminary experiments to show that this is unlikely to be true. These glycoproteins are certainly involved in registering the fibers in the tissue but do not subsequently play a role in texture.

## Summary

The respondents to this survey have shared a wide spectrum of research emphases and projects. Commonality of the responses ranges from product quality with emphasis on texture and tenderness, process technology, and meat grading systems to food safety. It is hoped the overview will provide the reader an insight to the global meat research initiatives and will be of assistance in planning future research programs.

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