RESEARCH OBJECTIVES AND REQUIREMENTS IN MEAT SCIENCE AND TECHNOLOGY

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Abstract

The future of the meat industry is very promising, taking into account the expected large increase of meat consumption in the developing countries. But in developed countries where meat consumption reached a plateau, new societal demands resulting from a safety crisis and the unreliability of meat quality are impairing meat consumption. These problems can be overcome but it will be necessary to give a priority to basic research and integrated multidisciplinary approaches.

INTRODUCTION

To get an idea of the future requirements of the meat industry and the related research objectives, it is necessary to briefly analyse the factors which are likely to affect it.

The global meat economy which represents an important part of the value of agricultural production, more than 50 % in developed countries and around 25 % in developing ones, has seen a steady increase in production, consumption and trade levels since the early 1980's. These trends have been stimulated by the consistent growth of income, the relatively low prices of feeds for animals on the world market, the development of large urban areas and the opening of various countries to an international supply of food. At the same time, structural changes affecting the animal production systems (vertical integration, concentration of production units in the poultry and pig sectors) have led to an increase in the competitiveness of poultry and pig meat compared with bovine and sheep meat (Gurkan, 1999). In the worldwide context of economic growth, without any unpredictable adverse events such as a world war or large climatic changes and with a sustained growth of the world population, we can expect a considerable increase in the demand and production of animal products and meats in the next 10-15 years. The FAO forecasts related to the horizon 2005 suggest " a reasonably balanced augmentation of production consumption, and trade essentially occurring in developing countries as well as a trend towards higher actual prices for all meats due to an expected increase in feed cost for animals ".

The influence of income on the consumption of animal products, in particular meat, is well known. Moreover, referring to the analysis of FAO statistics in the last decade (Sebillotte, 2000), it appears that for a group of 90 countries consisting of more than 4 billion people there exists a close positive correlation (r=0.82) between the average individual income per year and the consumption of animal proteins (elasticity of 0.55) as long as the individual incomes are less than 6000 to 7000 $ and the individual consumption of animal proteins is less than about 70g per day. For that level of protein consumption, a plateau seems to be reached, but this plateau is observed only in approximately 20 countries which consist of less than 20 % of the world population. In addition, there is a large variability between these countries around the average consumption of 70g/day/person dependent, without doubt, on social and cultural factors which would be interesting to know because this variability is not income dependant. From this set of data we can say that :

First, regarding meat supply in the world, the non satisfied demand is considerable in a great number of developing countries which will be able to buy meat soon. Therefore the objective is to increase productivity and to lower the price of meat in order to facilitate consumption of this important nutrition source. In France for instance consumption of animal products doubles when the price decreases by half (a factor of three for poultry). So the increase in production efficiency necessitates progress in genetics, biotechnology of reproduction, nutrition and animal health. The increase of meat production follows increased technology. The increase of meat production in developing countries will probably be mainly associated with the development of intensive farming systems having short cycles of production, located around the large urban areas, and concerned with the impact of production on the environment. Consequently, many developing countries, as the developed ones are currently doing, will strengthen their laws and regulations to protect the environment (Heinz, Bennett, 1999)

Second, consumption of meat products is also limited by factors other than income in developing countries where a variety of cultural factors and perhaps even physiological limits could have an impact on meat consumption. These factors are poorly understood but are of interest to industry in facing the emergence of new strong societal demands concerning food safety, ethical considerations relative to intensive production systems, and product quality.

I – SOCIETAL DEMANDS

1 - Food safety demand

As pointed out by Tarrant (1998) during the 44th ICoMST there is now a consumer crisis developing in many countries regarding food safety which has its origin in the series of food scandals that have erupted over the past. European consumers are more concerned about safety in food than in any other consumer products and the potential link between BSE and the new variant of Creutzfeld-Jacob disease has triggered a sudden lack of consumer confidence in beef product. In addition, consumers refuse the use of additives and hormones in animal production. The crisis is so important that under the pressure of consumer associations and media, governments have been forced to change their approach to food control, often taking away from agriculture departments the responsibility of food safety control. These changes signal a significant shift from priority on production now changing to consumerism in the public services.

These public developments have effectively put food safety at the top of the research agenda and by comparison the top nutritional issues (saturated fats and cholesterol) were found to be of much less concern to consumers in all countries surveyed.

2 - Ethical questions

Consumers demand not only taste or nutritional satisfaction, they also demand that the production of their foodstuffs respects a certain number of ethical matters. For example, they find it important that environmental problems are taken into account, by contrast to the excessive production practices of recent times that has caused considerable pollution problems. Today, it is important to lay foundations for sustainable agriculture with less waste and. it is, therefore, necessary to completely rethink certain intensive systems, such as intensive pork and poultry production. Animal welfare also becomes increasingly important because of such ethical considerations. This contemporary development has created the gulf that exists between consumers and producers. Producers using intensive systems have progressively transformed animals into egg, milk or meat producing machines, whereas at the same time, consumers, mostly living in urban areas and benefiting from the production intensification, have a personification of domestic animals. From this point of view, it is easy to understand the strong reactions that may be evoked by certain, sometimes abusive practices or at production and slaughter sites.

3 - Qualitative demand

In developed countries the food industry is no longer pushed by the production sector but pulled by the consumers. Consumption is continuously changing according to economical and socio cultural factors which are poorly understood and require further understanding to correctly manage the agricultural production. So, in addition to the increase in production levels, qualitative considerations such as productivity (lower production cost) and product diversification are necessary in order to fulfill a change in demand. The consequence of this consumer pulled food industry is the necessity to know the consumer well enough to predict demand.

We must seriously take the limits of the meat industry to adapt to a consumer driven industry. In particular, the meat industry is very traditional worldwide and has been slow to implement modern technology. There will be increased global competitiveness based on cost optimization and convenient products, and also a constant demand for new types of products.

Quality and diversification are the two key priorities for the meat chain. In order to face this challenge the meat chain must take into consideration all the steps from the production level to the processing industry. This will not be possible without significant basic research investments and particularly the use of new technology in order to control the animal production and thereby the characteristics of muscle and meat. This is the only way to improve the image of meat and the confidence of consumers along with establishing an efficient communication network with consumers.

II - REQUIREMENTS AND RESEARCH OBJECTIVES

1– Meat safety

Certainly the priority of the meat industry is to provide a safe product which has the confidence of consumers. In this area food borne illness of microbial origin is the most serious food safety problem in many countries. Every year in the USA foodborne infections cause millions of illnesses and thousands of deaths (Tauxe, 1997). In addition, most infections go undiagnosed and unreported which underline our dramatic lack of knowledge. As the epidemiology of food borne infections evolves, old scenarios and solutions need to be updated. Undoubtedly the major threat to food safety is the emergence of new pathogens. In the last 20 years, infectious agents have been either newly described or newly associated with foodborne transmission, such as E. coli 0157H7, which was first identified as a pathogen in 1982 and subsequently shown to have a reservoir in healthy cattle. Some known pathogens have only recently been shown to be predominantly foodborne, for example Listeria monocytogenes, Campylobacter jejuni, and Yersinia enterocolitica. These food borne pathogens share a number of characteristics. Virtually, all have an animal reservoir from which they spread to humans, that is they are foodborne zoonosis. In contrast to many established zoonosis these new zoonosis, do not often cause illness in the infected host animals. For reasons that remain unclear these pathogens can rapidly spread globally. For instance Yersinia enterolitica spread globally among pigs in the 1970s, Salmonella serotype enteritidis appeared simultaneously around the world in the 1980s and salmonella typhimurun DT 104 is now appearing in North America and Europe. Therefore, public health concern must now include events happening all around the world as harbingers of what appears in our respective countries. Many emerging zoonotic pathogens are becoming resistant to antimicrobial agents largely because of the widespread use of antibiotics in the animal reservoir. Therefore public health concerns must include the patterns of antimicrobial use in agriculture as well as in human medicine.

During the last 40 years different factors acting synergistically have favoured emergence of pathogens. They included changes in the genetic background of farm animals, new animal production systems, consumer food habits and food technologies and also the growth of international trade exchange. While these societal and environmental factors can have a profound influence on the success of emerging pathogens, bacteria can also employ a number of strategies at the cellular level that play a significant role in emergence and need to be characterized. Sheridan and McDowell (1998) reviewed the research dedicated to the general relationship between environmental stress and pathogen emergence, the mechanisms of pathogen adaptation to stress, and the implication of pathogen

adaptation on virulence. Acquisition of new data on the physiology and genetics of these micro organisms in order to facilitate new strategies to prevent their emergence as pathogens is a top priority.

Among the research priority is that dealing with the biological aggressors, the animal host and the method to prevent zoonosis. The bacterial genome plasticity is without any doubt responsible for new pathogen emergence, and its study is a priority. Indeed emergence of new pathogens results from new genetic combinations. Plasmids, phages and transposons represent a very large collective genome that is continuously exchanged between phylogenetically distant bacterial groups. These exchanges continuously generate, among the procaryots, a genetic polymorphism. The discovery of integrons allows the understanding of mechanism of genetic appropriation leading to acquisition of virulence forms. An example is the emergence of E. Coli 0157H7 through the acquisition by an ancestor 055H7 cytotoxic gene from Shigella dysenteria type 2 as a result of phage infection and the subsequent transfer of the Shiga like toxin genes. In the same way the very high mutational capacity of viral genomes contributes to infectious emergencies (for example Hong Kong influenza). Regarding the animal host we need to study in depth its relationship with the aggressor, the immunological mechanisms of farm animals and their regulation. The era of post genomic research offers new powerful tools. In addition to the development of new vaccinal and therapeutic approaches, animal genetic resistance must be explored in order to select resistant lines. Regarding scrapie in sheep for instance the discovery of resistant and sensitive variants is very promising (Elsen et al, 1999). Finally regarding the relationship between zoonosis and public health we need to develop research relative to the basis of microbial risk: detection of zoonotic contaminants, transmission and excretion phenomena, host specificity, and crossing of species barriers by virus. Clearly, in the food industry zoonotic contaminants requires control of the animal based on the knowledge of the contamination mechanisms during rearing, diffusion in and around organisms and also in the products. It is obvious that the tools to detect zoonotic pathogens during rearing and in the food chain must be improved. The example of the BSE crisis is particularly demonstrative.

Along with new pathogens, arrays of new food vehicles of transmission have been implicated in recent years. The new food vehicles of disease share several features. Contamination typically occurs early in the production process, rather just before consumption. Because of consumer demand and the global food market, ingredients from many countries may be combined in a single dish, which makes the specific source of contamination difficult to trace. These foods have fewer barriers to microbial growth; therefore simple transgressions can make the food unsafe. And because the food has a short shelf life, it may often be gone by the time the outbreak is recognized ; therefore, efforts to prevent contamination at the source are very important. New challenges to the safety of the food supply require new strategies for evaluating and managing food safety risks. The changing epidemiology of food borne diseases is a result of complex interactions and changes in pathogens, food distribution, food consumption and population immunity. Predicting the impact of a trend in one part of the food continuum presupposes understanding of the whole system. Aspects of the food processing and distribution system can amplify or attenuate the trend as it grows into a potential health hazard. While a full understanding of pathogen contamination, infection and survival is difficult, a systematic approach to assessing the impact of the pathogen on health may improve the quality of public health decision. Quantitative risk assessment is a possible approach to be developed for designing programs to address emerging food borne diseases (Lammerding, Paoli, 1997).

The essence of microbial risk assessment is describing a system in which microbial hazard reaches its host and causes harm. Unlike the field of environmental toxicology, quantitative risk assessment is still an emerging tool in the field of microbial food safety. (Sterrenburg, 2000). Because of recent initiatives advocating the widespread implementation of HACCP systems, quantitative risk assessment has been proposed as a means of providing health outcome-based specification of microbial criteria for HACCP plans. Currently international trade agreements have advocated that demonstration of increased domestic health risk is the only acceptable basis for barriers to international trade in food. So the most obvious users for quantitative risk assessment as applied to microbial food safety will be agencies responsible for food inspection, disease surveillance and food standards.

2 – Ethical problems : animal welfare

Both animal welfare and environmental protection matters have become major social issues and consequently legislation has become increasingly restrictive for the meat industry, at least at the level of the EU. The new rules aim to protect animals in intensive production systems, but also during transport and slaughter. They are based on available scientific data, but they may be revised according to new scientific information. Unlike traditional research subjects, such as health status and growth performances, animal welfare is difficult to assess. A multi-disciplinary approach is necessary, taking into account all biological aspects of the animal including the fact that animals are living, sensitive beings. Furthermore, the ethical dimension calls for studies of the social and philosophical background of the attitudes of the different parties implicated in the subject, such as producers, lorry drivers, abattoir personnel and animal protection organisations. Finally, the financial aspects of animal protection should be analysed in order to propose economical models to help different governing bodies in their decision making.

Our scientific community knows, of course, the impact of the problem and at the two most recent ICoMST conferences two comprehensive reviews have been presented, in 1998 by Manteca and in 1999 by Troeger. They have discussed the contributions and the actual limitations of neurophysiology as a tool to evaluate animal welfare and its relationship with slaughtering method. It is of major importance that farm animals do not suffer needlessly during slaughter. Animal welfare research is often problem oriented and although this type of research is important, the need for work at a more fundamental level should not be overlooked. Today, the priority is to assess animal welfare questions in a more direct manner than has been done in the past. This new orientation has implications on the theoretical and on the practical level. On the theoretical level, it is necessary to study the extent of the sensitivity that we believe animals have. We need to know how animals perceive their environment, on the sensory level, and also on the emotional level. At the practical level, it is necessary to evaluate in an integrated way concrete problems caused by husbandry

practices. This calls in particular for the development and validation of neuro-endocrinological tools in order to measure stress responses, and the use of epidimiological approaches or surveys in order to develop and validate appropriate animal welfare criteria.

2.1.- Sensory mechanisms and perception of the environment

Today, there is little scientific literature on how domestic animals perceive their environment. It is, however, important to obtain knowledge on this subject in order to optimise rearing conditions from the ergonomic and from the ethical point of view. Thus, the noise and light level of the environment, the palatability of the food or the social context (recognition of conspecifics and humans) may be adjusted to the perception and needs of the species. We actually lack adequate knowledge on the basic perception mechanisms implicated in perception of the environment, whether it is vision (which plays a major role in many species in the perception of conspecifics or humans) or olfaction, which is essential for social, sexual, maternal and feeding behaviour. Similarly, we know little about the role of olfaction in stress reactions or about mechanisms underlying odour perception in mammals. Finally, there are few studies which have been carried out on nociception or pain in these species. Many husbandry practices, however, are likely to cause pain, either acute (castration, debeaking, dehorning, tail-cutting, slaughter) or chronic (nutrition, force-feeding in goose and ducks, lameness). To reduce pain it is necessary to recognise and quantify it. The study of pain needs to investigate the behavioural and physiological expression of pain caused by husbandry practices, but also the neuro-anatomical aspects of pain, particularly nerve fibres and their transmitters implicated in the transmission of the signal to the brain.

2.2.- Stress reactivity: the mental universe

The notion of mental representation is central to the problem of animal welfare. Most researchers agree that the animal's appraisal of the situation is a major determinant of the stress response (Terlouw et al., 1997; Manteca, 1998). Emotion is a subjective state, which depends on the representation that the individual has of its environment. This state may give rise to a motor response (activity) and an underlying physiological response (nervous and neuroendocrine systems). The notion of stress is currently most often used to imply a negative or adverse subjective state and that is the way it is used here. We have actually no possibility to measure the subjective component of stress in animals. The belief that this subjective component does exist in animals is based on the analogy with humans. In similar situations, humans and animals show similar motor (e.g. fight, flight, immobilisation) and physiological responses (increase in heart rate, glucocorticoids, catecholamines). However, technology is progressing fast and nowadays it is possible to measure rather precisely local brain responses to specific stimuli. It may therefore be expected that within a reasonable time activity in specific brain structures can be linked to specific emotional states in humans. If this approach may be extended to the study of emotional states in animals, the problem of animal welfare and animal suffering in husbandry and slaughter practices will have taken an important step forwards. Despite the clear analogy that exists between humans and non-human mammals, major differences exist on the level of the cerebral cortex. Thus, humans have more developed associative areas, which are responsible for complex cognitive functions.

In order to reach our objectives for ethical animal production it will be necessary to develop an integrated systemic study. The understanding of mechanisms responsible for the integration of sensory perception and behavioural functions needs a very fundamental approach on laboratory animals. Brain structures, such as the limbic system, are central in this process. Studies on the neurobiological control of the neuroendocrine and of the autonomic nervous system should not only aim to increase our understanding of the regulation of body functions but also to gain knowledge on adaptive responses of the animal to the environment. Finally, specific attention should be paid to the corticotropic axis and to the autonomic nervous system: they reflect interactions between the individual and the environment and they mediate adaptation in critical periods, such as weaning, transport and slaughter, doubtlessly influencing production performances, growth and milk production as well as product quality.

3 – The quality demand

Consistency of quality causes particular problems in meat when between animal variability differences are added to those arising from processing and season. Despite a tremendous amount of research, quality remains an elusive goal in meat science and particularly the control of meat texture.

3.1. – Meat texture variability

Meat texture depends on two major structures of muscle tissues, the connective tissue and the myofibers. The connective tissue and its major component collagen, which does not change post mortem, affects meat texture by its concentration, its thermal properties and its spatial distribution, all characteristics exhibiting a large between animals variability (Purslow, 1995). For instance collagen content of L. Thoracis can vary by a factor 2 between comparable animals. Unlike collagen the myofibrillar structure is deeply affected post mortem with well known large effects on the mechanical properties of the muscle during the rigor mortis process and then the ageing. Regarding texture a very large between animal variability affects the ageing rate ranging from 1 to 5 fold difference for a given muscle type between similar animals (Touraille 1990) using the same slaughter, chilling and storage conditions. Similar results were related by Morgan et al (1991) and more recently by George et al (1999). In Australia, large scale consumer tests (Armstrong, 1999) provide evidence that this variability depends on a myriad of factors and to reduce it an approach based on critical contral point analysis (PACCP) was proposed (Ferguson et al, 1999) similar to the "blue print" of UK or "Label Rouge" in France. From the extensive research done it is claimed that the slaughter and the post slaughter period strongly influence the texture of meat (Dransfield, 1995). At least three biological factors have a large effect on texture, the myostatin gene mutation, the use of growth promoters (B agonists) and the percentage of Bos indicus blood in Bos indicus x Bos taurus crosses, and we could add the callipyge effect in sheep.

the QTL genome scanning approach are large and may contain very many genes and the task of identifying simple causative genes is not trivial. Secondly, since QTL techniques address the whole genome an association rather than a causative gene may be identified. So in most cases, efficiency will be fully reached only when quantitative trait genes will be known and allelic form responsible for any variation in performance traits will be identified, which will allow direct selection to be made in the desired direction. A functional genomic approach based on systematic and differential analysis (survey) of mRNAs of tissues and organs (e.g. muscle tissue) at differents stage developmental and different physiological status will soon open a very promising route to the identification of the genes underlying the variability in traits of interest. Such an approach will require simultaneously an in-depth characterization of the phenotypic traits of interest in animals exhibiting extrems of quality.

3.3. Methodological developments

Apart from meat scientists who want improved methods and techniques to deepen their understanding of meat features, expectations of consumers for meat quality grow constantly, which induces the necessity of methodologies for quality control at the levels of slaughtering, meat cutting and distribution. In our industrial societies, purchasers of any products are expecting an optimal quality/price relationship and consistency in quality. This is true for manufacturers who buy raw material for further processing as well as for consumers who purchase foods. Despite the great number of methods which have been proposed by researchers during the last decades, the number of methods which have actually been implemented in the meat industry is surprisingly very low. We need to take time to think about this discrepancy before developing new research. It seems indeed that most of the techniques proposed have not met the industrial and commercial requirements and according to Monin (1998) we could propose a list of key requirements for the success of any new proposals :

- existence of a real need and an assured benefit
- direct relation to the desired quality traits
- reasonable prediction accuracy
- realistic cost according to the value of the evaluated carcass or joint
- rapidity to comply with processing rates
- potential full automation
- non invasiveness according to the increasing concern of safety.

Knowing the specificity of the meat products we can understand why so few techniques have been implemented by industry up to now. Regarding the meat industry, a top priority is the development of automatic carcass grading which is still based on visual assessment for beef and lamb. Objective grading systems are needed to pay the producers and provide information about quality to the production system. Beyond an objective assessment of carcass classification according to the classical classification systems (EUROPA for instance) the ultimate goal must be the prediction of carcass, composition in order to get an actual economical value of the carcass. Development of non invasise methods with suitable calibration process may provide proper solutions to this challenge. Development of automated grading technologies are presently a priority in France and Europe.

Regarding the consumers, to fulfill their requirements regarding sensory properties of meat methodological developments are very necessary, particularly in the area of meat texture and prediction of meat tenderness. Unlike colour, which we know how to measure either in terms of intensity or chromaticity and which makes possible studying how many different factors affect it, we do not know how to measure texture. Therefore, according to the previously mentioned problem of consistency of meat texture, it is necessary to get basic new knowledge in this field. Meat texture has been studied for many years and numerous instrumental methods have been developed to replace sensory analysis which remains the reference method despite all its limitations. Among them, mechanical methods have been the subject of most of the work. However, most of the methods applied are empirical and do not allow a precise characterization of the mechanical properties of meat. Also, the results obtained are not always correlated with the tenderness score obtained with trained panels.

The mechanism of texture perception is still not well known. In particular, the sensorial receptors involved in the process of mastication and the stimuli at the origin of sensations have not been defined precisely which makes it difficult to develop tests reproducing the oral conditions of texture assessment. Moreover, fundamental rheological behaviour as well as fracture properties of meat have not been studied with a variety of cooking conditions and muscle origin. Research priorities should concern fracture properties of meat which are involved in the process of mastication and play a role in the perception of meat texture. A better understanding of the mechanism of mastication is also needed and can be achieved using electromyography and kinematics to analyse the mandibular movements (Mathonière et al 2000). Moreover, non-destructive tests have to be developed to determine the potential of tenderness of meat soon after slaughter. According to the fact that at least in the developed countries consumers are getting older, perception of texture could become a limiting factor to meat consumption, which makes research in the field of texture measurement a top priority for the meat industry.

Concerning consumers, product authenticity is becoming more and more important making necessary the development of the techniques for product identification. For instance, products with origin denomination generally are high priced (Parma ham, Iberian dry cured hams) and bring in higher benefit to the producers than ordinary products. Thus there is a need to protect such products by detecting possible cheating. These products are defined by their geographical origin, process method, and is some cases by feeding diet and animal breeds, all parameters we need to be able to identify in the final products. Research in this field is in progress, based on genetic approaches (DNA markers) and analytical chemistry associated with systems of data treatment. This research needs to be intensified because, beyond the products with origin identification, such methods will be very useful in general because of the level of international trade where traceability is more and more a necessity.

CONCLUSION

This contribution is not intended to be a comprehensive review of the research objectives in the field of meat science and technology. Its aim was to underline the importance for the meat industry of the new societal demands which could dramatically impair the development of meat industry and meat consumption and the associated research priorities. As stated by Tarrant (1998) unless meat eating becomes compatible with the humane treatment of animals, with environmentally sustainable production, and with eating that is healthy and safe it could be consigned to a minor role in the diet in developed countries during the next decades. These challenges for the future can be overcome by meat research but it appears that the complexity of the problems revised makes it necessary to focus on basic research more than ever, using integrated multidisciplinary approaches to the problems. This is far from the more typical applied research approach in the field of meat science and technology.

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