La revue scientifique
Viandes & Produits Carnés
Référence de l'article : VPC-2017-33-4-7
Date de publication : 19 décembre 2017
www.viandesetproduitscarnes.fr

Où va la recherche sur la viande ?

Historique et perspectives de la recherche scientifique et de la recherche-développement (R&D) sur la viande et les produits carnés à partir des publications de la revue « Meat Science »

Mots-clés : Recherche, Viande, Produits carnés

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Le précédent et l'actuel éditeurs de la revue "Meat Science" ont tracé l'historique des recherches sur la viande au dernier congrès international sur les sciences et les technologies des viandes à Dublin en Août 2016 dont un résumé est présenté ici.

Résumé :

Les professeurs David Ledward et David Hopkins, respectivement éditeurs passé et actuel de la revue « Meat Science », ont présenté oralement au 63ème Congrès International sur la Science et la Technologie de la Viande à Cork (13-18 Août 2017, Irlande) un historique des recherches sur la viande et les produits carnés.

Il est apparu que les moyens humains et financiers consacrés à la recherche scientifique et à la recherche-développement sur la viande et les produits carnés ont été considérables durant les 50 dernières années. Ce court article de synthèse inspiré de l'article publié dans Meat Science 132 (2017) 29–34 résume l'état des connaissances en sciences de la viande il y a 50 ans, quelles ont été les principales avancées jusqu'à présent et quels sont les défis à relever pour le futur.

Abstract: Where is meat research going?

Professors David Ledward and David Hopkins, respectively former and current editor of Meat Science, presented orally at the 63rd International Congress of Meat Science and Technology (13-18th August 2017, Cork) a history of research on meat and meat products.

It appears that the time and money spent for scientific research and for research-development on meat and meat products over the last 50 years has been considerable. This short review inspired from the article published in Meat Science 132 (2017) 29–34 summarises what was known 50 years ago in meat science, what have been the main findings so far, and in the light of current knowledge, what are some of the challenges for the future.

I. HISTORICAL BACKGROUND

Meat has been the centre point of most people's diets for thousands of years, and over the last 50 or so years, millions of man hours and even more euros have been spent on research and development in the area. Has Society (including the Meat Industry) benefited from this massive outlay in time and money?

It is an almost impossible question to answer, and the answer may well depend on the individual. Without doubt, much of our present understanding of meat science and technology was developed prior to 1970 and it is difficult to identify one single major advance in the intervening years that can be described as ground breaking, though undoubtedly several developments have led to consumers becoming more confident that a meat or meat product will live up to expectation.

Fifty or so years ago, colour and texture were seen to be major problems in meat marketing, and colour became more important with the advent of centralised butchery and packaging and much research was thus directed at this problem, even though a good basic understanding was already known.

For example, the importance of good animal welfare to maintain glycogen reserves and avoid dark firm dry (DFD) meat was established (Mitchell and Hamilton, 1933). However, despite this knowledge, issues like DFD have continued to be evidenced in industry and in a recent review by Ponnampalam *et al.* (2017), the level of incidence across countries was reported to be as much as 40% of consigned lots of beef. This represents a large economic loss with estimates from the United States of $172 million per annum (Underwood *et al.*, 2007). This has spurned further research to develop methods based on animal welfare principles to reduce the incidence in beef and also methods to detect the propensity of cattle to exhibit DFD so as to implement strategies to reduce the number of cattle exhibiting the condition at slaughter. In addition, the physiological basis of watery pork, later renamed Pale Soft Exudative (PSE) pork (Briskey, 1964) was being researched and the halothane sensitive gene primarily responsible for this condition in pigs was being investigated (Artru and Gronert, 1980). Over the last 40 or so years, the gene(s) responsible have been identified (Le Roy *et al.*, 1990) and breeding programmes have made this defect a far less common occurrence.

Prior to 1976 meat colour had been extensively researched, both regarding DFD and PSE, and the interconversion of the myoglobin derivatives. At that time, the object was to maintain the bright red colour of oxymyoglobin, which had led to the development of modified atmosphere packaging, normally involving carbon dioxide to control bacterial growth at low temperatures (mainly *pseudomonas*) and elevated oxygen levels to help stabilise the oxymyoglobin content and inhibit the formation of the brown metmyoglobin (Empey and Vickery, 1933, Ledward, 1970, 1984). Interestingly, consumers now seem less concerned with colour, with some believing that a brown steak is more likely to be of better quality, as it indicates an aged product. In addition, many consumers are now content to purchase vacuum skin packaged products where the purple/dark red colour of reduced myoglobin is dominant (personal observations). This trend will likely continue as new valued-added meat products in less transparent packaging have emerged in many markets, reducing the importance of the visual colour cue in meat selection. Colour defects including greening due to bacterial growth, (Nicol *et al.*, 1970) and pinking due to exposure to extraneous gases (Ledward, 1992) were ongoing problems, but of decreasing importance as the causes and solutions were resolved.

Following complaints about the toughness of New Zealand lamb, workers at Meat Industry Research Institute New Zealand had identified the causes of cold shortening in meat and this led to considerable research identifying the need to control the rate of chilling, relative to pH fall to minimise both cold and hot shortening post slaughter in muscle/meat (Locker and Hagyard, 1963). The understanding of the need to keep the sarcomeres stretched during rigor had led to investigations of the potential of hot boning and modifying carcase posture during rigor (Schmidt and Gilbert, 1970; Herring *et al.*, 1965). Hot boning is obviously attractive from an economic point of view as it saves space in the chiller and, perhaps more importantly, it enables better control of the chilling rate as in a smaller mass any temperature differential across the muscle will be smaller than in a muscle chilled on the carcass where the outside will cool more rapidly than the interior. There has however been minimal adoption of this approach for 'table meat" with most application being for older beef and sheep where the product is used for further processing. The concept of partial hot boning beef carcases from younger animals coupled with a suitable means to restrict pre-mature shortening of the muscle has been demonstrated to be possible without comprising tenderness (Taylor *et al.*, 2012). Regarding the control of *post mortem* glycolysis, and its effect on tenderness electrical stimulation (both high and low voltage) had been widely studied from 1951 (Harsham and Deatherage, 1951) and was adopted commercially in a number of countries in the 1970's and 80's (Hwang *et al.*, 2003). Further development of the technology has occurred whereby "safe" systems operating at medium voltage and with a square pulse have been rolled out to the lamb processing industry in several countries like Australia and Norway.

In addition, in the 1960's, work had started on identifying the enzyme systems responsible for *post mortem* conditioning, i.e. the increase in tenderness (and flavour) seen during extended storage (Drabikowski *et al.*, 1977; Penny, 1980). Over the next few years, there was much debate as to the importance of the calpains and cathepsins in the tenderisation process, but as the evidence accumulated it became clear that the calpains (and their inhibitors) were the most likely causative agents (Lawrie and Ledward, 2006). Although there was still some discussion as to the relative roles of the connective tissue and myofibrillar networks to meat texture, and their changes during storage, the majority view was that the myofibrillar network degraded during storage while the connective tissue changed little (background toughness). This is now generally accepted (Hopkins and Geesink, 2009).

Safety and nutritional quality are of more concern today than they were in the 1970's, but most of the problems that are being discussed today were still an issue then. For example, the possible carcinogenic properties of nitrite/nitrate in cured meats had been raised and attempts made to find alternatives to this additive (Lijinsky and Epstein, 1970). Carcinogens in high temperature cooked meat had also been identified (Miler, 1963). Also the fatty acid profile in red meat had been questioned as to its potential role in cardiovascular disease and attempts had been made to modify the fatty acid composition of meats by diet, relatively easy with monogastrics, but more difficult with ruminants (Cook *et al.,* 1970). It should be noted that in recent years the validity of the assertion that the intake of saturated fat is related to cardiovascular disease has been questioned (Chowdhury *et al.,* 2014). In addition, meat as a source of food poisoning bacteria has been researched for generations, research leading to industrial solutions (Empey and Vickery, 1933). Although prion related diseases, primarily Bovine spongiform encephalitis (BSE) are more recent problems, research on these has mainly been reported in medical/veterinary journals.

Adulteration of meat with cheaper ingredients has been a perennial problem and advances in DNA techniques have been a major advance, but even pre 1976 quite sophisticated techniques were being used to identify non meat and meat adulterants in fresh and processed meat (Hibbert and Lawrie, 1972). However, the sophisticated genome based techniques that have been developed over the last couple of decades have made the identification of species specific ingredients relatively routine (Lawrie and Ledward, 2006).

Although over the last 40 years many advances have been made regarding novel/new processes few have been successfully applied to meat. High pressure is receiving increased attention (Ma and Ledward, 2013), but even this "novel" process has been researched for over a 100 years and had been applied to meat in the 1960's (Macfarlane, 1973). Other technologies that have been applied include those designed to shape primals (Taylor and Hopkins, 2011). Processed products and exotic meats are becoming increasingly important to the Industry, but these have, in the main led to increases in existing knowledge, rather than major breakthroughs. For example, there are many studies that have investigated the use of various plant extracts to improve the keeping quality and safety of processed meats, but in many cases the commercial adoption seems less apparent.

II. FUTURE TRENDS

When one considers the scientific advances made over the last 40 years, with the pace of change apparently increasing, it is a daunting prospect to try and predict what the next 40 years will bring. Some possible areas for consideration are:

1) There is considerable concern around the world regarding climate change (global warming) due to the increasing production of greenhouse gases (GHG) from industry and agriculture including livestock as discussed in a previous workshop in France (Scollan *et al.,* 2011). Water use by livestock especially beef cattle is also an important issue, but figures reported by the media are often overestimated (Corson and Doreau, 2013). Certainly, meat animals do produce significant amounts of GHG, probably responsible for half of all such emissions (Rijsberman, 2017) and perhaps more pressure will be put on the animal production chain to minimise the output of such gases, although how this could be achieved is not obvious. Neither are the implications for meat quality, from animals "selected" or managed to produce lower emission levels. At the 2017 ICoMST meeting in Cork, Ireland several authors addressed the issue. In a keynote lecture, Rijsberman (2017) stated that "Meat scientists have a major role to play in the necessary transformation of global agri-food systems towards a new model of economic growth that is climate resilient, sustainable and provides green jobs". Tweaking the system can lead to some reductions in greenhouse gas emissions, but as Rijsberman concludes "it will require a major effort from all stakeholders, but the stakes are high, as business as usual is not an option". At the same meeting, Hyland *et al.* (2017) concluded that although off farm strategies could be helpful "on-farm sustainable intensification perhaps offers the most promise". Economic and political pressures will undoubtedly lead to more research in this area.

2) Producing meat without using farm animals is one way forward, and could address the above concern, and attempts to grow meat in the laboratory, from stem cells has been attempted, with significant success (Post, 2012), although the cost is currently prohibitive. However, when one considers the scientific advances that have been made over the last 40 years in genetics, as well as in cell biology, such a commercial goal may not be so unrealistic from a technical point of view, even though the concept is a matter of debate for social reasons (Hocquette, 2016). Additionally, as Ralston Lawrie so eloquently argued in the first editorial in Meat Science (Lawrie, 1977), much of the earth's surface is so inhospitable that animals are the only feasible means of producing food and further if these areas are not grazed other ecological problems are likely. Further goods and services provided by livestock (not only food security, but also soil fertility, biodiversity, water quality, rural vitality, human culture, etc) are often undervalued (Dumont *et al.,* 2016; Ryschawy *et al.,* 2017). Producing meat analogues has been researched for several decades using plant, fungal and offal proteins (Lawrie and Ledward, 2006) and colour and to some extent texture are not major problems. However, the unique flavour properties of meat and the time dependent release of the responsible compounds from the meat matrix are difficult to replicate. Will this be any different for meat grown in a test tube?

3) As we live longer, nutrition will become increasingly important and further work must continue in these areas with the development of meat products that are free of health concerns. Unfortunately, nutritionists cannot agree as to what makes a meat product healthy or not as evidenced by the current debates on saturated fat intake and cardiovascular disease (Chowdhury *et. al.,* 2014) and red meat intake and cancer (Ferguson, 2010). Also as we become more aware of our individual genetic makeup so meats and meat products will continue to be developed to meet our individual needs and how these change as we age. Given the protein density of meat it offers much to address muscle wasting observed in older people, when combined with appropriate exercise (Phillips, 2012).

4) Advances are likely in packaging as more dynamic materials are used that can indicate temperature abuse, and safety and inclusion of smart devices that can relay information about the provenance and history of the meat (Holman *et al.,* 2017). The rapid expansion of vacuum skin packaging is an example of recent industry adoption in the light of findings, which have confirmed the negative effects of MAP on tenderisation. Edible films, though much researched, may become commercial realities as their potential, on both convenience and environmental grounds, are evident. At the recent ICoMST Meeting in Cork, McMillin (2017) summarised the changes that have taken place in meat packaging and highlighted how bio based materials and their integration into composite packaging are

receiving increasing attention. However, active and intelligent packaging for antioxidant, antimicrobial and other functions are not, at present, being widely used. He also outlined future packaging considerations, including the use of nanotechnology and the wider use of interactive packaging systems. Morris *et al.* (2017), at the same meeting, presented a more detailed analysis of the potential of active, nanoparticle, antimicrobial technologies for meat packaging systems and those interested are advised to read these articles.

5) Given the consumer interest in developed countries in the origin and history of the animals used to produce meat, there is little doubt future work will focus on the communication of information down the production line ultimately to consumers. Recent developments have seen consumers at the retail level have the ability to scan a product to be given the history of the product and if from an animal how it was raised. This will be aided by some of the potential packaging systems already mentioned and the rapid development in phone based applications. As a consequence, on farm animal welfare and slaughter practices will need to continue to improve to counter adverse consumer views. This will be coupled with the challenge of communicating the health benefits of consuming meat as a source of proteins, specific minerals (Cashman and Hayes, 2017) and health claimable fatty acids.

6) On line measurement of carcases and meat has been an on-going challenge for the meat industry and development of x-ray technology is poised to play a part in the assessment of carcases for traits like lean meat yield. Measurement of other traits objectively like intramuscular fat to aid grading programs for eating quality will be more of a challenge, but the application of meat science knowledge has seen the development of robust grading systems that are designed to ensure consumers get what they pay for (Polkinghorne and Thompson, 2010). This is the objective of the Meat Standards Australia grading scheme, which predicts eating quality of beef or lamb, based on a combination of upstream and downstream data. Its added-value for the beef supply chain has been identified in Australia, and the system seems suitable for other several countries (Polkinghorne and Thompson, 2010; Hocquette *et al.,* 2014) as discussed for both beef and lamb in two workshops held in France (Pethick *et al.,* 2011; Pethick *et al.,* 2015). Spectral techniques such as visual/near infrared spectroscopy (Craigie *et al.,* 2017) have the potential to rapidly determine specific quality parameters. A weakness of many of these techniques is that they rely on sophisticated statistical methods to correlate aspects of meat quality with spectral data, with little need to understand the underlying scientific reasons for the correlations. Nevertheless, there is little doubt this will be an active field of investigation given the move in developed countries to increase 'objectivity" in the assessment of carcases and meat and to provide price signals which mirror quality variations.

7) Meat quality has been extensively researched and given present knowledge, the production of meat of reliable and consistent texture and flavour (Aaslyng and Meinert, 2017) is feasible as indicated above. However, no clear relationship was found in France between eating quality of beef and its retail price (Normand *et al.,* 2014). The whole production chain must be controlled, from the selection of animals of the appropriate genetic background, and if the general public can be convinced of its safety, genetic engineering could play a key role in this parameter. The management of the animals from birth to slaughter weight, especially their diet, must also be controlled and of paramount importance is the pre slaughter handling of the animals, where fortunately, good welfare and ultimate meat quality are very highly correlated. Post slaughter handling of the carcase, both pre and post rigor, needs to be carefully controlled, especially regarding chilling rate during rigor, so that minimal shortening of the sarcomeres results and proteolysis is encouraged. Post rigor the meat needs to be matured/aged/conditioned so that the more valuable muscles, low in highly crosslinked collagen, can undergo proteolysis to yield tender, flavoursome meat. The time must be approaching when one will be able to purchase a steak with defined eating characteristics (flavour, texture juiciness), in much the same way as we currently purchase a bottle of wine on which the characteristics are clearly and confidently printed. Such an approach will demand a whole of value chain focus with no step being avoided.

Acknowledgements:

The authors would like to thank the Journal Meat Science for allowing parts of a paper presented at the 63rd International Congress of Meat Science and Technology held in Cork, Ireland (Ledward, D.A., and Hopkins, D.L. 2017. Meat science from 1976: A history of the journal. *Meat Science,* 132, 29-34) to be presented here with modification.

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