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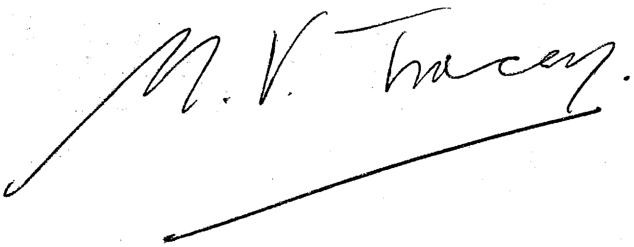
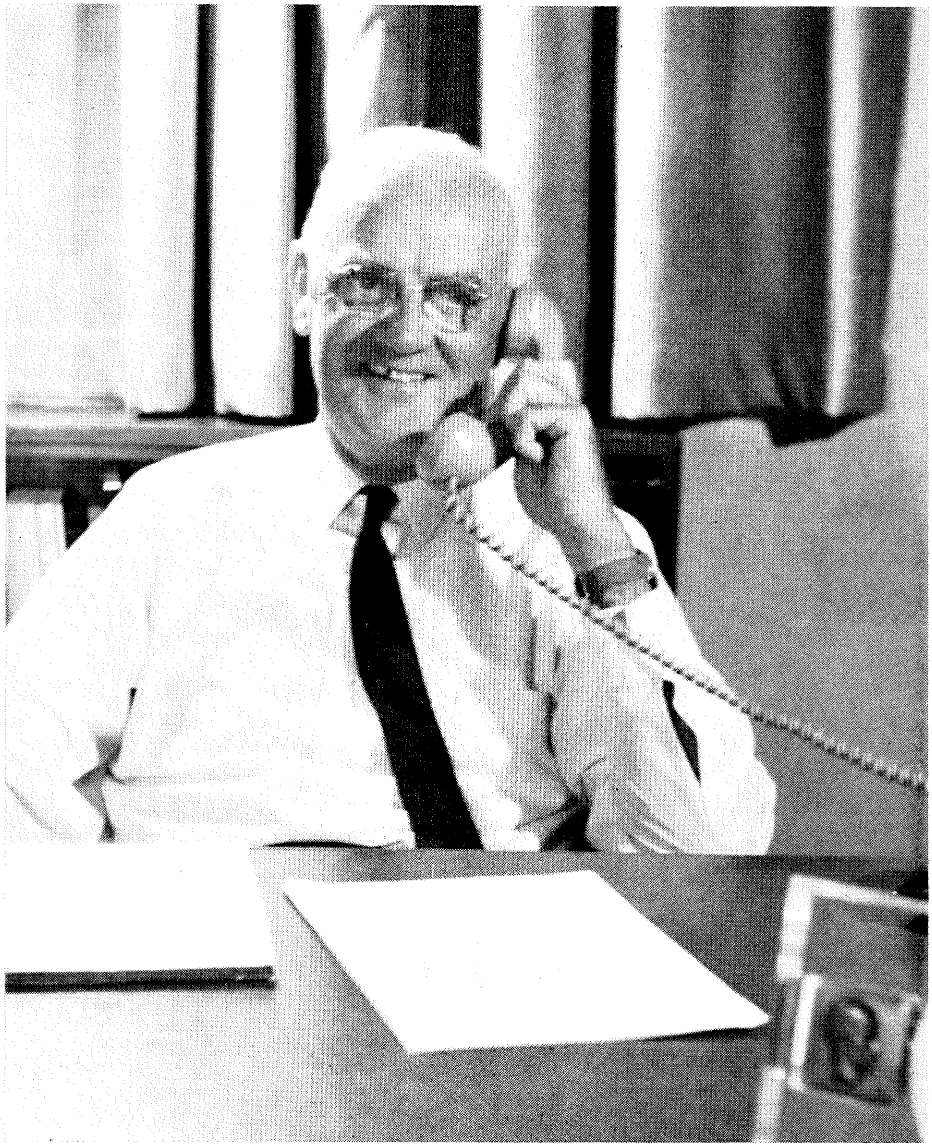
FOREWORD

This issue of the *Food Research Quarterly* is a tribute to the distinguished career in the Division of Dr W. J. Scott and will give the reader some idea of his central role in creating the flourishing group of microbiologists from whom its strength and reputation in food microbiology derive. The emphasis is on meat research rather than microbiology, however, and this is fitting, for Dr Scott was deeply involved with the then Chief of the Division in planning and bringing to fruition the great expansion of work on meat that has occurred with the financial help of the meat industry in recent years. From the time of his appointment as the Division's first Assistant Chief in 1960, Dr Scott devoted himself to the creation of the Meat Research Laboratory at Cannon Hill, and on his retirement from the Division was able to leave behind him not only a structure of bricks and concrete but, far more important, a new entity in the form of a young, able, and enthusiastic research group devoted to work on meat and its products.

The papers in this issue are by Dr Scott and some colleagues who have known him for very many years. Three of the papers were presented at a meeting held to mark Dr Scott's retirement. The wide range of attendance—50 representatives from the meat industry, 30 from the universities and State Departments of Agriculture, and another 50 from Head Office and many Divisions of CSIRO—can only have been a source of pride and satisfaction to Dr Scott. It was particularly fortunate that it was possible to invite Dr Ingram, a microbiologist and Director of the ARC Meat Research Institute in Britain, who has been a close friend and colleague of Dr Scott since they worked together in the Low Temperature Research Station at Cambridge before the war. His contribution and that of Dr Vickery, former Chief of the Division, together with Dr Scott's own views on meat research in Australia, have been printed in this special issue of the *Food Research Quarterly* as forming that part of the meeting most closely related to Dr Scott's lifetime of work in CSIRO.



Chief, Division of Food Research



W. J. Scott, B.Agr.Sc., D.Sc., first Officer-in-Charge of the Meat Research Laboratory Cannon Hill.

Tribute to Dr W. J. Scott

By J. R. Vickery

Dr Vickery, who retired in 1967 as Chief of the Division of Food Preservation, is a close friend of Dr Scott and a colleague of many years' standing. This 'Valedictory Oration'—to give it the official title—was delivered at the farewell dinner for Dr Scott on the first night of the conference.

On a cold afternoon in July 1933, I waited on the platform of the interstate station in Brisbane, to greet a newly appointed research officer—the third on the staff of the CSIR Meat Research Laboratory, Cannon Hill. I had been advised by our Head Office staff in Melbourne that the new man was very tall, so I did not have much difficulty in finding him in the crowd. Thus it was that I first met William James Scott, and began an association of 39 years.

His letter of appointment, signed by the late Mr Gerald Lightfoot, Secretary of CSIR, makes interesting reading. It states that Mr Scott, as he was then, was appointed to the post of biochemist. I do not know why the position was so described, because we intended that he should work mainly in bacteriology; perhaps the CSIR Executive of the day did not recognize microbiology as a valid scientific discipline. The letter of appointment also stated that he would receive the princely salary of £343, or $686 p.a. Despite hard work and outstanding contributions by Bill Scott, his salary 2½ years later was still only $736. It sounds very meagre to modern ears, but, of course, Australia was then only beginning to emerge from the terrible economic depression; there was strong competition for all jobs and salaries were low.

It was a very small and, by modern standards, ill-equipped laboratory to which Bill Scott came in 1933. The staff was Bill Empey, a young technical assistant Mac McDonald, a part-time typist Miss Ella Todd, and myself, to be joined in the succeeding year by a physicist, the late Arthur Riddle, and another technical assistant, Douglas Ohye, who is still with the Division of Food Research in Sydney.

This small team had a definite job to do, viz. to work out the conditions of handling, cooling, and transport that would enable chilled beef to be successfully exported to Britain. I shall not bore you with technical details, but it will suffice to say that bacteriological studies were paramount and Bill Scott made a major contribution to them. Professor Wadham, Dean of the Faculty of Agriculture of the University of Melbourne, had told me that Bill was one of his outstanding students, and his calibre was made clear to us in a series of classical papers on the growth of microorganisms on muscle, and through his contributions to two bulletins outlining the essential conditions for the export of chilled beef.

The time from 1932 to 1938 was in many ways a heroic period of applied science. We had a small staff and inadequate equipment which we had often to supplement by begging, borrowing, and occasionally stealing. Through a fine team effort the work came to a very successful conclusion by 1938, and this was due, I think, to a fortunate combination of factors. The meat industry gave us good support and put their facilities at our disposal. We were young and enthusiastic. We were compelled by CSIR regulations to work six days a week but, on many occasions, for many weeks on end we also worked every Sunday morning. We could use the facilities of the Brisbane Abattoir at the weekend, and play around as we liked with the conditions in its chilling rooms.

Bill Scott ranged widely outside the laboratory during this period, conducting microbial surveys in meatworks up and down the coast and as far distant as Wyndham in north-western Australia. Along with his colleagues, he frequently inhabited ships' 'tween-decks for long periods when experimental shipments were being prepared.

By 1938 it was clear that Bill was likely to become a leader in food research and that he therefore needed experience in overseas laboratories. So, in July 1938 he and his bride, Molly MacArthur, sailed for England where he spent a year working with R. B. Haines at the Low Temperature Research Station, Cambridge. Then there followed a year in the Bacteriology Department of the University of Wisconsin, U.S.A.

When Bill returned to Australia in October 1940 to take up the position of senior bacteriologist with the then Division of Food Preservation and Transport at Homebush, we were heavily immersed in problems concerning the supply of foods to the armed forces, and these considerably increased when American forces arrived in this country and in the south-west Pacific area. So, for a great deal of time during World War II, Bill was tied to rather mundane tasks needed to reduce the health hazards in foods supplied by Australia to the armed forces.

The opportunity came at the end of the war for Bill to do what he had long planned: to embark on some investigations of fundamental importance in food science. He completed his work on the bacteriology of stored eggs, and then started his work on the water relations of microorganisms, which continues to this day. He collected a brilliant team of research workers—first Milton Salton and later John Christian and Bill Murrell. This work established Scott's international reputation as an outstanding food microbiologist, and the results of the work have had a major impact on food technology practices everywhere. It was no surprise, therefore, when the University of Melbourne awarded him the degree of Doctor of Science in 1957.

The size and importance of the bacteriology group at Homebush, and subsequently at North Ryde, greatly increased and in 1960 Bill Scott was promoted to be Assistant Chief. In this capacity he acted as Chief of the Division of Food Preservation on a number of occasions.

In the late fifties and early sixties we were trying to build up the resources of the Meat Research Laboratory to be commensurate with the growing size and diversity of the Australian meat industry. By 1963, the promise of substantial funds from the Australian Cattle and Beef Research Committee made it possible to plan new laboratories and greatly expanded facilities and staff. However, we still lacked a highly qualified leader, despite my search in many countries. It was therefore very fortunate that Bill Scott agreed to take this difficult job, and the Executive appointed him as Officer-in-Charge in February 1964. Before he was formally appointed, I pointed out that it would not be possible for him to be a candidate for the position of Chief of the Division when I retired, and that he would have to remain in his new job for at least five years. He loyally adhered to these conditions and, in fact, stayed in the job for over eight years.

I think it is interesting to point out the remarkable similarities surrounding the appointments of the leaders of meat research in Australia and in Britain. Bill Scott and Maurice Ingram, the Director of the ARC Meat Research Institute, were outstanding food bacteriologists; neither had applied for their jobs but had been invited to accept. Finally, both are tall men, standing about two metres high.

Bill has built up here in Brisbane a magnificent research facility; it has the full support of the meat industry, and therefore it will be a major force in helping to maintain the leading position the Australian industry now occupies in the export markets of the world.

May I add a personal tribute to Bill for his constant loyalty and support during my period of some 27 years as Chief of the Division, and my thanks for his friendship over nearly 40 years.

Now that he is coming to the end of his career in CSIRO, I feel sure that he can look back with great pride to fine achievements in scientific research. As the author of some 37 research papers and about 12 general scientific articles, Bill Scott has left a record that will endure because he has stamped his name in the annals of food research.

I am sure that I speak on behalf of all his friends when I say that we are going to miss him very greatly. We wish Bill a long period of happy retirement and profitable agricultural pursuits. To his wife, Molly, we also extend our best wishes. Many will know that she has distinguished herself as an artist, and we trust that she may long continue with her skills.

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Meat Research for Australia

By W. J. Scott

Dr Scott spoke of the future of the Australian meat industry in this paper, which closed the second day of the conference.

Search for Industrial Efficiency

I am especially pleased that we have today a conference attended by representatives of many sections of industry as well as by scientists who come from a variety of scientific disciplines and are interested in various aspects of animal science, food science, and technology. I would, therefore, like to talk about some of the wider issues—in other words, matters affecting the prosperity and efficiency of the industry as a whole. I would like to set down what I believe are the magnificent opportunities available to us in this country to develop further a meat industry of substantial dimensions and of unrivalled efficiency. If, however, we are to attain these goals we shall need to watch efficiency at all levels of the industry and do all we can to ensure that different sections of industry collaborate in the pursuit of national objectives. If at times I sound somewhat nationalistic, I can only ask the indulgence of our visitors from overseas.

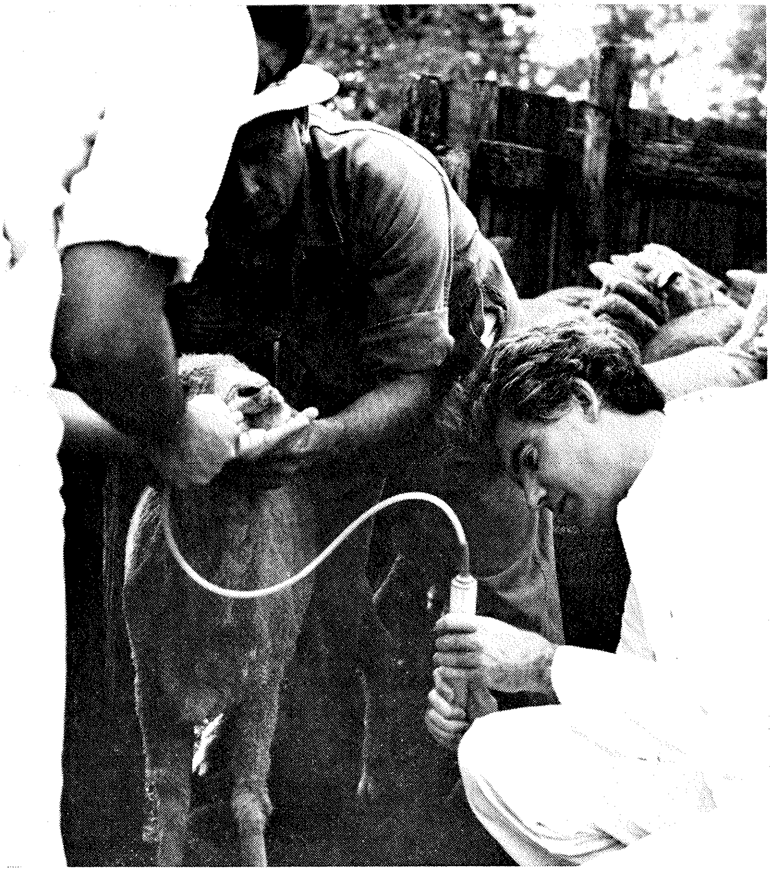
Opportunities for Expansion

In comparison with other countries, we in Australia seem well situated to plan a great expansion of our meat industry. There are many reasons for this. We already possess a large meat industry in which production is increasing much more rapidly than local consumption; the fraction of production available for export is already around 50% and is very likely to exceed 60% within the next three or four years. Moreover, we have large areas of land suited for animal production throughout the year. We also enjoy wide climatic variations including some regions with substantially uniform and reliable rainfall, others with a Mediterranean-type climate, and, in northern Australia, very large areas with a predominant summer rainfall and a regular winter drought. For many of these areas we have already developed techniques that have greatly increased the productivity of the pastures, and various authorities have estimated that animal production could readily be increased five- to ten-fold when the regions are more fully developed.

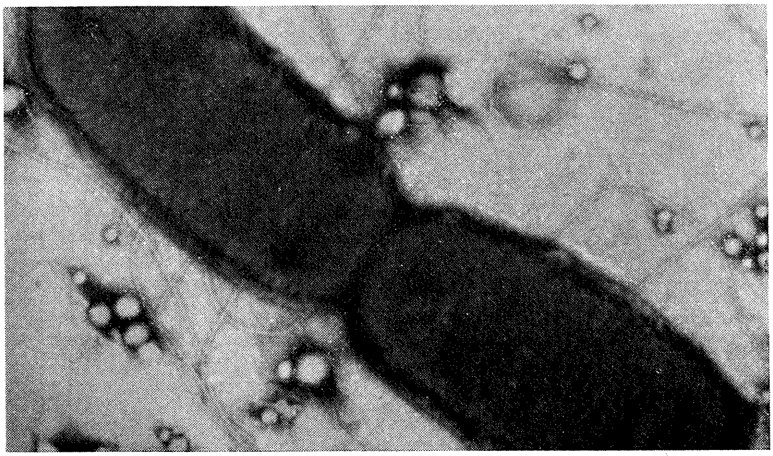
Moreover, of the areas available for animal production, there is a substantial fraction where the rainfall is too low or too uncertain for successful agriculture. We are, therefore, in an especially good position to exploit the pastures in these regions for sheep and cattle production. In many areas the quantity and quality of the pasture are not sufficient to give rapid rates of growth, but we must not overlook the invaluable capacity of the female breeding ruminant for producing regular crops of calves and lambs on such diets as these which provide little more than maintenance requirements.

In the more favoured regions, Australia already produces large quantities of the cereals and other high-energy plant products that would be valuable as finishing rations for large numbers of ruminants or, if desired, could be used for expanding the production of pigs and poultry. Imaginative people have shown us the possibilities of other species; Professor McFarlane has reminded us of what could be achieved in our very arid regions with camels, Dr Frith has pointed out the possibilities of farming our native marsupials, and Dr Day has been busy establishing an Institute of Marine Science. Perhaps this will be the site for a project on meat production by marine turtles.

Our animal industries are well served by many research groups in CSIRO, in the universities, and in State government departments, and the country has had some notable success in the eradication of animal diseases. In addition, we have a veterinary inspection service of world standard and over a hundred abattoirs meeting exacting international standards—abattoirs whose installed slaughtering



One interest of the Meat Research Laboratory is to improve the microbiological quality of meat. Here a scientist takes a sample of rumen contents to test for *Salmonella* bacteria.



Two *Salmonella* cells about to separate after cell division. Because *Salmonella* is a potent source of food poisoning, many importing countries legislate to keep out meat that may be contaminated.

capacity is not yet always fully utilized. We have, too, a beneficent Government which has constructed some thousands of miles of beef roads and large water storage facilities for irrigation. The Ord River dam has opened interesting possibilities for increasing animal production in that part of tropical Australia now that the world seems to have enough rice and cotton for the time being. Many authorities forecast that meat can expect to find a strong demand on world markets at least for the next 10–20 years.

Altogether then, it certainly appears that circumstances are very favourable for increasing meat production in Australia, provided that we can offer goods to meet the specifications of the various markets at prices acceptable to consumers.

Some Areas of Challenge

If, as appears to be the case, Australia is poised to expand its meat industry, let us look at the overall scene and see if we can identify problems that may limit our ability to produce goods that we can sell at a profit. First, we have to produce the animals, second, we have to process them and convert them into products meeting the requirements of the market, and third, we have to distribute the meat and sell it. If the industry is to survive, all sections must continue to be profitable. Producers must be prosperous and able to invest in improvements that will increase profitability or reduce costs of production. Processors must operate profitably, and be able to furnish the large and increasing amounts of capital needed for modern abattoirs and meat processing. Similarly, the carriers and merchants responsible for transport and selling must receive returns on their investment in the essential process of bringing the goods to the consumer.

Barriers to Increased Animal Production

Professor Butterfield has pointed out that the ideal carcass has maximum muscle, minimum bone, and optimum fat. Although not a quantitative description, it reminds us of what is needed. Similarly, we can point out that the ideal meat animal has maximum fecundity, maximum rate of growth from birth to maturity, and minimum natural mortality. Unfortunately, our principal meat animals, cattle and sheep, are species of low fertility. The cow has a low level of multiple births and in Australia produces, on average, from 0·5 to 0·9 calf per year depending on the environment. The higher figures are taken from properties with adequate standards of nutrition, management, and disease control, while the lower ones come from larger properties in the tropics where little control is exercised. The ewe is somewhat more fertile than the cow, but in Australia multiple births are not frequent and management to give two pregnancies per year is not yet a commercial reality. By contrast, the sow can raise 10–12 pigs at each pregnancy and under intensive management can be mated twice a year; the hen can, of course, produce 200 fertile eggs during one year. Pigs and poultry, therefore, add a great deal of flexibility to the capacity to produce meat, since here the animal population can be built up rapidly. In our cattle herds in northern Australia where the calving percentage has been around 55%, the capacity for natural increase is indeed very small. At this level each cow produces only four calves during a breeding life of seven or eight years, and thus only one female besides her own replacement. An increase in the calving percentage from 50 to 75% would mean that each breeder would produce an average of two females in addition to her own replacement. In other words, a 50% increase in calving doubles the rate at which the population can be built up by recruiting extra females into the herd. In practice, even after allowing for, say, 10% mortality and a culling rate of 20% the benefits are much more dramatic. The causes of low fertility in our cattle herds include factors connected with disease, nutrition, and management, all of which need more research. But we should not sit back to await the results of research; much could be achieved and achieved quickly by wider application of existing knowledge.

Improvements in the productivity of flocks and herds have been made over the years, but much still remains to be done. With sheep, improvements in wool production have been substantial, but for meat production any improvement in performance is still mainly at the planning stage. A national beef records performance scheme is still in its early development. A great deal has been achieved with the introduction of *Bos indicus* cattle, and the use of these in cross breeding has increased substantially the heat tolerance, tick resistance, and rate of growth of cattle in much of tropical Australia. Even more rapid progress could be secured through the wider use of progeny testing for evaluation of sires, and by extending the use of superior animals by means of artificial insemination. As a nation striving to improve the efficiency of our animal production we cannot afford the luxury of assessing the excellence and monetary value of our livestock merely by visual appraisal. By so doing we are ignoring the results of scientific research in many countries and the achievements of breeding programmes based on sound scientific principles. Having obtained our calf crop, we are growing the calves for a further three years in many areas before being able to market them at, say, 500 kg live weight. On high-quality pastures in southern Australia we can reach comparable weights in about 18 months. Thus it would certainly appear to be in the national interest to transfer calves soon after weaning to pastures supporting high rates of growth.

If breeding performance cannot be assessed by visual means, it is equally unsatisfactory to use these means in appraising meat animals for slaughter. The use of objective criteria for assessing beef carcasses, and their use in a national classification scheme, should greatly increase the efficiency of producers. With such information they can compare the profitability of different breeds and management systems, and are thus in a position to respond readily to market forces. If the trials being undertaken by the Australian Meat Board are successful, we can expect to see a classification system applied also to sheep and pig carcasses.

Meat Processing

Here I am using a wide definition of processing to include the whole process of converting meat animals into products for sale. In other words, this is the conventional area of meat research, 'from farm gate to plate'. For many of its research needs Australia already has, in the Meat Research Laboratory, a national centre for research on the preservation and utilization of meat. I do not propose to dwell on the details of the Laboratory's research but rather to point out that the Laboratory should have the capability of studying problems in some depth, and so increasing our knowledge and understanding of animal tissues used for food. The scientists in meat research should be encouraged to obtain answers that will have a wide applicability across the nation and that can be applied in modifications of present technology. I do not think it either necessary or desirable to duplicate this research facility within the next 10 years. There are, however, a number of opportunities for innovation in abattoir technology, bringing in greater mechanization and automation, with the object of reducing costs and improving the quality of the product. Processes for mechanical skinning and mechanical deboning are two examples where considerable benefits are likely. Some of this work could be undertaken at the Meat Research Laboratory, but I would suggest that progress would be increased by carrying out some of this development work by joint CSIRO–industry teams working at various centres throughout the country. Tasks concerned primarily with the development of equipment might be contracted to engineering firms or to an appropriate university department. In some cases consultation with regulatory agencies would be necessary to ensure compliance.

Research and development in meat processing merit much more attention than they are receiving at the present time. As industry generally lacks skills and personnel in this field, it should be developed further at the Meat Research Laboratory, especially in the Industry Section. As management becomes aware of the importance of research and development to its competitive position, each company will wish to carry out more of this scientific work itself, especially in the development of new products for export. Considering the low level of expenditure on research and development in the Australian meat industry, a growth rate of 15–20% per year over the next 10 years would not be excessive.

A practical difficulty is that not all small establishments will have the resources to carry out their own research and development. They may, however, combine with other sections of industry in joint endeavours, or purchase ready-made technology from others.

Market Research

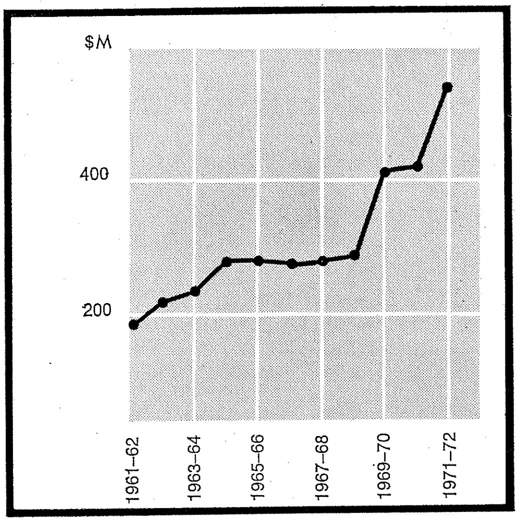
If we are to expand the markets for our meat we must know more about consumer requirements. Because of the present high rates of consumption there would seem to be little prospect of expanding consumption per head within Australia. There should be good prospects of finding new outlets in many countries overseas where incomes and living standards are rising. Perhaps this function could be taken up by the Australian Meat Board and exporters. With the appropriate information on consumer requirements, promising products could be developed and their suitability assessed by test marketing. Favourable results leading to firm orders and/or long-term contracts could then be placed with interested exporters.

Enquiries in markets where price is a major factor will keep the industry in touch with the demand for products that are blends of animal and plant proteins. In turn, we should acquire skills in what is sure to become an increasingly important outlet for meats.

Conclusions

Having dealt with some of our present industrial practices and mentioned some areas where we might seek improvements in the sections of the industry dealing with animal production, meat processing, and marketing, I come now to my conclusions.

Bearing in mind the size of the Australian meat industry, its prospects for growth, and the demands for change, I would suggest that the national investment in science and technology for the industry is out of balance. Government research is probably at a level that is adequate or nearly so, but it should be matched by a much greater use of technical skills in industry, especially in the processing and marketing fields. In particular, the processing section of the industry should embark on a programme of building from the ground up a considerable capability in research and development. It should begin now to employ competent professionals in chemical and mechanical engineering, in food technology, and in market research. Such personnel should be selected and given further training with a view to promoting them to positions in top management within the next decade. At the end of this period the pressures for further change will have increased substantially, and industry will have the combination of managerial and technical skills which will be needed if animal proteins are to make their most effective contribution to human needs. The interdependence of the sections of the industry dealing with animal production, processing, and marketing cannot, I believe, be overemphasized. All sections need to be in very good communication with each other. Similarly, the scientists in meat research need to be in good communication with the rest of science and with the whole of the industry. The challenge, it seems to me, is to achieve some cohesiveness in the pursuit of national objectives, and at the same time provide opportunities for a competitive situation that will provide rewards for those who develop the most efficient systems of production, processing, and marketing. I feel very strongly that the more closely scientists and industry work together, the better it will be for us all.



The value to Australia of its meat exports has climbed steeply over the past 10 years.

Present and Future Developments in Meat Research

By M. Ingram

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Professor Ingram, Director of the ARC Meat Research Institute, was invited to Australia especially to attend the conference and to present his views on the challenging problems and possibilities facing the meat industry.

In the past, animal production has mostly been conducted on the naive assumption that if healthy animals were normally reared, the meat would be all right; and in those circumstances there has been a natural tendency to take meat research to mean work on animal production. But nowadays—and probably still more in the future—what comes to be regarded as 'normal' departs increasingly from the traditional. It is a far cry from the free-ranging animal, eating natural fodder, to the beast that is intensively reared, kept in confined quarters, and fed on a mixture of straw and urea, perhaps laced with dried poultry manure; and that seems to be the portent of things to come, in Britain even if not yet in Australia. At a time when the old assumptions are ceasing to be valid, present-day users of meat are awakening to a realization of the commercial importance of some of the quality defects which begin to appear when traditional ways are abandoned. That is why there is suddenly a general interest among animal producers in the nature and measurement of meat quality, and why there has been of late years a world-wide proliferation of Meat Research Institutes largely devoted to the study of quality rather than quantity. Accordingly, in speaking about meat research, whether present or future, I shall say little about animal husbandry since it is something distinct from meat research as understood here; but of course one cannot have meat without animals, and their husbandry must always form a background to any discussion of meat—a truth which I feel in the present context it is appropriate to emphasize before I begin.

Looked at from this point of view, the aims of meat research may be regarded as being to provide the answers to a series of questions: what does the animal consist of, and how is it possible to influence its composition? How can we get what we want out of the animal, and how do we evaluate the resulting meat? How can meat be preserved and stored, and how can it best be utilized?

Composition of the Animal

When breeding or rearing animals for meat, the composition of the resulting carcass should be one of the main criteria by which the success of the enterprise is judged. In the past, partly because it is not easy to estimate the composition of the animal body, this frequently was not done. Nowadays, when there is an increasing perception of the importance of leanness, or the proportions between the various joints, information about composition is more commonly sought, and there is a correspondingly greater interest in the means of estimating it.

For many purposes, a simple approach to the problem suffices. For example, in a breeding programme aimed at reducing fatness in sheep, Dr Kirton at Ruakura, New Zealand, has simply homogenized the whole carcass and estimated the proportion of fat in a sample of the homogenate. To avoid destroying the carcass like this, some have tried to estimate the proportion of fat from the density of the animal, fat being lighter than lean. Equally simple in aim, though technically far more sophisticated, are procedures for estimating the amount of muscle, i.e. lean tissue, in an animal's body from the amount of potassium it contains, since the potassium is practically confined to the lean tissue. One may introduce radioactive potassium in known amount and find out how much it is diluted, since this will indicate the volume in which it has been dispersed and by inference the volume of the muscular tissue. Alternatively, one may try to measure the normal potassium content of the carcass—an index of the muscular tissue—by measuring the natural radioactivity from the potassium; this has the advantage that it can be done without any harm to the live animal but the technique is elaborate and expensive.

Such procedures are far too complex for routine use, where some simple estimate which can be made rapidly is required. As an example we might take the weight per unit length, perhaps corrected for fatness as Professor Yeates suggests; and the estimate of fatness may now be made from ultrasonic measurements on the live animals, e.g. of back fat thickness at one or two selected points, as in the British pig progeny testing programme. A recent suggestion has been to take food conversion into account; other things being equal, a low food conversion is an indicator of fatness since it requires several times as much food to produce fat as to produce lean tissue.

All procedures such as the foregoing, however, have the great disadvantage that they only estimate the composition of the body as a whole, and often only one aspect of it. There is now a desire to follow simultaneously the disposition of the several constituents, because experience has shown that to concentrate on control of just one may lead to undesirable variations in others.

It is believed that an experienced buyer can tell how an animal will dress out merely by looking at it; in other words, that the external dimensions of the animal, if correctly interpreted, can reveal information about its internal composition. In fact, the Armour Company claims to have identified 25 measurements from which it is possible to calculate such commercially valuable factors as dressing-out percentage, degree of fatness, and proportions between fore- and hind-quarters. For any method to be of practical use, of course, it must be possible to make the necessary measurements in the time available for holding the animal, which is commonly too short to permit many measurements to be made directly. Hence special methods are necessary; that first proposed by Armours was to establish the contours of the animal from stereo photographs, as in map-making. My colleagues are exploring a simpler and cheaper procedure called 'moiré', which produces a contour pattern of shadows on the surface of the animal or carcass. An alternative suggested by Armours was to put the animal in a box of light beams intersecting in three planes, so that the three shadows established the shape. My colleagues use mirrors to provide simultaneous photographs in three planes. In any case, from the shape so established rather long calculations are needed to deduce the particular measurements and combinations thereof that may be required. Until recently, the labour of making such calculations would have been prohibitive; now, they can be done by computer in a fraction of a second. But all this, unfortunately, converts a method that is simple in principle into one that in practice is very complicated and expensive.

Instead, attempts are now being made to gain some visual impression of the internal structure of the animal, either by means of X-rays (which would be too dangerous in routine use) or by means of ultrasonic sounding. Recent ultrasonic techniques can be used, not merely to measure back fat thickness at isolated points on the animal, but to reveal the shape of the subcutaneous fatty layer and, more or less successfully, the shape of the muscles that underlie it. When such sections are made at several different points in the animal body, a fairly good estimate of composition and disposition of the tissues is possible. It is an awkward complication, though, that because of the way the carcass is hung during slaughter, the disposition of the tissues in the carcass is somewhat different from that in the live animal.

The purpose of all these techniques for studying the composition of the animal body is to monitor the outcome of attempts to change the properties of the body and carcass, by breeding or by feeding or whatever.

Attempts to Influence the Constitution of the Animal Body and Carcass

The generally accepted picture of growth is that bone develops first, then muscle, and finally there comes the phase in which fat deposition predominates. The shape and composition of the carcass obviously depend on the relative rates of these three processes, and their relative progress with age in different parts of the carcass, which do not all grow in unison.

Nobody wants bony animals. On the contrary, the 'blocky' type with relatively short leg bones and thick muscles is preferred. To get the short bones their growth in length must cease relatively early. Can anything be done to influence this, beyond the blind selection now practised by the breeder? Bones grow by the activity of a thin layer of special cells just below the head of the bone. These cells add to the length of the leg bone shaft by depositing on it a new layer of cells which calcify after they have been formed, leaving the original layer to add to the shaft further layers of cells which will subsequently calcify in their turn. The presence of this layer is revealed when all the connective tissue is cooked out of the bone, the end coming off where the uncalcified cells were. Connective tissues 'harden' with age in bone, tendon, and arterial walls; the reason for the hardening change is the formation of particular cross-links between the molecular strands of the proteins which form the connective tissue, chiefly collagen: if the cross-links form early, apparently, the tissue 'hardens' and growth stops early, and the bone is correspondingly shorter. Current research by my colleagues is establishing the nature of the relevant cross-links, and suggesting ways to control their formation.

Muscle consists of many fibres, but it would be wrong to describe them as innumerable. For a small animal like the mouse, in which the number of fibres in the muscle is so small that they can actually be counted, it seems clear that a characteristic number of fibres has already been formed before the embryo is born, and that growth after birth simply consists in the enlargement of fibres already formed. For the larger muscles of meat animals, attempts to estimate the enormous numbers of fibres involved run into obvious difficulties, but present indications suggest the same growth pattern applies. In general, the larger the animal, the larger the muscle and the larger the number of fibres. If it were possible to stimulate formation of a greater number of fibres at the embryonic stage, the muscles of the adult might be larger and the animal itself also correspondingly larger. In the embryonic muscle, each fibre springs from a nucleus, and the nuclei are thought to multiply by division to reach a characteristic number, before producing fibres. It seems that if multiplication of nuclei went on longer there would be more nuclei, more fibres, and hence larger muscles. My colleagues are about to try a drug that is believed to produce this kind of effect. But, of course, there may be awkward side effects if the balance of growth is interfered with, as I shall soon illustrate in a different connection.

Apart from some such interference, we can only select for breeding those animals which are most efficient in converting food into lean tissue, but this simple approach appears likely to run into serious trouble that will soon require a lot of research. The point can be illustrated by the story of the man with the donkey which ate an inconvenient amount of straw; he decided to see whether his beast could manage with less and so the next day he gave it less, and the following day a little less again, and, since the donkey still seemed all right, on the next day still less, and so on; but just when he was on the point of success, feeding the donkey on nothing at all, the creature unfortunately died. You may think this a stupid story, yet it represents in effect just what our animal selectors try to do. Their targets of 'greater efficiency of food conversion' and 'higher daily gain' mean, put simply, getting more and more for less and less. Somewhere along that road, obviously the machinery must begin to fail, but we are too ignorant of physiology to predict exactly where.

Among meat animals one would expect this sort of difficulty to arise first with pigs, because they have been much the most 'improved'; they breed faster than cattle, and they have more progeny than sheep. And with pigs, indeed, there are already indications of difficulties of the kind just mentioned.

● First, we begin to have pigs that cannot stand up. In Britain, a high proportion of progeny-tested boars are condemned for leg weaknesses of one kind or another. One might speculate that this happens because they put on weight too quickly for the supporting structure; or in slightly different terms that selection is for animals which at a given weight are physiologically young, so that molecular cross-linking associated with maturing of connective tissue lags behind and makes that tissue less strong than it should be. This as yet is only speculation: as far as facts go, little is known about the causes of the leg weakness, it is not even known whether the trouble arises from one cause or from several.

● A second example may be softness in the fat of some pigs. This is an increasingly frequent cause of complaint, although it is not clear whether it represents a real trend or whether complaints arise because fats that were considered hard enough in the past are not sufficiently hard to withstand the high-speed slicing involved during modern production. This character of the fat, in several kinds of crossbred pigs, was recently made the subject of a collaborative study by the Animal Breeding Research Organization, the Food Research Institute, and the Meat Research Institute in Britain. The results can be broadly summarized by saying that the fat was unusually soft whenever there was more than two-fourths of Hampshire blood in the cross. This indicates that the character is certainly hereditary, but it does not necessarily prejudice the Hampshire breed as a whole, because only a limited number of lines were included in these crossing experiments.

● The third and well-authenticated example of the sort of difficulties that can arise from attempts at improvement is the 'pale watery muscle' or PSE condition in pig flesh. This is caused by an unusually rapid production of lactic acid in the muscles after death, as can be revealed by a measurement of the acidity (pH) at some standard time, say 45 minutes, after slaughter. In recent improvement programmes it has been repeatedly observed that greater production of lean muscle tends to be associated with a more rapid post-mortem production of acid giving a tendency to the PSE condition, whether improvement was obtained by selection within a single breed or among crosses, and whether the experience was in Britain or in some other country.

The vital question here is whether the particular defect is inevitably associated, for genetic or physiological reasons, with the characters desired. These three examples pose this question in differing degrees. In the case of soft fat, there is as yet only a hint that there may be a connection with those characters for which the Hampshire breed is favoured. With leg weakness, the fact that it is unusually common among progeny-tested boars indicates that it has something to do with the basis of selection involved, but the connection must remain obscure until the causes of the weakness are clearly known. In the case of the PSE muscle, however, the evidence is strong, if circumstantial, that there is a close connection between this defect and the desired characteristic of good production of lean muscle. Hence one might expect the Large White breed, the basis of British pig production and at present happily free from this defect, to develop it if selection pressures are continued as in the past.

When dealing with defects of this kind, one would hope that some would not be so closely linked with the desired characters that the two could not be separated after genetic manipulation. But it seems likely that successive obstacles will arise along the 'improvement' road and will present increasing difficulties until eventually, it seems certain, there will arise defects which for fundamental if unknown reasons are inseparable from the characters desired. If this argument is correct, similar defects should arise at a later date in other meat animals besides pigs, as improvers go on striving for their goal of increased yield of lean meat with lesser food intake.

As regards fat, both quantity and composition are important. The deposition of an excessive quantity of fat represents a spill-over of surplus energy, which is favoured by lavish feeding regimes aimed at maximizing rate of growth in weight; clearly such maximization is an unduly wasteful procedure. The tendency to convert food not into body-building protein but into wasteful depot fat is evidently influenced by growth hormones in relation to the age of the animal. It is also under partial control of the sex hormones; hence our current interest in research on the rearing of male animals and the use of hormones in feeding regimes. Improved knowledge here could in future produce leaner meat and save huge quantities of feedstuff. The basic facts are daily confirmed as we look at our human fellows: the fat boy is an oddity, whereas middle-aged fat men and—even more—fat women are commonplace, although only in affluent societies. The composition of fat has already been mentioned by inference, in the reference to soft fat in pigs. Physical softness is accompanied by chemical unsaturation, which leads to a further technological disadvantage, namely development of rancidity. On the other hand, chemically saturated fats, such as are produced in ruminants by hydrogenation in the rumen fermentation, are suspected of causing heart disease. Accordingly, at the CSIRO Division of Animal Physiology, workers made the experiment of feeding unsaturated fats in a manner ingeniously contrived to by-pass the rumen. Thereby they did indeed achieve a ruminant fat which was softer than usual; but, unfortunately, it had the technically undesirable properties that could have been expected.

So far, I have spoken only of the major constituents determining commercial and nutritive value. We can do no more than note the existence of a host of minor constituents of more or less importance, about which we are deeply ignorant, and which must become the subject of investigation in future. For example the substances responsible for flavour, lack of which is now a common cause of complaint, are made accessible by modern research techniques in a manner scarcely conceivable 20 years ago. Much the same is true of the minerals and vitamins important in both animal and human nutrition; we shall certainly wish to know more than we do at present about their occurrence in different animals or in different parts of an animal. Hormones, I have mentioned already.

Getting the Meat Out of the Animal

Turning live animals into meat means slaughter, and here our practice goes back literally to the days of Moses. The principal improvements have been mechanical, permitting the handling of larger numbers of animals, and there is certainly a need for much further research on abattoir machinery, which is largely neglected by official agencies. The fundamental nature of the slaughter process remains almost unchanged, and we are remarkably ill informed as to the probable consequences of any significant departure from traditional practice.

Of course, such departures might involve changes in the system of meat inspection. Change is in any case desirable, at least in Britain; for example, the present system was devised mainly to protect against tuberculosis and this is now rare in meat animals, while trouble from salmonellosis, which is now quite common, will most probably escape detection.

The most obvious change in slaughtering has been the introduction, on humanitarian grounds, of the practice of stunning the animal before slaughter, with electricity or carbon dioxide. But it is still debatable whether such procedures produce better meat, or are even more humane, than a skilfully handled pole-axe or pistol. Attempts to develop better practices in stunning are hampered by our almost complete ignorance of their possible side effects; and the same is true of any varying of practice in bleeding.

The practice of general hygiene, too, needs to be improved, but here most of the fundamental research has been done. What is now chiefly needed is the application of its conclusions.

Classical research in the thirties by Dr Scott and Dr Vickery established the importance of low temperature and humidity in controlling bacteria during chilling immediately after slaughter. Ten years ago, however, Dr Marsh and his colleagues in New Zealand showed that too rapid chilling could cause toughness, an observation since confirmed by many others. More recently, my own colleagues have shown that slow cooling is one of the most important factors in bringing about a high production of drip. Because of these complex relations, it is evident that different cooling regimes would be desirable for different purposes. These facts seem to have been unknown to the Australian authorities who framed the meat chilling regulations now before the Codex Alimentarius, for the unique time/temperature schedules they recommend are such as would certainly be expected to cause quite serious toughening in lamb and beef.

How to Evaluate the Product

In deciding the value of the product there are, broadly, two very different groups of people involved—the meat trade and the consumers. The trade is concerned with meat in bulk, usually with the properties of carcasses, or of frozen meat in boxes, for example. The consumer has to buy small pieces on the basis of their appearance, although she is really interested in their eating quality and wholesomeness.

To estimate the composition of carcasses, one can use methods similar to those described for the live animal, often with a much higher degree of accuracy. The procedure for gauging density, for example, becomes relatively accurate, especially in the absence of bones; a Danish machine for estimating the fat percentage in boneless meat has recently appeared, based on this principle. But for routine use even such comparatively simple procedures may be too elaborate and some form of visual estimation may be all that is possible, especially with carcasses. My colleagues have been trying to refine this type of procedure by the use of photographic standards, as part of a new beef classification scheme in Britain. As regards fatness, classification by some visual means appears feasible, but attempts to estimate proportion of bone to lean have been less successful. As a baseline for all such procedures, definite knowledge of the composition is required, and this can be obtained only by dissection of the carcass into the relevant parts, as precisely as possible. It would obviously be an advantage if the same information could be derived by dissection of only part of the carcass, especially if that were an expendable part like the shin joint. Much research has gone into the exploration of such possibilities, but without any general success. Using dissection techniques, Dr Butterfield, working in Brisbane, made the striking demonstration that the proportions between the main muscles in different cattle are virtually the same, so that the differences we notice between breeds arise from differences in subsidiary muscles and above all in the deposition of fat. The inference must be that, if we want a radically different distribution of lean tissue in the carcass, we must learn to exploit animals like the 'double-ender', even if such beasts are regarded as horrors by the aesthetic standards of breed societies.

The consumer's difficulty is that the appearance of meat tells her nothing about its probable toughness or flavour. Indeed, the butcher is almost equally ignorant when he knows nothing about the origins of the carcass. Appearance may also be a poor guide to keeping quality under modern conditions, in which the meat may be packaged or ascorbic acid may be added. But control of toughness now seems conceivable. That which is needlessly generated by inappropriate chilling can be avoided, thanks to the work in New Zealand; that which arises by natural toughening of the tissues with age, for instance through cross-linking in the connective tissue, can be avoided by enzyme treatments like that patented by Swifts. Especially with cattle of the type coming from extensive ranching operations in the Northern Territory, where several years are needed to attain commercial weight, research on artificial tenderizing of the aged connective tissue would seem highly desirable, unless their meat is to be confined to markets where toughness is of no importance. Of course, the exploitation of more tender meat implies the ability to recognize it, to label it accordingly, and to charge a higher price for it, and the Armour Company have patented an instrument which claims to predict the tenderness of beef; it seems probable that this would be most useful with meat done 'rare', i.e. not cooked throughout most of its mass.

The hope in attempts to evaluate meat is to ensure, so far as possible, that the best kind of meat is produced. This implies some means of transmitting the result of the evaluation back to the producer of the animal, or the slaughterer of the carcass, in such a manner that the producer of the good is rewarded while the bad is penalized. The implication here is that there must be a scale of quality, against which some corresponding scale of price can be set. We should be accustomed to such notions in relation to carcass grading, but they are novel in relation to consumer quality because of lack of the necessary knowledge—a lack which can only be supplied by future research.

As regards wholesomeness, because up till now it has been assumed that animals normally reared and in a healthy condition, i.e. passing inspection at slaughter, would produce wholesome flesh, no further checks on the wholesomeness of meat have usually been made. But the basic assumption now seems questionable, when we have pastures polluted with herbicides or pesticides and an increasing use of feedstuffs containing additives like drugs and hormones; moreover, our current bacteriological problems are not readily diagnosed by inspection before death. Some examination of the meat itself begins to seem desirable; but the methods and rationale of such examination have still to be developed.

Preservation

The preservation of meat by cold storage or freezing was a major preoccupation of the Low Temperature Research Station throughout its existence and of Dr Vickery and his colleagues here, and the main important considerations were well established a generation ago. It is therefore disappointing to see how frequently they are still disregarded, in Britain at least. For example, it is common to find automatic defrost systems which cause repeated upward excursions of temperature by as much as 5 degC; and there is a widespread acceptance of the idea that $-17 \cdot 8°C$ is an adequate temperature for the long-term storage of frozen meat, despite good evidence that much lower temperatures would be desirable. A recent survey by my colleagues shows that the majority of firms in Britain would be unable to meet the temperature conditions now being suggested by international organizations, and we suspect that the situation may not be much better elsewhere. In general, what is needed in this field is the application of research results already long known. Nevertheless, industry in Britain has put forward the proposition that defective refrigeration installations arise partly from lack of the basic data about the thermal properties of meat that is needed to design realistic installations; and my colleagues are consequently seeking to get such information, especially for beef. Recent publications from New Zealand, on models simulating sheep carcasses under refrigeration, reveal a similar interest there.

The most interesting recent development in the field of meat preservation has arisen from new methods of packaging. This is far more than a matter simply of convenience to the purchaser, though that may have been the origin of the practice. It has already led to important changes in the marketing structure of the industry, through the suitability of packaged meat for sale in supermarkets. But the possibilities extend beyond this, to centralized prepacking at the point of slaughter, with the distribution only of prepacked cuts—conceivably of consumer cuts without bones. Such a development would revolutionize the meat industry, especially in a country like Britain which is hampered by the existence of a large number of inefficient small rural slaughterhouses existing for a local trade. The technical difficulties in the way of such a development, ranging from the bacteriological quality of the initial meat to changes in colour and a tendency to drip, in relation to the nature of the packaging material and the atmospheric composition within the package, are all the subject of continuing investigation in various places.

Research on the traditional method of preservation by curing has aimed at greater yield, greater speed, greater uniformity, and a milder product. Greater yield is obtained by manipulation of the pH of the meat or the addition of polyphosphate, especially if a cooked product is intended. Greater speed has been obtained by the automatic and metered injection of brine, by hot curing, and by devices like tumbling. Automatic injection of brine, especially by the multi-needle system, promotes greater uniformity of cure; besides being desirable in itself this is essential if one aims at a mild product, since one must avoid variations which would cause serious under-curing locally and so give rise to bacteriological problems. Research in this area has received great impetus lately from the discovery that nitrite, which with salt is the essential ingredient of curing mixtures, not only can be poisonous in itself but may also generate traces of cancer-promoting substances in cured meat; consequently, there is now strong pressure in various countries to minimize addition of nitrite, or even to eliminate it altogether although this would require entirely new techniques.

Lightly cured products, perhaps also lightly cooked, and packaged in partially permeable film packages, are representative of a rapidly multiplying class of semi-preserved meat products which are convenience foods finding increasingly ready sale. They seem likely to require a great deal more control in future of composition, identity, and bacteriological safety. It appears as if much research will be needed to guide and control the development of this rapidly expanding group of products.

Processing

I will say only a few words about processing. To the processor, two of the most important properties of meat are its capacity to bind water and to bind fat. Poor water-holding capacity is revealed in fresh meat by the release of drip, and in cooked meats by production of excessive amounts of gelatin. Addition of a polyphosphate brings about improvement, especially in cooked products, but this is to some degree objectionable, and a more fundamental solution would be preferable. Recent research shows that part of the trouble may arise through the denaturation of meat proteins if the meat reaches its normal post-mortem acidity while it is still warm—a condition which prompt cooling helps to avoid. But this does not adequately explain the drip that arises as a result of freezing, for which a preventative is badly needed, since it remains one of the principal objections to frozen meat. The problem appears likely to involve the permeability of the sarcolemma, the membrane surrounding each muscle fibre, and this is one of the key points of muscle research at the present time. Work on capacity for binding fat was greatly assisted by the development of a simple method for measuring this property in the Beltsville Laboratory of the U.S.D.A. Subsequent work has shown the importance of subtle changes in the physical state of the fat, which take place at different times after death, according to temperature. Clearly there is a need for extensive physico-chemical investigations of the relevant properties and the reasons why they change.

Early results from Canadian work indicate that shortly after slaughter meat has an unusual capacity to bind salt, and this is slowly lost during storage. Work in my Institute has confirmed this finding; it is presumably caused by the ion-binding powers of the meat proteins, but almost nothing is known about it yet. The phenomenon could also be important in relation to salty flavour, and it is a confusing element in attempts to estimate salt content in cured meats.

Cooking

We are rather ignorant about what goes on in cooking. Thus, it comes as something of a shock to discover that in the centre of a large steak done 'rare' the temperature during cooking barely returns to blood heat—in effect one eats such meat raw, as if it were warm from the animal. There is a need even for the simplest descriptions of this kind. To take a more sophisticated example, it is striking that the toughness of cold-shortened meat is developed only as a result of cooking; such meat in the raw state is, far from being tough, unusually tender; we have no idea what the changes are, during cooking, which create the toughness. There are, of course, new methods of cooking like radio-frequency heating, which are undergoing development for such purposes as mass catering.

Conclusion

You will realize that in making this brief survey of the large field of meat research, present and future, I have been forced to omit subjects which may be important to you and whose importance I myself recognize. One of these is the utilization of by-products, a subject sadly neglected in Britain because of the scattered nature of the slaughter industry; it is, on the other hand, a topic vital to the success of large meat-works of the type catering for the Australian export trade. Another example is disposal of effluent. This too is apt to be ignored in my home country, where effluent can usually be disposed of through urban sewage systems, in a manner not possible for large works isolated in the countryside. But I believe that, for example, the waste of first-class blood protein will soon come to be regarded as intolerable, and that much greater efforts will have to be made to improve the utilization as food of various other parts of the animal body. It seems rather stupid to make such a fuss about producing novel protein of doubtful quality, for example from microorganisms, when we throw so much good animal protein away.

Taste Panel Techniques

I. Reproducibility, Reliability, and Validity

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This article is based on a talk given to the Brisbane branch of the AIFST on 24 February 1971. Dr Howard retired in 1971, after nearly 40 years with CSIRO, much of it spent in work with meat. He was Officer-in-Charge of the Meat Research Laboratory when it was located at the Brisbane Metropolitan Abattoir. His interest in the sensory evaluation of tenderness in meat led to the award of a Ph.D. from the University of Queensland in 1968.

Introduction

Taste panels are used in food science and food technology primarily for two purposes: (1) to study the response of consumers to various sapid materials and the variation among consumers in this response; and (2) to study the variation in the sapid properties of materials, due to production conditions, using the response of consumers as a yardstick. In both cases the experimental data are the observed responses of consumers. In (1) the consumers are under study, and hence the description 'consumer preference panel', while in (2) the product is under study, and hence the term 'analytical panel'. The nature of the data so obtained is thus of interest to both the psychologist and the food scientist or technologist.

For consumer preference studies, one must use a panel large enough to be representative of a broad spectrum of potential consumers. The panel, therefore, does not need to be specially selected for tasting acuity, nor need the members be experienced in assessing their reaction to sapid materials. For analytical panel studies, it is adequate and usually desirable to rely on the statements of a few tasters of good taste acuity who are experienced in assessing their reaction to a particular product. The analytical panel is not necessarily representative of any particular section of the consuming public, though obviously it should not be grossly atypical. Data from the analytical-type panels cannot be used directly in market research without relating their statements to those of the particular group of consumers, but these panels are particularly useful, and often the only means available, for studying the changes in quality of a food brought about by technological operations.

In any field of study, the data obtained should be (1) reproducible, (2) reliable, i.e. measuring what the investigator expects to measure, and (3) valid, i.e. measuring in the way the investigator expects. With 'objective' measurement, as used in the physical sciences, it is generally assumed that reliability offers few problems and validity none, and effort is concentrated on reproducibility. With the 'subjective' measurement obtained in taste panel studies, all three factors must be considered.

Study of taste panel techniques largely began towards the end of World War II. Food technologists carried out numerous studies on reproducibility and reliability and used information from psychological studies on taste and olfaction. Reviews and books in most European and other languages were collated by Amerine *et al.* (1965). The more salient aspects will be discussed. On the other hand, the problem of the validity of subjective measurement has as yet been largely confined to studies by psychologists and has had little or no impact on food technology. Reproducibility, reliability, and validity are all of importance for both consumer preference and analytical panels, but since the differences are largely a matter of degree this article will be couched in terms of analytical panels.

Reproducibility

Almost any change in conditions can, potentially at least, modify what a person perceives when presented with a specific situation on a specific occasion and hence can lead to lack of reproducibility of responses. This is so whatever the form of response. Basically the controlling factors are motivation and ability, though these will often not be independent.

Motivation

Many factors come under the heading of motivation. In general, a person will be a better taster the more he is interested, either in the product as such or in the results of the trial being conducted.

Extent of hunger is important—a taster is not likely to perform well when satiated after a meal, nor can he be expected to do so when really hungry and hence more interested in eating food than in assessing its properties.

Reward and punishment are further factors affecting motivation and hence reproducibility. Reward may be seen by the taster in terms of prestige or personal satisfaction gained through performing well. In this latter case, feed-back of results is therefore desirable. Punishment is more difficult to assess. Where there is some form of payment the threat of removal from the panel may well maintain high performance but most forms of punishment are of value only as a threat and lose their efficiency if used.

In an early bibliography on organoleptic measurement Dawson and Harris (1951) summarized the situation as follows: 'Successful conduct of taste panels is frequently as much a matter of human relationship as a scientific problem. Panel members must have an interest in their tasting ability and these feelings must be sustained. Informal conferences should be held periodically and imagination must be eliminated.'

Ability

Obviously ability will depend largely on motivation but this will vary from person to person. Even when motivation is at a maximum there are still individual variations in the ability to discriminate between samples on the basis of taste characteristics and to characterize the taste impressions. Discrimination can be improved by practice but there are also underlying physiological or genetic effects that set limits to ability. Fatigue and poor health, particularly respiratory infections, may reduce discrimination. The case of the flavour of phenylthiocarbamide is the classic case of an apparent genetic effect. This substance is tasteless to some people, bitter to others, with a few people ascribing other flavours to it. Many other compounds with the –CS–N= group show a similar effect. Sensitivity to phenylthiocarbamide varies between ethnic groups, and there are similarities in sensitivity between closely related persons; but all the facts cannot be explained on the simple basis of a single recessive gene.

As in the case of reproducibility, ability to discriminate is affected by hunger. Ability also varies with the temperature and condition of the product and the conditions under which tasting is carried out, particularly the extent of freedom from distraction.

It is evident from this short and selective discussion of the factors influencing ability that it is impossible to predict their relative importance. Consequently, in taste panel work it is essential to standardize, as far as possible, every aspect of the procedure—preparation of the sample, presentation of the samples to the tasters, and the environment in which the tasting is done; and it is important to maintain interest and ensure understanding by adequate pre-trial briefing and post-trial feed-back of results. It is clear that this can be done more successfully with analytical than with consumer preference panels. Where extensive analytical taste panel studies are to be undertaken, preliminary research into the optimal environmental conditions for the particular product will almost certainly indicate ways of improving panel performance.

Reliability

That a taster gives reproducible responses under a given set of conditions is no indication that these responses are reliable and useful. He may be giving consistent answers to the wrong questions or his consistency may be dependent on the particular set of test conditions. The simpler the question the more likely it is to be meaningful and correctly interpreted. The experimenter has the task of deciding whether the panel is giving reliable data. To do this he should understand measurement and the types of error that may occur, particularly with subjective measurement.

Measurement

Measurement of the magnitudes of a property of a set of things involves assigning numbers to the magnitudes so that the relations between these numbers in some way represent the relations between the magnitudes. However, there are potentially large variations in what these numbers may mean. In the simplest case the numbers may only mean that the magnitudes of the property lie in the same order as the numbers given to them. This is the case in the scale used for measuring the hardness of minerals, and will usually be the case where estimates of preferences are given. The data are then given on an 'ordinal' scale. Obviously one cannot go much further with such numbers. Comparing the means of two subgroups of the data would be meaningless. Also, if three samples score 1, 2, and 3 on an ordinal scale it cannot be said that the difference between the first and the second is the same size as that between the second and the third. If this relationship is required then the data should be scaled either on an 'interval scale' or on a 'ratio scale'. With many properties, particularly those with a qualitative aspect, such as tenderness, it is impossible *a priori* to consider any particular magnitude of the property as zero and the selection of a magnitude on the scale as zero is arbitrary; in this case the scale can only be an interval scale. However, when a meaningful zero is available as in, say, intensity of flavour, the possibility can be considered not only that differences in magnitudes of the property correspond to differences in the numbers assigned to them but also that ratios of the magnitudes correspond to ratios of numbers assigned to them; if this is so, the scale is a ratio scale. Obviously data on a ratio scale are the most amenable to mathematical manipulation. The type of scale that can be used depends on both the material and the measurement technique.

Techniques of Sensory Measurement

One of the most common methods of sensory measurement and the one used almost exclusively in food studies is that which is known, in psychological parlance, as the method of subjective estimates. In its simplest form, the taster is asked to give directly a number which he considers corresponds with the magnitude of the property he is asked to assess. The taster may be intuitively able to do this, or may be able to learn. Various forms of aid are often given in that descriptive terms rather than numbers are used. Thus the taster may be asked to tick off the appropriate descriptive term in a sequence such as in Figure 1(*a*), and numbers will then be given to the terms. Obviously scores that fall outside the ends of the scale cannot be given. In a modified version the taster may be asked to mark, on a line of fixed length between two points, the appropriate position in relation to the descriptive terms given to the two points as in Figure 1(*b*), and the distance of the mark from one end will be used as the score. In this modification scores beyond the identified limits may be given.

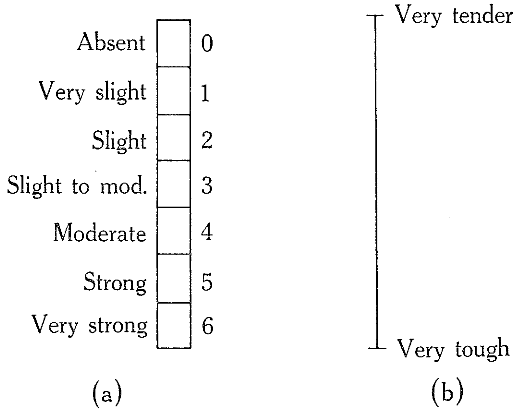

Fig. 1.—Scoring systems for subjective estimations.

While data obtained by this technique have frequently led to useful results and the scores often correlate well with those produced by other techniques, it is evident that, logically at least, the scaling cannot *a priori* be claimed as better than ordinal.

The method of 'equal appearing intervals' provides a better approach. The basic principle is that two samples are provided which are accepted as standards and then others are found which can be placed in relation to these, so that the differences between each pair of consecutive samples are the same. Further samples can then be scored in relation to this set. The system can be extended to values on the scale outside those of the standards, but the technique requires much time and material and if it is to be used on more than one occasion the standards must be permanent. If one standard can meaningfully be given the value zero the scale will potentially be a ratio scale with a unit difference dependent on the score given to the other standard. Otherwise it will be an interval scale with zero and unit difference dependent on the scores arbitrarily assigned to the standards. It is possible that the task given to the taster is simpler than that in subjective estimation but this can only be determined by empirical testing.

The final measurement technique is that of fractionation. This also uses two standards but, instead of there being a set of equal steps between them, a direct estimate is made of the ratio of the difference between the test sample and one standard to the difference between the two standards. As with equal appearing intervals, the unit difference will be fixed by the value assigned to the standards and will be a ratio scale if one standard is a real zero. Whether this technique is more or less difficult or effective than that of equal appearing intervals is, again, determined by empirical test.

Errors in Sensory Measurement

Whatever measurement technique is used, errors can be expected from making an incorrect judgment of a sample as distinct from not being able to make a reproducible judgment. A score may be biased by the score given to the preceding sample. This commonly occurs in 'discrimination' tests, when pairs of samples of varying differences are assessed for the presence or absence of a difference, which might be considered as ordinal scaling of each pair. A taster who has found a difference with all the initial pairs in a series may continue to report a difference when it is no longer evident to him, and similarly may continue to report no difference after a series of pairs in which he observed that no differences were evident. There may be a similar tendency, in the direct assignment of scores (whether by subjective judgment, equal appearing intervals, or fractionation), to refrain from making a change when several samples have scored the same. However, once a decision is reached to report a change this may be scored excessively.

Time and positional biases often occur. The first or last samples presented in a series or at the two ends of a line of samples may be scored differently from when they occur at other positions in the series. With taste and smell, further time effects may occur. The effect of the first sample tasted or smelt may be to produce a short-term change in the sensitivity of the physiological apparatus involved; or physiological fatigue may have a long-term effect.

True or false information about the expected magnitude of the property may influence the value reported by the taster. Such information may be derived from knowledge of or conjecture about the experimental treatments that have been used on the samples, or it may be suggested by changes which can be noted in some other property. A related cause of error is what is known as the 'halo' effect, which applies particularly when questions of pleasantness and unpleasantness are involved. If one property of a given sample is found to indicate a high level of pleasantness, then all other properties of the sample are likely to be favourably scored even when they are in no way really enhanced.

The halo effect is particularly evident with inexperienced tasters, and in the literature on organoleptic measurement by subjective estimation many references are made to the training of tasters. By this is meant (1) teaching tasters to avoid making the types of error discussed above, particularly that associated with the halo effect, and (2) giving the members of a panel sufficient experience with the product being tested so that each member will give the same score for any sample of it. Howard (1956) has shown that with subjective estimation of the intensity of flavour of cooked mincemeat the first of these aims can be satisfactorily achieved by training but, while all the tasters may learn to assign the same scores to a set of samples while training as a group with feed-back as to their performance, when they are left to themselves without feed-back they quickly revert to a scoring system of their own which, while quite reproducible, differs from person to person. If this occurs it does not make the results for any one test unreliable, but if results from several tests are to be compared, then the panel must contain the same members on each occasion. This is evidently a counsel of perfection, but if tasters are functioning well the score of any missing member on a particular occasion can be fairly accurately estimated from his known correlation with the rest of the panel and this value can be used.

From this brief discussion of some of the errors that may arise in sensory measurement, it is evident that it is impossible to predict whether any particular effect will operate in a given situation. The experimenter must be aware of the possibility of such errors and design the tests so as to eliminate them or compensate for them. Some procedures that can be adopted include using a dummy first or last sample, reversing the order of tasting, or balancing the sequences and restricting the number of samples to avoid fatigue.

Validity

Even when an experimenter is satisfied that the data provided by a panel are reproducible and measure the property he is studying without bias, he still cannot be satisfied that they are valid, i.e. that they are in accord with the mathematical model he is using to interpret the data. Some confidence can be placed in results that fit a pattern and allow of interpretation by a simple convincing hypothesis, but such factors do not constitute validation. Further, if statistical analysis is to be applied to the numbers derived from any measurements made, then the numbers must be capable of being related to an interval or ratio scale. It is not necessary that all measurements be made by a technique which is validated in the particular experiment, but it is necessary that a validated system or systems be available by which any particular system can be standardized. Studies with subjective measurement of various properties have shown (Galanter and Messick 1961) that results by equal appearing intervals and fractionation (in the form of direct ratio estimation) are not necessarily linearly related. In addition Jones (1959), working with data from the U.S. Quartermaster Corps Food and Container Institute, showed that it was necessary to apply a sigmoid transformation to subjective estimate scores to bring them into agreement with a scale he developed by a method which aims at producing equal appearing intervals from a knowledge of the error variance of the scores. Where there is an appropriate objective measurement of a property, which is presumably related to the subjective measurement on a ratio scale, measurements by fractionation techniques usually produce results consistent with the relationship:

$$\text{Subjective measurement} = C \times (\text{objective measurement})^{\beta};$$

whereas such a simple relationship may not be given with other techniques (Stevens and Galanter 1957). While this is not a reason for placing implicit faith in fractionation techniques, it is a basis for accepting direct ratio estimation as a possible technique for producing valid scales of magnitude of subjective properties. Part II of the paper will describe how scales produced by this technique can be validated and will give an illustration for a series of properties.

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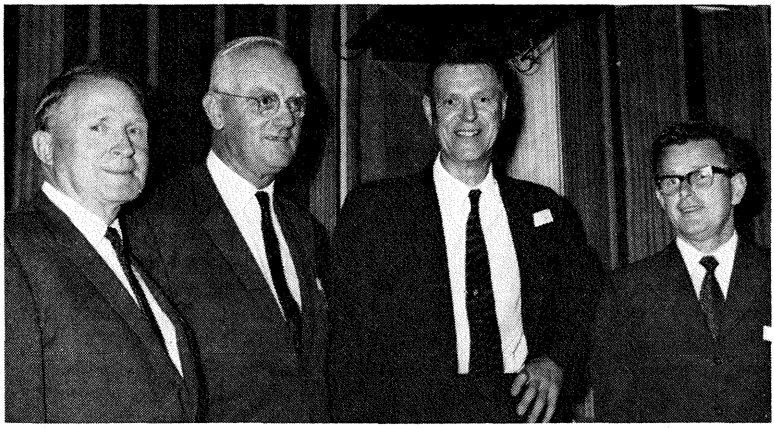
Other Items of Interest at the Conference



The overseas speakers at the conference, with Dr Scott (*from left*): Professor A. M. Pearson (U.S.A.), Dr W. J. Scott, Professor M. Ingram (Britain), and Dr C. L. Davey (N.Z.).

The conference was opened by Mr C. S. Christian, who is the representative of the CSIRO Executive on the Australian Meat Research Committee. Mr Christian reviewed the history of meat research in CSIRO and of the Meat Research Laboratory, and pointed to the major role Dr Scott has played in both of these.

The title of the conference was intended to generate discussion useful in planning for the future, in addition to reviewing current issues in meat research.

Dr M. A. S. Jones, Director of Technical Services of the Australian Meat Board, reviewed the Meat Board's objectives in supporting meat research. The industry, through the Australian Meat Research Committee, has contributed $21 million in grants for meat research, including $1 million to the cost of establishing the present Meat Research Laboratory. Its most urgent needs now, Dr Jones suggested, were for market research and for a system of carcass classification. Information on these subjects could help the industry to tailor production to the needs of available markets. Research aimed at increasing production and profitability while keeping prices at a reasonable level was also required to help it offset the challenge of meat analogues and meat expanders.

Mr R. G. Jones, a representative of the meat processing industry on the Meat Research Advisory Panel of the AMRC, gave figures that demonstrated the importance of the meat industry to the Australian economy and its growing role in export earnings. He hoped to see an extended Industry Section where day-to-day technical problems could be tackled, and also the provision of facilities for educating people from industry. While emphasizing the importance of basic research, Mr Jones asked that particular attention should be paid to the development of production and processing techniques to bring Australian standards up to international levels.

Besides Professor Ingram from Britain, overseas speakers included Dr C. L. Davey from the Meat Industry Research Institute of New Zealand, who reviewed the work at that centre. Attention is focused there on lamb rather than on beef research and future work there will be increasingly concerned with examining the characteristics of live animals in relation to eating quality and with the development of new products, particularly in areas of preservation and presentation.

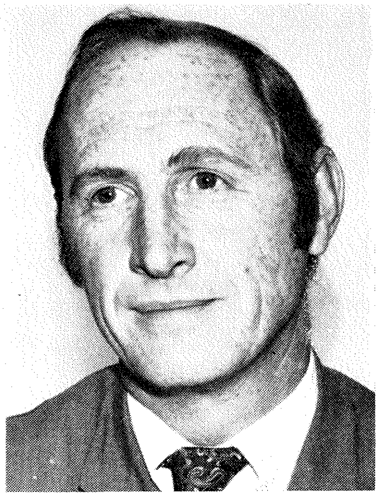
The final overseas speaker was Professor A. M. Pearson of Michigan State University, who spoke about the present role of meat analogues and meat extenders and their probable influence on the meat market. Americans were now eating 1 kg of soy product per head each year as compared with about 100 kg of meat, but it was predicted that the consumption of soy product would rise to 10 kg per head by 1985.

Several other speakers at the conference dealt with the importance of physics, engineering, and transport in the meat industry, and with the indispensable role of quality control. Papers were presented on 'Connective tissue', 'Tenderness and manufacturing properties', 'Meat flavour', and 'Salmonella'.

News from the Division

New Appointments

Dr D. J. Walker began duty as Officer-in-Charge of the Meat Research Laboratory and Assistant Chief of the Division of Food Research on 29 August. He brings to the Meat Research Laboratory and to the



Dr D. J. Walker

Division a wealth of knowledge concerning the nutrition and welfare of the ruminant and a proven ability in research leadership. Dr Walker graduated in biochemistry from the University of Sheffield in 1955, and gained a Ph.D. degree in biochemistry (microbiology) in 1958, working during that time with Professor Elsden who is now Director of the Food Research Institute in Britain. He was appointed to the CSIRO Division of Nutritional Biochemistry in 1958, and became leader of the Microbial Biochemistry Section. His interests have been mainly in rumen microbiology but have also extended to other aspects of the nutrition of the sheep and to the energetics of growth. In 1967 he shared the Stichting-Ilra International Lactic Acid Prize. Dr Walker is a member of the Committee on Microbiology and Nutrition of the International Union of Nutritional Sciences. He has close contacts with scientific work in New Zealand, and was recently invited by DSIR to work in the Division of Applied Biochemistry in Palmerston North.

Dr J. R. Yates

Dr John R. Yates, formerly of the CSIRO Division of Protein Chemistry, has been appointed leader of the Industry Section at the Division's Meat Research Laboratory, Cannon Hill, Brisbane. Dr Yates replaces Mr L. E. Brownlie who resigned earlier this year to become Assistant Director of Technical Services with the Australian Meat Board.

Born in England, Dr Yates graduated M.A. from Cambridge University in 1957 and won a CSIRO Postgraduate Studentship to travel to Australia. In 1960 he was awarded a Ph.D. for studies on wheat proteins, in Melbourne, where he then took up a CSIRO Post-doctoral Fellowship tenable in the Division of Protein Chemistry. From 1960 onwards Dr Yates worked on applied problems of the wool industry, including methods of depilating and drying sheep skins. During 1966 he travelled overseas, lecturing and visiting a number of research institutes; then followed a period of further work on methods for removing hair from skins, using enzymes. This led to secondment to Novo Industri in Copenhagen for two years. While with Novo Industri he introduced the new enzyme process to the tanning industry as an improved alternative to the conventional sodium sulphide method. Dr Yates returned to Australia in April this year, and commenced duties at the Meat Research Laboratory on 10 July.

Dr D. Graham of the Plant Physiology Unit has been appointed acting leader of the CSIRO Wheat Research Unit at Ryde, during the absence overseas of Dr D. H. Simmonds, for approximately one year from 21 August.

On 1 August Mr Paul Greenfield received temporary appointment as Experimental Officer at FRL; his work with Mr J. D. Mellor of FRL on 'Mechanistic studies in cyclic pressure freeze drying' led to a Ph.D. degree from the University of New South Wales, and to the award of a CSIRO Post-doctoral Fellowship tenable at the University of Massachusetts at Amherst.

Dr Ross Hood returned to FRL as an Experimental Officer on 17 July, after a period of leave from the Division during which he studied at the University of Minnesota and was awarded a Ph.D. degree for a thesis entitled 'Adipose tissue cellularity and lipogenic activity in porcine and bovine animals'.

Mr D. R. Smith joined MRL during October, and will take up duties as Extension Officer for the Industry Section in Melbourne after a period of training at Cannon Hill. His main duties will be to develop and maintain liaison with meat processing firms in Victoria, South Australia, and Tasmania. Mr Smith holds an associate diploma in applied chemistry from the Royal Melbourne Institute of Technology; he was previously product development manager with a leading Melbourne smallgoods company.

Visiting Workers

Dr M. L. Reed, Lecturer in Biology at Chancellor College, University of Malawi, joined the Plant Physiology Unit on 31 July as a guest worker for approximately five months. He will be investigating, with Dr D. Graham, the relationship between carbonic anhydrase and photosynthesis.

Mr John Faragher, of the Scoresby Agricultural Research Station of the Victorian Department of Agriculture, spent some time during September at FRL, working on the physiology of colour development in fruit with Dr W. B. McGlasson.

Work Overseas

Dr J. H. B. Christian, Associate Chief, commenced in September an overseas visit of 15 months.

After attending a symposium in Reading on the Microbiological Safety of Foods and a meeting of the International Commission on Microbiological Specifications for Foods, he will be based in London to study developments in national and international food microbiological standards, particularly those of the European Economic Community.

Secondment

Mr J. B. Davenport, of the Physical Biochemistry Section at FRL, has accepted a three-year secondment to the Reserve Bank of Australia, commencing early in January 1973. His chief interest will be the administration of the Rural Credit Development Fund, and he will become the scientific liaison officer of the bank.

Mr Davenport will continue as editor of *Search*, the official organ of ANZAAS.

General

The 44th ANZAAS Congress was held in Sydney from 14 to 18 August 1972. Members of the Division contributed papers in a number of Sections, especially that on Food

Science and Nutrition, which was under the Chairmanship of Dr B. V. Chandler of FRL.

Much of the present work on fish involving FRL's Biochemistry Section has been concluded and it has been decided that in future, investigations on fish will generally be the responsibility of the FRL team based at the Tasmanian Regional Laboratory. This team, now known as the Tasmanian Food Research Unit (TFRU), will be led by Dr June Olley.

FRL is completing construction of a 4000-bushel 'blanket' cool store for trials on fruits and vegetables.

Seminars and Meetings

In July a meeting was held to discuss fatty liver and kidney syndrome in chickens. Representatives from industry, from the Veterinary Research Institute at Glenfield, the University of Sydney, the Victorian Department of Agriculture, and CSIRO Division of Animal Health, and members of the Food Research Laboratory participated in the meeting. The possible causes of the disorder were discussed, current work was reviewed, and plans for future and collaborative work were considered.

In August a seminar on recombined dairy products was held at DRL and was attended by nearly 100 representatives from the dairy manufacturing and associated industries, State Departments of Agriculture, Australian Dairy Produce Board, and CSIRO.

The aim of the seminar was to bring together current commercial and technical knowledge on recombining dairy products, to identify those areas in which further information should be sought, and to stimulate thinking on possible products for the future.

Fifteen papers were contributed and discussed. A limited number of copies of the Proceedings are available and may be obtained from the Officer-in-Charge, Dairy Research Laboratory, P.O. Box 20, Highett, Vic. 3190.

In September, an interdivisional meeting of research personnel was held to discuss research problems relating to ruminant food products containing high levels of polyunsaturated fatty acids. Those attending included representatives from the Division of Animal Physiology, the Victorian Department of Agriculture, and the Dairy, Meat, and Food Laboratories of the Division of Food Research. Matters discussed included the proposed collaborative project with the Dalgety–Agrilines Consortium, the state of previous, current, and proposed research, the work in progress in the U.S.A., and a number of specific topics.

Extension Schools

In August the Industry Section of MRL ran two three-day schools on quality control techniques for people from the meat industry at the Institute of Agriculture of the University of Western Australia in Perth. Both were well attended, having 26 and 22 participants. Speakers included Mr Dennis Roberts (Extension Officer, Perth) and members of the Industry Section, Brisbane.

While the speakers were in Perth, the Meat and Allied Trades Federation of Australia (Western Australian Division) took the opportunity to arrange a special one-day quality control course for senior meat industry executives.

Valedictory Functions

On the first evening of the conference described elsewhere in this issue, a dinner was held in honour of Dr Scott, and was attended by more than 150 people representing all sections of the community involved in meat research. The valedictory oration was given by Dr Vickery, and delegates, colleagues, and friends, together with their wives, had the opportunity to offer their warm good wishes to Dr and Mrs Scott for his retirement.

Later in June, a staff farewell dinner, attended by over 70, and a final afternoon tea function took place at the Laboratory. On this last occasion, a presentation of two armchairs was made from the staff of the Division. Dr Scott's final act at MRL was the planting of a poinciana tree on the lawn in front of the Laboratory.

On 8 September, the FRL Staff Club held an informal dinner at Ryde to commemorate Dr Scott's retirement. Amongst the 70 present and former members of CSIRO and their wives who paid tribute to Dr Scott were Mr Tracey, Dr Christian, Dr Judith Howard, and Dr Stewart (Division of Animal Health).

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