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Changes in spoilage pattern as a result of irradiation.

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Any particular food is normally spoiled by a characteristic association of micro-organisms, whose activities ultimately produce typical changes in appearance, odour or taste; and experience has taught the consumer to recognise these changes as signs that the food is no longer fit to use. Irradiation alters these characteristic patterns, and so removes the normal warning signs. Hence it is important to investigate the nature of the alterations.

Such investigations are laborious, and ours have so far dealt with only one set of circumstances, which merit brief explanation.

a) We have worked only with chicken meat, because this suffers relatively little organoleptic damage on irradiation.

b) We have used doses insufficient to sterilse, because sterilising doses - even with chicken - produce such damage to an undesirable degree.

c) We have stored at temperatures below 5°C because, at higher temperatures, the possibility that pathogenic organisms might develop would necessitate a degree of control which we cannot yet excercise.

Within these limits, we have studied two broadly different systems.

i) The chicken meat from all of the carcases, without bones or skin, was minced and packed under nitrogen in shallow aluminium cans, depth 1 cm. capacity 30 g. In this system, micro-organisms are distributed throughout the mass; and conditions probably become anaerobic rapidly, through the consumption of residual oxygen by the tissues - the samples were stored at 0° overnight before irradiation, to allow this to take place. The organoleptic results of this treatment have already been described.

ii) Eviscerated whole carcases were used. Here spoilage is caused by the development on the surfaces of a slime of aerobic or facultatively anaerobic bacteria, chiefly derived - as with other meats - from surface contamination during handling. The carcases were wrapped in sealed but loose polythene bags, to prevent misleading contamination subsequently; this created conditions of high humidity, and may have partly restricted access of oxygen.

The canned minced chicken will be considered first.

Control material contained about 10^5 bacteria/g. - a comparatively small number for minced meat, since this was prepared in a hygienic manner, in the laboratory. After 14 days at 5°C, numbers had increased to about 10^8/g. and the meat stank, behaviour similar to that of other meats. The nature of the bacteria will be described in a moment.

The numbers of bacteria at the outset of storage were reduced by irradiation, the diminution being roughly exponential with dose over the range used, which is the classical picture (Slide 1). There was moreover no clear evidence that the radiation exerted any selective action between the groups of bacteria which were distinguished. (Slide 2). If the samples were frozen at about -60° for irradiation, the dose needed to achieve a given kill was increased $2\frac{1}{2}$ times - this factor is roughly the same as for organoleptic changes.

The storage life at 5° increased progressively with the dose of radiation, though with 100 Kr the increase was trifling - about 3 days (Slide 3). With 175 Kr, different cans spoiled at very different times, some still being sound after 3 weeks. With 250 Kr, little change occurred during 3 weeks, but the bacteria had begun to develop in some cans after 6 weeks, and after 43 weeks only one can out of 6 showed little change.

This is shown in Slide 4, which reviews the analysis of the nature of the bacteria. In the control meat, the striking feature is the replacement of the initial flora by a spoilage flora consisting predominantly of lactobacilli and Gram-negative rods, with some faecal streptococci, a reflection of the near anaerobic conditions prevailing: the absence of strict anaerobes may be ascribed to the low temperatures. With the highest dosage 250 Kr, the Gram-negative rods had apparently been completely eliminated; and the lactobacilli almost so, for they were absent from 2 of the 3 cans examined towards the end of their storage life, though dominant in the one can where they were present. These lactobacilli appearing on storage in the irradiated samples were somewhat different from those in the controls: they belong to the genus Microbacterium and resemble organisms isolated at the American Meat Institute from irradiated minced beef.

The odours of the spoiling irradiated samples are not noticeably different from those of controls - described as putrid or faecal (besides the irradiation odour); which is perhaps not surprising as rather similar lactobacilli predominated in most cases. Two points may be mentioned: the same odour was several times detected in cans with comparatively low bacterial counts (order of $10^4 - 10^5$/g.); and nothing unusual was noted in the two cans (250 Kr, 21 days) where streptococci predominated. No greening was observed in any of these samples.

Let us turn now to the whole chickens. The increases in storage life following different doses of irradiation are shown in Slide 5: with the higher doses the increase is substantial, greater than has been attained with CTC alone. The effects of CTC and irradiation were approximately supplementary. The length of the storage life was determined by briefly opening the bags and smelling the birds, taking care not to introduce contamination.

The flora on control birds consisted of a mixture of green fluorescent Pseudomonas with similar but non-pigmented organisms (which used to be, and by many French workers still are, called Achromobacter). During storage at +3°, the latter group became almost wholly predominant, (Slide 6).with the development of a typical putrid smell. This situation is broadly the same as with other meats.

Irradiated samples behaved differently. In our first experiment they developed a quite different odour - sweetish, not so strong, and developing gradually so that it was more difficult to decide precisely when a sample should be adjudged spoiled. The spoilage flora consisted almost wholly of Achromobacters (Slide 6). This agrees with American suggestions that Pseudomonas are unusually readily killed by irradiation. It also illuminates two other features of the situation. First, a reason why CTC supplements irradiation is probably that the important organisms resisting irradiation are sensitive to tetracyclines. Second, subsequent work has suggested that Achromobacters are less active than Pseudomonas in producing amine-like compounds, especially with restricted access of air; which may be why, as agents of spoilage, they produce less putrid smells.

A similar experiment, with a rather higher dose, gave an essentially similar result - a preponderance of Achromobacter on the irradiated birds (Slide 7), and sweetish odours on spoilage. There were some differences: the flora on the control birds was more diverse including a significant Gram-positive element. Correspondingly, lactobacilli occurred on some of the irradiated birds: from the predominance of similar organisms under anaerobic conditions, this might be related to partial restriction of air supply by the wrappers.

A further experiment, still incomplete, is exploring the effects of somewhat higher doses, in more detail. At doses exceeding 250 Kr, the survival curve ceased to be exponential with dose, indicating the survival of a somewhat more resistant group of organisms (Slide 8). Detailed examination revealed that, as before, the Pseudomonas were the first to be eliminated by small doses below 250 Kr, and that the population surviving 500 Kr consisted mostly of yeasts (Slide 9). The predominance of yeasts was however only temporary, for they had evidently been overwhelmed by bacteria in the final spoilage flora. (This does not happen in the presence of CTC, which the yeasts resist better than the bacteria). A striking feature of this experiment was the predominance of non-pigmented Pseudomonas in the spoilage flora of the irradiated samples, though Achromobacters were common around the 250 Kr level; while at 825 Kr pigmented Pseudomonas appeared in quantity. Though the reasons for such differences from the earlier experiments are unknown (these carcases came from a different slaughterhouse), the predominance of Pseudomonas was signalled - with control and irradiated birds alike - by putrid smells resembling those in the earlier experiments.

One naturally hopes to interpret the behaviour of different organisms during spoilage in terms of their physiological peculiarities. For example, the behaviour of the yeasts in the last experiment is readily understood because they are more resistant to radiation than bacteria, but have much lower rates of cell division. Again, the near elimination of non-pigmented Pseudomonas by modest doses of irradiation, with their rapid assumption of dominance during cool storage, are consistent with the known properties of such organisms and their presumed susceptibility to radiation. We naturally wish to know whether our Achromobacters are in general more resistant, whether the pigmented Pseudomonas prominant on the 825 Kr samples are exceptions to this

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rule, whether the Microbacteria and Streptococci of the minced chicken are unusually resistant, and so on. Our experiments for this purpose are in progress now; and the only indication so far is that the Achromobacters of the irradiated birds do indeed possess a greater resistance than the other organisms involved.

The most important practical aspect of such investigations is their bearing on the safety or otherwise of meats treated in this manner. As regards the eviscerated whole carcases, nothing untoward has yet appeared. The spoilage flora of the irradiated birds has consisted of non-pathogenic organisms similar to those which occur commonly on normal meats, under refrigeration, and the chief peculiarity is an unfamiliar smell towards the end of the storage life. With the canned minced meat, on the other hand, the prevalence of faecal streptococci - not signalled by any obviously unusual feature - raises some doubts; for where organisms of this group have grown on meat it has sometimes been suspected that food poisoning has ensued. This situation requires further study, but a desirable preliminary is a greater degree of precision in identifying the food poisoning streptococci.

It should be obvious that the above considerations would not apply to partially sterilised meats stored at higher temperatures. Without refrigeration there is the possibility that dangerous salmonellas, staphylococci, and clostridia might grow. Hence extensive investigations, of a kind similar to those just described, will be necessary before radio-pasteurisation without refrigeration can be recommended for meats.

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The Application of Scientific Methods to Meat Production

By J. HAMMOND

In applying scientific methods to meat production two aspects have to be considered. Firstly increase in quantity, for with the increased standards of living now taking place in all civilized countries there will be an increasing demand for meat. Surveys made in this country have shown that as the income level rises more meat is eaten.

Secondly improvement in quality is required for if the quality is poor the consumer turns to alternative foods, such as fish, cheese or eggs. Throughout this paper the definition of quality is taken as that for which the consumer will pay more than the average price. Both aspects will be dealt with in this paper.

<u>Beef</u> - The highest quality comes from the pure beef breeds, but in a thickly populated area such as Europe this is expensive to produce, for the breeding cow produces only one calf per year. The best beef we can produce at a reasonable price is that which comes from dual-purpose cows in dairy herds crossed with a beef bull, preferably one which colour-marks the calves so that they can be distinguished as bred for beef purposes. Calves born from cows in dairy herds are a by-product of the dairy industry and so are cheaper than those from beef cows kept solely for the purpose of producing calves.

The extension of Artificial Insemination has made possible the production of colour-marked calves even in the smallest herds. Better breeding from bulls proven for good milk yields and greater efficiency in the Dairy Industry (freedom from T.B. and Contageous Abortion) have led to fewer heifers being required for herd replacements and so only the better cows in the herd are now inseminated from a dairy or dual-purpose bull to breed replacements, and the worst third of the cows can be mated with a beef bull to breed calves to be reared for beef.

In many cases too all the heifers are mated to a beef bull for the calves of beef breeds are smaller than are those of dairy and dual-purpose breeds and so there is less difficulty in calving. Experiments in crossing large and small breeds of cattle show that while nutrition limits the size of the calf in the small dam genetics limits it in the large one. These maternal effects last for a considerable period of the young animals life and so in crosses between small beef bulls and large dairy cows one obtains a calf which grows more

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quickly than from a pure beef breed. That this effect is a maternal one and not due to sex-linked growth factors is shown by the fact that fertilized eggs of the small Welsh ewe transplanted into a large Border-Leicester ewe produce lambs which grow more quickly than do those left in the Welsh ewe.

A method which is now available for increasing the number of calves for beef production without increasing the number of cows kept is that of producing twins by hormone injection. This method has been tested experimentaly with cattle but so far has not been used in practice, although with sheep it has been used on many farms. The blood serum of mares pregnant between 45 and 90 days contains a substance, P.M.S. which when injected subcutaneously in appropriate amounts (2,000 i.u.) 4 days before oestrus is due will cause on the average two eggs to ripen, although individuals vary from 1 to 3. In order that the twins shall be strong at birth it is necessary for the cow to be well fed during the last 6 weeks of pregnancy.

The newborn calf is all head, legs and bone but as it grows up the body first lengthens and then deepens and the muscle to bone ratio increases. The rate at which these changes occur depend on the plane of nutrition on which it is reared. Calves reared for beef purposes therefore have to be reared on a higher plane of nutrition than that adopted for rearing dairy heifers. Two main systems of rearing colour-marked beef calves are used (1) Multiple suckling whereby a cow yielding 9,000 lbs of milk rears 10 calves in groups of 4, 3, 2 and 1 in succession, each group being suckled for 90 days and the cow going to them night and morning (2) Early weaning whereby the calf after 3 weeks on milk is fed dry pellets of suitable composition with no further milk. Experiments at Cambridge have shown that a calf reared for beef needs high plane feeding for 8 months and this not only enables it to be slaughtered a year sooner, but also gives an animal of better conformation, for on low plane nutrition bone has priority of growth over muscle and fat (see later).

The conformation and composition of the animal is of great importance in determining its value to the retailer, for the producer has not only to please the consumer, but also to give the retailer a carcass which will show him a profit when cut up. A high proportion of rump (38 d. per lb.) and loin and buttock (28 d. per lb.) is required as compared with neck (10 d. per lb.) and brisket (7 d. per lb.). A young animal which has been well fed throughout has a much better conformation in this respect than one which has had a store period. The ribs are late growing parts of the body and in old animals they form too large a proportion of the carcass and so lower its value as a whole.

There are many advantages in slaughtering cattle at an early age and light weight as compared with that at which they were formerly killed. The average live weight at slaughter in England and Wales is now $9\frac{1}{2}$ cwt. and ages range from $1\frac{1}{2}$ to $2\frac{1}{2}$ years. The farmers money is turned over more quickly, the food conversion ratio is better, the carcass yields a greater proportion of the high price joints and the grain of the meat is finer so that it is tender without the necessity for adding marbling fat. One of the reasons why our pure beef breeds of cattle are small is that the grain, or size of muscle bundle, is finer and so gives better eating qualities. This fineness of grain however can be also obtained by killing the larger colour-marked crosses at an earlier age. Much more work is required on muscle fibre and muscle bundle size related to eating qualities. In sheep after about the third month of foetal life muscle fibre formation ceases and thereafter all increase in weight of muscle is due to increase in muscle fibre size.

Mutton and Lamb - There are two main reasons why the production of lamb is increasing and mutton decreasing in this country. The first is a matter of production and the second a matter of carcass quality.

The first reason is that of convenience of production. The limit on our output of meat is set by the supply of winter feed. If mutton is produced it involves winter feed and a reduction in the number of ewes that can be wintered. Since most of our sheep are kept on grassland lambing just before the grass begins to grow in the spring enables the flush of spring grass to be cashed without labour costs through the lamb crop which is sold to the butcher before or as the grass growth slows down later in the year. Under these conditions high fertility and good milking ability in the ewes is important for by this means the greatest differences between winter and summer feed requirements are obtained. Fat lambs are usually marketed at from 10 to 16 weeks old at carcass weights of 35 to 50 lbs. In general the industry is stratified in breeds and crosses to suit environmental conditions. On the hills and mountains hardy breeds of low fertility are kept : some of these are crossed with rams of breeds of high fertility and milk yield and their female offspring sent to

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good lowland grass to become the dams of fat lambs when mated with early maturing mutton type rams. Experiments with injections of P.M.S. hormone (700 i.u.) 12 days after the last oestrus have shown that the lambing percentages can be considerably increased. Attempts now being made to increase output by twice a year lambing by injections of progesterone followed by P.M.S. have met with limited success.

The second reason why lamb is preferred to mutton is that the quality of the meat is higher; the joints are smaller, the grain is finer, there is less fat and the proportion of weight in the low priced joints such as the ribs is relatively smaller. The price per lb. of carcasses of different weights shows that while in most breeds the price falls as the carcass increases in weight it falls much more quickly in early maturing breeds such as the Southdown where heavy weight animals have a lot of fat than in late maturing breeds like the Scottish Blackface where little fat is put on.

Dissection results from sheep of different ages show that the maximum rate of growth occurs in the different tissues of the carcass in a definite order. Central Nervous System first, followed by bone, then muscle and lastly fat. In an early maturing breed the peaks of these growth curves come closer together so that it fattens as it grows. While in late maturing breeds the peaks of the curves are drawn wider apart. Similarly on a high plane of nutrition the peaks come closer together while on a low plane of nutrition they are drawn wider apart.

The physiological basis whereby these differences in level of nutrition affect the composition of the animal and the proportion of its parts is that the early developing tissues and parts of the body have priority over the later growing tissues and parts for the nutrients from the blood stream. When on a high plane of nutrition all tissues get equally supplied with nutrition according to their growth requirements, but when the animal is on a low plane of nutrition the Central Nervous System and bone have priority over muscle and fat and they continue to grow while fat and muscle growth ceases. Under very low planes of nutrition such as sub-maintenance fat and muscle tissue is absorbed into the blood stream and nerve tissue and bone continue to increase in weight from this source.

A points scale has been drawn up for evaluating quality in a lamb carcass based partly on measurements and partly on eye appraisal. Standards were set by a carcass selected by meat traders on Smithfield market as being an ideal one. In order to find out how a lamb should be fed in order to produce this ideal type of carcass, lambs were reared on different planes of nutrition to a carcass weight of 30 lbs., changes in plane of nutrition being made when the lambs were 6 weeks old. The most suitable lambs were the High-High plane (56 days old) followed by the Low-High (125 days): the High-Low (125 days) came next and the Low-Low (295 days) last. Those finished on low plane had a higher proportion of bone to meat, as might be expected from the priority of nutrients theory given above, while the older animals had a higher proportion of the low priced ribs for these bones are late developing ones.