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CSIRO Food Research Quarterly

Changes to content of Food Research Quarterly

Beginning with this issue, Food Research Quarterly will be publishing papers which arise from studies conducted by the CSIRO Division of Human Nutrition.

The Division of Food Research welcomes these contributions from its sister Division at a time when information is emerging on links between diet and health. Both Divisions recognize their responsibility to advise and assist the food industry, as well as health professionals and consumers, in these matters of vital interest.

As CSIRO's main centre for the study of diet in relation to human health, it is most appropriate that the Division of Human Nutrition joints with the nation's most prominent food research establishment in an endeavour to keep all relevant people and institutions informed on the findings of recent research.

Coronary disease and hypertension, both nutritionally related disorders, account for over 50% of mortality in Australia and a high proportion of health costs. It is therefore fitting that the Division of Human Nutrition's initial contributions to Food Research Quarterly examine some nutritional aspects of cardiovascular disorders.

News from the Division

Dr D.J. Walker — Chief of the CSIRO Division of Food Research

The appointment of Dr D.J. Walker as Chief of the Division of Food Research was announced on 28 November 1986 by Dr A.D. Donald, Acting Director of the CSIRO Institute of Animal and Food Sciences.

Deston Walker, PhD, DSc, FAIFST, graduated in Science from the University of Sheffield in 1955 and was awarded the PhD degree in biochemistry from that University in 1958. He joined the CSIRO Division of Nutritional Biochemistry in Adelaide in the same year, and developed research interests in the microbiology of the rumen, in other aspects of nutrition, and in the energetics of growth. His contributions to science were recognized in 1968 by a joint award of the Stichting-Ilra International Lactic Acid Prize and in 1977 by the award of the DSc degree by the University of Sheffield.

In 1972, Dr Walker transferred to the Division of Food Research as Officer-in-Charge of the Meat Research Laboratory in Cannon Hill, Queensland, and as an Assistant Chief of the Division.

During Dr Walker's 14 years at Cannon Hill technology-oriented research and development on meat was expanded markedly. New initiatives included the microbial conversion of bile acids to steroid pharmaceuticals, research on electrical stimulation of beef carcasses, and development of novel technology for the

slaughtering and dressing of cattle. He was also successful in persuading the meat industry to increase its levy to facilitate expansion of the Laboratory's industry services group.

Dr Walker brings to his new position a wealth of experience in successful research collaboration with industry and a valuable insight into industry funding gained from service as CSIRO representative on the Australian Meat Research Committee. He will find ample scope for his talents in responding to the recommendations of the recent Divisional Review Committee.

Dr J.H.B. Christian ends his term as Chief

On December 31 1986 Dr J.H.B. Christian ended his term as Chief of the Division of Food Research. By then, Dr Christian had become one of the world's most respected food microbiologists and had helped build the Division's reputation with both his research and his leadership over a period of 35 years. Fortunately for CSIRO and the food industry, he will stay on with the Division in an active research and consultative role.

During his career as pioneer in research on water activity and microbial growth, Assistant Chief, Associate Chief and then Chief of the Division, John Christian was accorded many honours. Among the more significant he would include: Foundation Fellow of the Australian Academy of Technological Sciences; Fellowship of the Australian Institute of Food Science and Technology; the Award of Merit of the Australian Institute of Food Science and Technology; Chairmanship and membership of several international commissions.

John Christian's leadership as Chief for the past eight years was characterized by his strong defence of Divisional research programmes in the face of fiercely debilitating funding cuts. He was nevertheless obliged to reduce research effort in areas to which he had a strong commitment and his decisiveness served him in good stead.

In the gloom of this most difficult period in the Division's history, Dr Christian was still able to draw upon his innate good humour and an apparently endless store of happy anecdotes to bring lightness and cheer to his colleagues. It is good to know that he will continue to share his talents with his friends in Food Research.

At a function held at North Ryde on 10 February 1987 to mark the completion of Dr J.H.B. Christian's seven-year term as Chief of the Division of Food Research, Dr A.D. Donald, Acting Director, Institute of Animal and Food Sciences, unveiled a portrait of Dr Christian which had been presented by the staff to the Division. The portrait had been prepared by Mr W.E. Rushton, Divisional Photographer.

Retirement

Miss E.M. (Sandy) Henderson

Miss E.M. (Sandy) Henderson retires from CSIRO on 10 April 1987 after almost 26 years in the Division of Food Research. She took up a secretarial position at North Ryde on the day that the new Divisional buildings opened their doors after transfer from the Homebush abattoirs. Since then she has served as personal secretary to all of the Division's four Chiefs. A meticulous and prodigious worker, she was renowned for her fierce loyalty to the Chief of the day and for providing the comprehensive secretarial support that made possible the efficient administration of a large Division with staff stationed at 10 or more locations throughout Australia.

Outside her office duties, Sandy's colleagues, especially the ill or injured, have benefitted greatly from her earlier experience as a nursing sister. She served for many years as secretary of FRL's small bore rifle club and, as keeper of the records, never overlooked a birthday. We wish her many happy and healthy years in retirement to enjoy her beautiful garden and her beloved dogs.

Sausage — a food of myth, mystery and marvel

By D.R. Smith[A]

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Introduction

Sausage is one of the oldest processed foods known to man, and its origin is shrouded in antiquity. Sausage consumption was commonplace thousands of years B.C., and reference to its preparation and consumption can be found in Homer's Odyssey, c.900 B.C. The term "sausage" is relatively modern, and is derived from the Latin "salsus", which means salted, or literally, preserved meat.

Virtually all peoples of ancient Europe are known to have produced and consumed sausage of some type. At corresponding points in their development, most races practised some form of sausage-making, even if sometimes rather rudimentary. For example, American Indians combined chopped, dried meat with dried berries to form a cake which could be stored against food shortages. Sausage of various kinds was popular with people of all classes in Greece and Rome during the time of Caesar and Imperial Rome.

Sausage types such as temicina, circeli, and botuli were popular in pre-Christian Rome, where one, a mixture of pork, black pepper and cumin seed, became associated with the Lupercalian and Floralian festivals. There are two points here worthy of reflection. The first is the name of one of these sausages, botuli, and the unmistakable resemblance of its name to microbiology's most serious, but fortunately rarest, food poisoning organism, *Clostridium botulinum.* This resemblance is not coincidental. *C.botulinum* was isolated and identified from sausage. Thus the condition "sausage poisoning", which was made a reportable disease in Germany in the 19th century, was almost certainly botulism. Since the evolution of sausage was inevitably by trial and error, one wonders how much unfortunate emphasis time has placed on the errors. The second point reflects just one more example of Man's perversity. The Lupercalian and Floralian festivals were rather bawdy events, and are said to have been fertility rituals in part. Several authors have suggested that the spicy taste and phallic shape of sausage is undoubtedly related to their prominence in these events. These festivals involved other pagan rituals, including the sacrificial slaughter of goats and dogs. These actions offended the early Christian church, which condemned the eating of sausage simply because of its association with these festivals. After becoming Emperor of Rome, Constantine the Great embraced Christianity, and he subsequently prohibited sausage eating altogether (Gehman 1969; Coxe and Coxe 1978; Gerrard 1969; Joy of Knowledge Encyclopaedia 1978). Unfortunately, the nett effect of this decree was to deny people something they enjoyed. As a result, the illicit production and consumption of sausage in Constantine's Rome was an early meat industry equivalent of the "bootleg era".

Several Emperors later, Constantine's decree was revoked, and the masses were once again permitted to consume sausage legally. In 494 A.D., when Pope Gelasius 1 converted the Lupercalian festival of February 15 to the Feast of the Purification, total respectability was apparently achieved by the sausage-eating populace. However, this reinstated respectability was not to be uninterrupted for ever more.

Sausages of today are descendants of the "gizzards filled with blood and fat" that were popular with the ancients, and Constantine the Great was not the only Emperor whose ire was stirred by the humble sausage. Whilst sausage was greatly enjoyed by the Romans in Nero's time, and again following the actions of Pope Gelasius 1, the Byzantine Emperor, Leo VI was less than impressed with some forms of sausage, and during the 9th century he issued the following inexorable decree:

"We have been informed that blood is packed into intestines as into a coat, and set before man as an ordinary dish. Our Imperial Majesty can no longer permit the honour of our State to be tarnished by these abominable devices of the gluttonous. Whoever henceforth converts blood into food shall be severely

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scourged, smoothly shaved, and banished from our realms forever." (Copsey 1949). Makers of today's black puddings, beware!

However, sausage survived Leo VI, and eventually gained total respectability. Its continuing evolution has ensured the appeal of a very wide range of sausage products.

Salami appears to have originated in the ancient Grecian town of Salamis, on the Cyprian east coast. Although Salamis was destroyed about 450 B.C., the salami sausage style was apparently widely known and appreciated by then, and clearly seems to have been the forerunner of the many popular European varieties. Examples include Danish, Italian, Spanish, French, Hungarian and German salamis.

Salami from hotter climates tends to be more salty and often drier, in response to the need for greater care to preserve the product. Stronger spicing is often used to mask some of the saltiness. Northern European and Scandinavian salamis tend to be less salty and more mildly seasoned.

Processes in addition to salting such as cooking, drying, smoking and fermenting evolved as methods of preserving the products. Processing methods often tended to suit the geographic area in terms of product preservation, and distinctive spicing, i.e. drier products with strong spice flavours provided more protection against both bacterial degradation and off-flavours such as oxidized fat.

Processing details and product decoration led to the development of an enormous range of recognizably different sausage products. They are frequently named after the town or geographic area of origin, and Berliner (Berlin); Braunchsweiger (Brunswick); Genoa salami (Genoa); Goteborg (Gothenburg); Frankfurter (Frankfurt) and Bologna (Bologna) are just a few examples. Consequently, a strong similarity exists between the evolution of sausage and cheese in terms of the number of varieties and the frequent naming after geographic areas.

Spices are an essential part of sausage, and as spices of Oriental origin became available, their use in addition to indigenous condiments enabled European sausage-makers to greatly expand the variety of products available. The importance of spices to such a large and expanding trade added its own further encouragement to the Oriental spice trade, thereby contributing to some colourful chapters in the early history of transcontinental trade.

Evolution of sausage

There can be no doubt that the use of various parts of animals' intestinal tracts as sausage casings closely followed man's early attempts to preserve meat. Some form of convenient container in which to suspend, dry and store pieces of meat, and subsequently mixtures of meat and other ingredients, would have been necessary. The intestinal tract was a ready source, providing both easily-closed containers (e.g. tying or knotting of casings) and containers with one end already naturally closed (e.g. the caecum, which is a closed tube associated with the small intestine, and is also known as the "bung").

The use of both indigenous and imported spices developed through the centuries, being encouraged by both the desire and need to mask any unpleasant tastes (one can imagine that rancid fat flavours, caused by oxidation of fat, would have been one such taste found less than desirable), and to add attractive odours and flavours to the products.

The need to use as much of the carcass as possible would also have been apparent. The relative disinterest of the Australian consumer in offals and fancy meats is in large part an Australian phenomenon, prompted by the absence of a tradition similar to the European development of sausage products. The increasingly ready and economical supply of fresh meat from soon after white settlement as the national herd and flock flourished has encouraged the Australian consumer to view many manufactured meat products as inferior to fresh meat. With a less lavish supply of red meat throughout Europe and the Mediterranean area through recorded history, there was both the need and the opportunity for people of these regions to combine all potentially edible by-products with muscle meats and spices. As a result, a significant proportion of traditional European sausages consist basically of a cured (i.e. nitrite-containing) red meat emulsion, of widely varying texture and moderately varying fat content, in which is suspended fat and/or one or more edible offals in some preferred form, e.g. chopped, diced, minced or strips. Consequently, a very large proportion of the meat consumed in European countries is in the form of sausage products, most of which are seen as high quality items equivalent in value to fresh meat.

Fermentation as an effective method of both preservation and flavour development appears to date from at least several centuries B.C. Whilst the use of fermentation was fortuitous, and not properly understood until recent times, it has been used for well over 2000 years, thereby establishing a distinctive category of sausage products.

The processes of salting, curing (treatment with sodium or potassium nitrite), smoking, drying and fermenting all contributed greatly to the early development of sausage, through their stabilising effects on the meat products. The addition of salt reduces the availability of water to support bacterial growth, whilst the addition of nitrite prevents the growth of *Clostridium* organisms. Many of the phenolic compounds deposited by smoking make the surface of sausages much less suitable for microbial activity. Drying, like salting, also reduces the availability of water, whilst fermenting increases the population of desirable bacteria, thereby making it more difficult for undesirable bacteria to become established. The efficacy of these processes could only have been established by trial and error over a long period of time. This has given rise to a deal of the mythology surrounding traditional sausage products to this day. For example, it is still easy to find traditional sausage-makers who reject out of hand the idea of using starter cultures (i.e. adding to the raw meat-mix concentrated doses of the desired bacteria) in fermented sausage, believing that the handed-down method of "back-slopping" (supplementing subsequent sausage batches with meat from preceding batches) is the only acceptable and "real" method. The fact that without elaborate microbiological testing one cannot be sure early enough that the fermentation in that preceding batch was correct is simply ignored by these traditionalists.

The variety of sausage products available is large, the number of recognizably different products being estimated at between 700 and 900. Cheese is the only other foodstuff available in such a vast array of different kinds — there are claimed to be over 2000 different forms of cheese.

Despite the large number of different sausage varieties recognized, it is not difficult to account for this phenomenon. There are many possible variations associated with the formulation, flavouring and processing of sausage. It requires only a relatively small change in any one of these to make a substantial difference to the final product. It is this fact which explains how a typical European butcher-cum-sausage-maker (i.e. "fleischmeister", which literally means "master of meat") can, with the help of maybe only one assistant, maintain a supply of several dozen different sausage types. By way of explanation, a basic sausage mix could be composed of relatively lean beef and/or pork, in some chosen ratio, with pork fat being used to provide sufficient fat in the meat emulsion. The meat emulsion could be fine, medium or quite coarse in texture. It may or may not be cured. If the emulsion is not cured, it could be sold as either fresh sausage, or as a cooked product. If cooked, this would probably be either by steam or water cooking. The product may or may not be subjected to smoking. The seasoning mix used for the sausage could vary, depending on whether a "hot" or "mild" seasoning is desired (there is much scope for variation here), and on whether the product is to be cured or not, or smoked or not. A further variation could be that the basic meat-mix itself be cured, smoked and dried to make a shelf-stable product. Additionally, a garnish of some type (e.g. chopped or cubed fat, some edible offal, vegetable pieces, or a combination of these) could be incorporated into the basic meat-mix. In each case, the finished meat-mix is filled into a casing of appropriate type and size before being subjected to any of the cooking/smoking/drying processes. With a schedule of operations planned in advance, the sausage-maker could quite readily cover all the above variations plus considerably more from one basic meat-mix. The fact that almost all European sausage products are cured and cooked means that refrigerated shelf lives are reasonably long. Many of the fermented and/or smoked and/or dried variations of sausage do not require refrigeration, so it can readily be seen how the enterprising sausage-maker can present such a wide variety of products to his customers.

Processing methods

Man's oldest method of cooking was the open fire, so the use of heat and smoke would have been recognized early as useful methods for preparing and preserving meat. The use of drying, whether by air, sun or fire, was also known long before recorded history. Preserving meat by salting was also practised early in the history of man. In fact, in about 1300 B.C., the ruling Chinese Emperor decided to take advantage of the popularity of salting meat by imposing a tax on salt — clearly, opportunism is nothing new to politicians!

Water and steam cooking were considerably later developments, as they could not have been practised without the use of suitable containers for heating water. Even so, the development of cooking utensils is credited to Mesolithic Man, around 8000 B.C.

Drying and dry cooking

The result of drying or dry cooking is evaporation of moisture. Drying is often conducted at or close to ambient temperatures over lengthy periods of time (e.g. many salami types), although some drying processes involve gradual elevation of temperatures. Dry cooking will cause rapid surface drying, usually with an associated characteristic flavour development, due to condensation reactions and surface concentration effects. Dry cooking processes are usually carried out at quite high temperatures, e.g. roasting and grilling. Consequently, dry cooking is of a relatively short duration, and restricted to intact-muscle, or whole- or sub-primal (e.g. slices of steak) pieces of meat, which may have been prepared in some way prior to cooking (e.g. marinading, stuffing).

Smoking

Traditional smoking is still widely practised, and involves a smouldering fire on a hearth in a room with restricted air flow. Depending on the product being made, smoking may be a cold or warm process. Cold smoking involves hanging product in a non-heated chamber into which smoke is introduced, whereas in the warm process, the chamber is heated, often with steam or hot air, whilst the smoking takes place.

Emphasis is placed on the selection of woods for smoking, although it has been suggested that provided strongly resinous woods are avoided (they yield rather acrid tastes) the effect of wood species on the smoke flavour of the product may not be very marked (Cahill *et al.* 1971). There is little if any evidence to prove the claimed superiority of hickory smoke. It is also worth reflecting on the amount of hickory that would have to be burned in the USA (and even more so in Australia, where it is neither cheap nor readily available) to account for the quantities of "hickory-smoked" products available. It is likely that in the presence of any substantial level of spices and/or fermentation effects, distinguishing the species of wood used from the residual smoke flavour in the product would be a daunting task for a taste panel.

When smoke flavour is desirable without appreciable product dehydration, the humidity of the smokehouse is carefully controlled to limit moisture losses. Additionally, water is often incorporated into the product formulation to offset the dehydration effects of smoking.

Artificial smoke flavours are in fairly wide use now for high-volume products (e.g. frankfurters) for two particular reasons; shorter processing cycles can be achieved, and environmental anti-pollution laws can be complied with more easily (as smokehouses can emit unacceptable levels of air pollutants). There remains, however, considerable resistance to the use of artificial smoke flavours in the traditional European products. It is argued that they are simply not the same as the real thing, and in many instances this is undeniably the case. As long as anti-pollution regulations can be complied with, it is likely that traditionally-smoked sausage products will be available.

Salting and curing

Salting and curing used to involve concentrations of sodium chloride and sodium or potassium nitrate at levels controlled only by the whims of the sausage-maker. Given the absence of both refrigeration and concepts of hygiene in times past, perhaps this free-wheeling approach to the control of additives was a blessing in disguise to the consumer. No doubt, by today's tightly regulated standards, these additives would always have been used to excess.

It has only been in quite recent times that legislation has come to closely control the use of additives, and to insist on adequate refrigeration and standards of hygiene. Again, hindsight suggests that this has been fortuitous — without the means to control temperatures and humidities closely through universally available refrigeration, and without a sound knowledge of sausage processing methods and requirements, the imposition of today's stringent controls on curing ingredients on an ill-informed industry would have had calamitous results.

Salting has a preserving effect on meat by reducing the availability to microorganisms of any water present in the sausage. If sufficient salt is present, the water in the system is unavailable to microorganisms, which need water to proliferate. As with the other methods of extending product shelf life mentioned above, this use of salt has long been practised on a trial and error basis. It is only within the last one hundred years that any sound understanding of salting has developed.

A major problem with preservation through salting is that the high level of salt required makes the product unsuitable for immediate consumption. Consequently, fully salted meat needs to be well washed, or preferably soaked in large quantities of fresh water to reduce the salt level to acceptable taste levels.

Curing is actually the effect of nitric oxide on fresh meat. In ancient times, sodium or potassium nitrate was a normal contaminant of common salt, and so found its way into meat products. In these products, the nitrate is reduced stepwise by bacterial fermentation to nitrite, and then to nitric oxide. One particularly valuable effect of nitrite is its inhibition of *Clostridium* species, as mentioned earlier. This is another example of technical knowledge unknown even as briefly as one hundred years ago. This further emphasizes the trial and error nature of the development of sausage.

Fermentation

The inherent stability of the products of early sausage-making activities was primarily due to the controlled conversion of sugars to acid by a unique group of lactic acid bacteria. They were not the predominant microflora on the fresh meat, but their growth over that of the initially dominant microflora was favoured by the processes of salting, curing and drying, even though the early sausage-makers did not understand this. During the lactic fermentation, the sugars present are converted to various organic acids, particularly lactic acid (Bacus 1984). This increased acidity inhibits food-borne pathogens and other undesirable micro-organisms, and also causes protein coagulation, creating the firm texture characteristic of fermented sausage.

Fermentation is becoming a more reliable and predictable process as the use of starter cultures becomes more widespread. Traditionalists in the sausage-making fraternity still view the use of starter cultures with misgivings. However, the need to be as certain as possible about the outcome of production is overwhelming in terms of consistency, yields, public health aspects and cost control, and any reliable aid towards these ends is now considered by the more informed sausage-maker.

Acidity, moisture content, and water activity measurements are also being used increasingly to supplement, and probably eventually replace the traditional methods of checking the product by visual inspection and "feel" (literally, checking its firmness by manual touch). Tasting is one of the traditional methods of assessment which, fortunately, seems unlikely to ever be supplanted by technological developments.

Fermentation plays a major role in much sausage production today, and is frequently one segment of an overall process which includes smoking (warm or cold) and maturing (i.e. allowing acid development and controlled slow drying). The use of starter cultures, exemplary hygiene in respect of meat and production facilities, and the close monitoring referred to above combine to remove virtually all risks from modern production methods for fermented sausage.

A common occurrence during fermentation is the growth of mould on the surface of sausage casings. This happens principally because the warm and humid conditions in a maturing room favour the growth of most moulds present. There are quaint beliefs even yet on the part of some traditional sausage-makers that without the growth of mould on the sausage casing, certain fermented and dried salamis will not have the correct taste. In fact, there is no analogy between the ripening effect of certain moulds on cheese (e.g. Camembert, Brie) and on sausage. In the case of sausage, any mould growth should only be on the outer surface of the casing, and not penetrate the meat. Occasionally, a random flora of moulds is found growing on the casings of fermented sausages. This must be viewed as an abnormal situation, and corrective steps need to be taken promptly, otherwise tainting problems and real public health hazards may develop. Thorough sanitizing of maturing rooms on a regular basis is a very difficult task, and an easier way around the problem is to ensure saturation of that room with an acceptable mould, thereby greatly inhibiting the activity of undesirable moulds. "San Francisco Salami", which is generally known in other parts of the USA as Italian Dry Salami, is identifiable by a white coating of a *Penicillium* mould when the product is sold in chub form. When undesirable moulds appear, manufacturers of this product spray an aqueous suspension of the required mould onto new product entering the fermentation rooms. However, this deliberate application of the *Penicillium* mould is usually infrequent due to its well-established presence in most fermenting rooms (R. Mucklow, personal communication). This method solves very effectively the otherwise inevitable and very difficult problem of growth of undesirable moulds. A similar process is used in many European sausage plants.

Sausage classification

The classification of sausages, what they are made of and how, and what they are called and why has been likened to a Gordian knot, a strange and untidy intertwining of history, politics, secrecy, tradition, myth and pride. Some idea of this complexity is contained in the following quote:

"Then there's Kielbasa. It would take pages to talk about Kielbasa. Suffice it to say that in Poland frankfurters and salamis are Kielbasa, but here (i.e. USA) Kielbasa is Polish Sausage. But not always — sometimes Polish Sausage is called Kielbasa anyway. But salami is never Kielbasa — except in Poland" (Anon. 1983).

If it can ever be properly unravelled, sausage classification would make a complex book in its own right. The source of the preceding quote provides descriptions of a brief but useful cross-section of Old World sausage products.

"The Book Of The Sausage" (Coxe and Coxe 1978) provides an extensive alphabetical listing of sausages, and includes basic comments about their appearance and preparation as well as their country of origin. These authors, too, have avoided the daunting exercise of attempting to classify sausage products. Another publication, "Principal Characteristics of Sausages of the World Listed by Country of Origin" (Kinsman 1983) provides an extensive listing of sausage types, and classifies them very broadly in terms of degree of dryness, whether cooked or smoked, texture, intensity of seasoning and types of meats used.

Another useful approach to sausage classification is by reference to their water activity (a_W). Broadly, a_W is a measure of the availability to support microbial activity of water in a product — the lower the a_W, the less the microbial activity. It follows then that if the a_W of a sausage product is low enough, that product does not require refrigeration to achieve a long shelf life.

By far the majority of sausage produced in Australia requires refrigeration, whether or not the product has been smoked, simply because the a_W of these products is high enough to support rapid microbial activity at higher temperatures. This would greatly reduce the shelf-life of the products. However, there is an increasing supply of smoked and dried "continental" sausages available to Australian consumers, such that selections of these products are now a familiar sight in butcher shops, delicatessens and "deli-bars" in supermarkets. The fact that they maintain their wholesomeness whilst displayed unpackaged at room temperature is due to two factors in particular. Firstly, during production they are dried to a sufficiently low a_W to at least substantially inhibit microbial activity, and secondly on subsequent open display they can continue to slowly dry, thereby preventing the development of undesirable microflora.

Sausage and the future

Sausage will doubtless continue as an important and sought-after food, particularly the high-quality traditional products. However, as the marketplace becomes ever more competitive, more attention will need to be given to appropriate marketing approaches for these products.

There is no reason to doubt that the market for the more mundane and larger-volume sausage products will also continue. It will, however, be of great importance to see that the demands of modern society do not detract too much from the character of sausage in its many forms. Despite the fact that the pun in the following passage refers to an English rather than an Australian product, the moral of the following quote carries a most appropriate warning:

"Obviously, mass-production demands the maximum standardization. When a machine fills sausages at the rate of one-and-a-half miles per hour, all the previous processes — chopping, blending, seasoning, etc. — have to be highly streamlined. In The Frank Muir Book you will find a splendid lament for the passing of the old-fashioned sausage. The author writes, 'Even the sausage, the fine old British banger, knobbly and individual, is being displaced by a product of automation, a computerized, portion-controlled, geometrically accurate disc. As T.S. Elliot might have written, "this is the way the World ends, not with a banger but a Wimpy" " (Coxe and Coxe 1978).

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Fish oil fatty acids — the answer to heart disease?

By P.J. Nestel

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Introduction

The most exciting recent development in the area of dietary fatty acids concerns the "omega 3 or n-3" group of fatty acids. Although the biology of α-linolenic acid had been studied for many years, the great potential of n-3 fatty acids in health and disease has been recognized only recently. This has come about through the rediscovery of the abundance of n-3 fatty acids in fish and their possible role in preventing heart disease.

The possibility for this has been suggested by Dyerberg *et al.* (1982) from their observations of Greenland Eskimos who appear to be relatively immune from atherosclerosis. Their daily consumption of fish averages 400 g which contains several grams of eicosapentaenoic acid (EPA). Interestingly, even small amounts of fish eaten regularly may confer some protection (Anon. 1985).

The n-3 fatty acids

While α-linolenic acid (18 carbons in length, 3 double bonds; 18:3) is widely distributed in terrestrial plants within the chloroplast membrane rather than in the seed oils, the longer polyenoic (several double bonds) fatty acids of marine oils are present in much higher concentration in fatty fish. From a nutritional point of view, larger amounts of n-3 fatty acids can be obtained by eating fatty fish or fish oil concentrates than by eating plants or edible seed oils. The nature of these fatty acids varies widely among species of fish. Fish from the cold northern oceans contain more EPA (or 20:5) than docosahexaenoic acid (DHA or 22:6), while fish from temperate southern Australian seas contain relatively more DHA (Gibson 1983). This may be important because these two major fatty acids do not have identical metabolic effects. Adequate comparisons have not been made between the potential of α-linolenic acid and the longer more unsaturated marine fatty acids, in human biology.

TABLE 1

The families of polyunsaturated fatty acids

n-6 Group (1st double band at Carbon 6)	n-3 Group (1st double band at Carbon 3)
Linoleic acid	**α-Linolenic acid**
- 18 carbons, 2 double bonds (18:2)	- 18 carbons, 3 double bonds (18:3)
- main source seed oils	- main source plants, linseed
	Eicosapentaenoic acid
	- 20 carbons, 5 double bonds (20:5)
	- main source fish
	Docosahexaenoic acid
	- 22 carbons, 6 double bonds (22:6)
	- main source fish

What do these n-3 fatty acids offer?

It has been suggested on theoretical rather than experimental grounds that there may be a desirable ratio of dietary n-6 to n-3 fatty acids of around 5 (Budowski and Crawford 1985). There is a preponderance of n-6 fatty acid (linoleic acid or 18:2) in the recent diet of western countries due to the high consumption of seed oils. By contrast, the lipids of wild plants and non-domesticated animals (such as the kangaroo) eaten by non-agrarian people contain a much lower n-6:n-3 ratio (from 2:1 to 4:1, in contrast to a ratio of above 10 in our present diet).

The n-6 and n-3 fatty acids give rise to different families of so-called eicosanoids (20 carbon derivatives) such as prostanoids and leukotrienes, which are regulators and modulators of many biological systems in man including coagulation, inflammation and even immunity. For instance, linoleic acid gives rise (via arachidonic acid) mainly to the "2" series of prostaglandins and thromboxanes which are biologically much more potent than the "3" series derived from the fish oils. The same applies to the leukotrienes derived from the n-6 and n-3 fatty acids, respectively. This explains the capacity of the n-3 fatty acids to suppress some of the pathways of thrombosis, as well as of inflammatory and immune responses

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because their weaker products displace the more potent derivatives of linoleic acid. This will be exploited widely in diseases as varied as atherosclerosis, organ transplantation, rheumatoid arthritis and even cancer, if preliminary indications are borne out. In fact clinical trials are already in progress overseas.

However even DHA and EPA differ significantly as substrates for leukotriene formation and their consequent capacity to interfere with that family of leukotrienes which comes from linoleic acid and which is a highly potent initiator of inflammatory responses. With increasing knowledge it seems likely that we will be able to manipulate not only the proportions of the "2" to "3" series of prostanoids but also the balance of the most appropriate mix for specific diseases.

The potential for changing the development of atherosclerosis through consuming n-3 fatty acids comes about by altering this balance. An increase in bleeding time of whole blood and a decrease in the aggregability (clumping) of platelets, important factors in the development of both atherosclerosis and its clinical complications, have been reported at highish intakes, 2-20 g EPA daily (Anon. 1985). An anti-inflammatory effect, mediated through the change in the nature of leukotriene production in leucocytes, also required at least 3 g of EPA daily (Lee *et al.* 1985). This may be highly relevant to atherosclerosis since the influx of cholesterol-laden monocytes from the blood into the arterial wall, such as occurs with cholesterol rich diets during the initiation of atherosclerosis, may be reduced by marine fatty acids. A blood pressure lowering effect has also been reported in man and in experimental animals given fish oils. It is likely that some forms of hyperlipidaemia (high blood fats) may also be optimally controlled by eating fish oils. This group of fatty acids is therefore most promising as one for reducing the incidence and complications of atherosclerosis, because several key processes appear to be influenced in a favourable direction.

Importantly, even in established coronary disease when the circulation to the heart muscle is decreased, experiments carried out by Drs Charnock and McLennan in this Division show that the n-3 fatty acids may exert some protection against sudden death (Charnock 1985). This is often caused by a type of heart rhythm which renders the heart pump inefficient. They have shown in rats fed tuna oil, that ventricular fibrillation (the heart muscle flutters instead of contracting forcefully) can be largely prevented when the rat's coronary circulation is occluded.

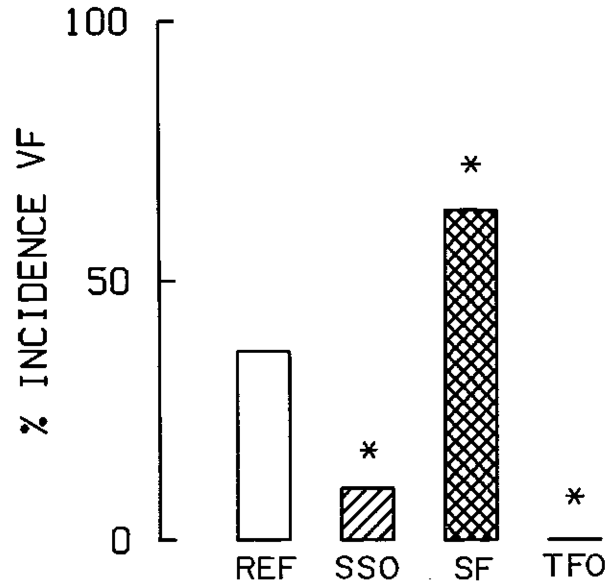

Fig. 1. Percent incidence of ventricular fibrillation occurring during coronary artery occlusion.
Reference diet (REF) — mixed animal and vegetable oil.
Sunflower seed oil (SSO)
Sheep fat (SF)
Tuna fish oil (TFO)

Sunflower seeds, rich in linoleic acid were less effective (Fig. 1).

Recent studies in patients with clinical coronary heart disease emphasize the significance of our findings. When patients develop 'unstable angina", a very dangerous complication, thromboxane production increases markedly (Fitzgerald *et al.* 1986). This is almost certainly due to the increased clumping of platelets into microthrombi in the coronary arteries which can lead to myocardial infarction (heart attack) or ventricular fibrillation and sudden death. Moreover, patients with severe multivessel atherosclerosis have very high rates of thromboxane formation.

The blood fat lowering effect is mainly on plasma triglycerides which is dramatic and probably exceeds the capacity of most current drugs. The extent of this effect is dose related although the optimal daily intake has not been established. It would appear to be no less than 2-3 g n-3 fatty acids (EPA + DHA) daily but is probably closer to 5 g. This is also important for heart disease because high triglyceride levels under some circumstances can also lead to premature coronary disease.

The triglyceride lowering effect is mediated mainly through inhibition of hepatic formation of very low density lipoproteins (VLDL) the major vehicle for triglycerides made by the body. We have shown that the rate of VLDL triglyceride and of VLDL apo B (protein) production can be greatly reduced in people eating fish oils (Nestel *et al.* 1984).

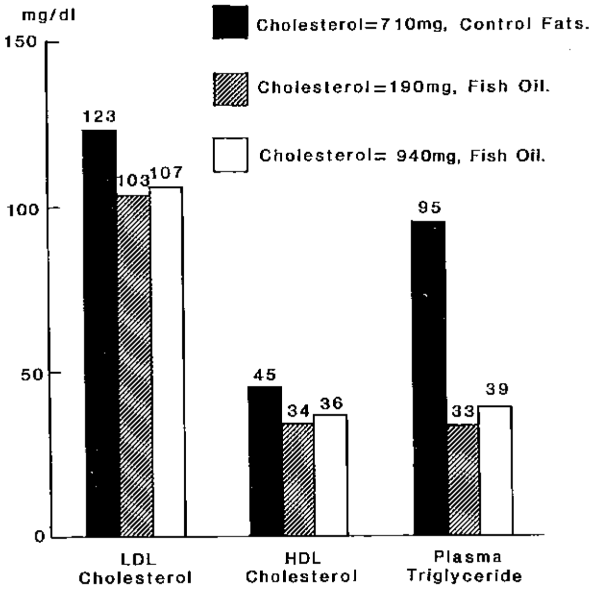

Fig. 2. Normal volunteers were given the 3 diets as shown above (3 weeks for each diet). Results show that a high cholesterol intake when eaten with a fish oil enriched diet, did not raise LDL cholesterol levels. All values with the cholesterol + control fat diet were significantly higher than with the 2 fish oil diets.

Drs Topping and Nestel have also shown that livers of rats fed fish oil show a number of effects which collectively account for the substantial reduction in VLDL secretion (Wong *et al.* 1984; Wong *et al.* 1985). Both in perfused livers and in isolated liver cells, fatty acid synthesis is diminished but fatty acid oxidation is increased which together greatly reduce the availability of fatty acids for the formation (esterification) of glycerides. Furthermore, several key enzymes processing this esterification are inhibited by fish oil feeding.

Although blood cholesterol levels are not readily lowered, we have found that the usual rise in plasma cholesterol which occurs when people eat a cholesterol rich diet (eggs) becomes minimal if fish oils are eaten at the same time (Nestel 1986) (see Fig. 2). This suggests that people may be able to eat a wider range of cholesterol containing foods, if fish oils are included in the diet.

Conclusion

- Dietary n-3 fatty acids profoundly influence biological functions in the human body. These include blood coagulation, the production of both thrombogenic and antithrombogenic compounds by blood platelets and the endothelium of the artery, the net effect hopefully leading to less atherosclerosis formation. Some forms of high blood fats are correctible, blood pressure is reduced and fatal forms of heart rhythm may be preventible.
- These factors and others may be responsible for the low rates of coronary heart disease in populations eating large amounts of n-3 fatty acids. Benefits may also be demonstrated for other important diseases but results are at a preliminary stage.
- The relative benefits of the three commoner n-3 fatty acids, α-linolenic acid from plants, and eicosapentaenoic acid and docosahexanoic acid from fish, are not known. The significance of the differences in their biological properties remain to be determined.
- The possible hazards associated with increased consumption of n-3 fatty acids need investigation. Their capacity to suppress the immune system and inflammation may be undesirable generally, though exploitable for specific disease states.
- The optimal doses of these fatty acids have not been established. Until answers to these questions are known, advice about the widespread usage of n-3 fatty acid concentrates should be discouraged.
- Current advice should focus on regular consumption of fish.

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Fatty acids in canned fish

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Introduction

In affluent Western societies, the *per capita* intake of dietary fat tends to be high (about 40% of dietary energy), and hence fatty acids, the main constituents of fat, are a major component of the diet, often in excess of 100 g/person/day.

The fatty acids, linoleic and linolenic, are regarded as essential fatty acids for animals and humans because they are required for the normal growth and function of body tissues, but cannot be produced in the body from other fatty acids. Linoleic and linolenic acids must therefore be obtained from the diet. Two families of polyunsaturated fatty acids are derived from these two primary essential fatty acids by the metabolic processes of desaturation (insertion of double bonds) and chain elongation (addition of two carbon atoms). Some of the long chain polyunsaturated fatty acids thus produced are precursors of a variety of 20-carbon compounds, known collectively as eicosanoids, which include prostaglandins, prostacyclins, leucotrienes and thromboxanes. These eicosanoids act as regulators of a wide variety of physiological functions (Willis 1984).

Linoleic acid is termed an ω6 or (n-6) fatty acid because the first double bond (counting from the methyl group) follows the sixth carbon atom. In shorthand notation it is 18:2 ω6 (eighteen carbons, 2 double bonds, n-6). α-Linolenic acid is an ω3 fatty acid (n-3) with the first double bond after the third carbon atom (18:3 ω3). The double bond systems of these naturally occurring fatty acids and their derivatives are always methylene-interrupted, i.e. each pair of unsaturated carbon atoms is separated from the next pair by a methylene group.

The ω6 structural feature is retained in all the ω6 polyunsaturated fatty acids derived from linoleic acid, and likewise the ω3 configuration is characteristic of all those fatty acids derived from linolenic acid. There is absolutely no biological interconversion between the ω6 series and the ω3 series of fatty acids, although the same desaturation and chain elongation enzymes are involved in their parallel biosynthetic pathways. There exists also an ω9 pathway which utilizes oleic acid (18:1 ω9) as the primary fatty acid and which comes into operation during a deficiency of linoleic acid or linolenic acid. The ω6, ω3 and ω9 pathways are shown in Figure 1.

The richest sources of ω6 fatty acids in our diet are the polyunsaturated edible oils (safflower, sunflower) used in table margarines, which contain linoleic acid. The primary ω3 fatty acid linolenic acid is not as abundant in our diet as linoleic acid, and occurs in leafy vegetables (spinach, cabbage) as well as some edible oils (rapeseed, soyabean). Linseed oil contains a high level of linolenic acid (over 50% w/w), as well as up to 20% linoleic

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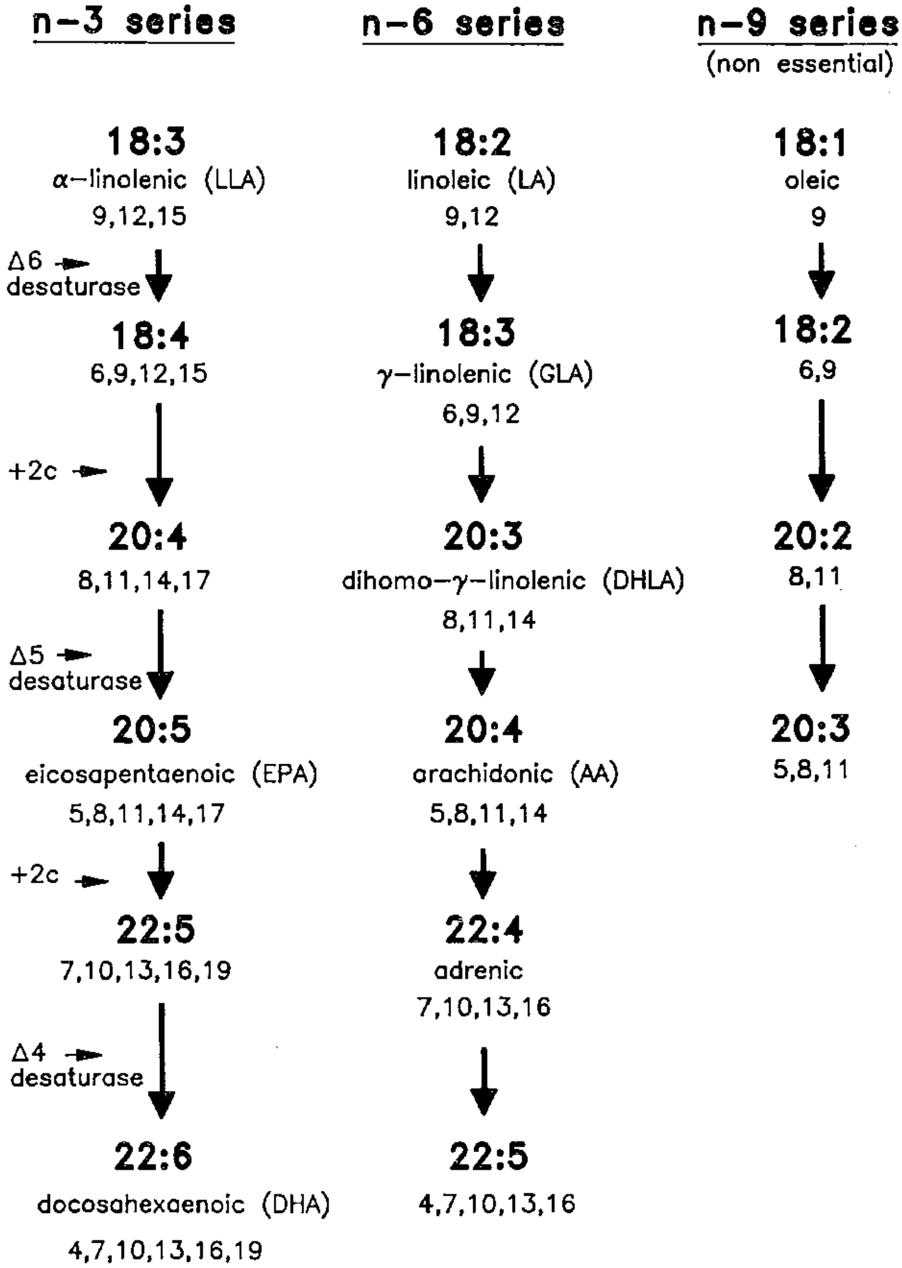

Fig. 1. The pathways for the desaturation and elongation of long-chain unsaturated fatty acids.

acid, but is not generally used as an edible oil. Dietary sources and distribution of linolenic acid in animals have been comprehensively reviewed by Tinoco (1982). Polyunsaturated table margarines in Australia generally have low levels of linolenic acid (below 1%) although in the USA, where unhydrogenated soyabean oil is a common component, margarines with up to 3% of linolenic acid in their fatty acids are available.

The most significant dietary sources of preformed long chain ω3 fatty acids such as eicosapentaenoic acid (EPA, 20:5 ω3) or docosahexaenoic acid (DHA, 22:6 ω3) are fish and fish oils. In the 1950s a great deal of research was carried out on the use of dietary marine oils to lower blood cholesterol levels and triglyceride levels in man and animals (for reviews see Peifer 1967 or Stansby 1969), but interest in this area subsided for almost two decades.

In the last few years there has been a considerable resurgence of interest in the ω3 fatty acids of fish and fish oils (for reviews of recent developments see Kinsella 1986 or Sanders 1985), following the studies of Dyerberg *et al.* (1978) who suggested that dietary EPA exerted a protective effect against atherosclerosis and thrombosis. Currently there is great interest in dietary fish and fish oils as potential moderators of these disorders (Dyerberg 1986).

The fatty acid compositions of some Australian seafoods were reported by Pearson (1977, 1978). The lipids of some species of Australian fish contain significant amounts of the ω6 fatty acid arachidonic acid (20:4 ω6) as well as ω3 fatty acids (Gibson 1983; Sinclair 1983; Fogerty *et al.* 1986; Evans *et al.* 1986). In this respect they differ from fish of the northern hemisphere which have low levels of ω6 fatty acids in their tissue lipids.

It was of interest to us to examine the dietary fatty acids available from canned fish purchased in Sydney in 1986, to see what variations existed between different products. A further point of interest is that tuna may be packed in soya bean oil, which contains linolenic acid, and sardines may be packed in sardine oil (sild oil) or edible oil such as soyabean oil. This means that the balance of ω6 to ω3 fatty acids may vary enormously between different types of product.

Canned sardines, salmon, tuna in brine, tuna in oil and mackerel in brine were purchased at supermarkets in Sydney in July 1986 (Table 1). Each can was opened, the entire contents tipped out and weighed, then thoroughly mixed to provide a reasonably uniform test sample for fat and fatty acid analysis. Since canned sardines contain considerable amounts of free-flowing oil, some cans were opened and the oil allowed to drain into separate containers. After draining off the oil, the "drained sardines" were analyzed separately.

Fat content and fatty acid composition were determined by methods described elsewhere (Fogerty *et al.* 1986). Fatty acids available per 100 g of product were calculated using lipid conversion factors based on 0.3% phospholipids and 0.23% free fatty acids, the remaining fat being regarded as triacylglycerols (Fogerty *et al.* 1986).

The perceived benefits of including fish lipid in the diet have created a market for edible fish oils, which may be obtained from pharmacies and health food stores in liquid or capsule forms. Analyses of the fatty acids of some of these products were undertaken for comparison with those of the canned fish.

Results and discussion

The aim of this survey was to compare the amounts and types of dietary fatty acids available from various types of canned fish, for example from tuna in brine as opposed to sardines in oil, rather than to examine individual brands within each product type. Brand names may, however, be obtained from the authors.

The results for the canned fish are shown in Tables 1 to 4. Data for percentage fatty acid composition (i.e. gas-liquid chromatography (g.l.c.) data) may be obtained from the authors. The data have been arranged in order of increasing fat content of samples within each group of canned fish.

Tuna in brine

The data for tuna canned in brine (Table 1) show quite clearly that the dietary intake of fish fatty acids from canned fish will be directly dependent on the fat content of the fish, as would be expected. With the exception of samples 8 and 9, tuna in brine had a fat content below 2% w/w.

The percentage fatty acid compositions (from g.l.c. or calculated from Table 1) of these low-fat samples were similar, and not unlike those reported for four commercial species of tuna (Roubal 1963). The fatty acid composition of the canned tuna will depend not only on the species of tuna used, but on a variety of other factors, such as the diet of the fish and the fat content of the tissue. With our limited set of samples there were indications that as the fat content increased beyond 2%, the levels of palmitoleic acid (16:1) and EPA rose, while the levels of stearic acid (18:0), DHA and ω6 fatty acids fell. The percentages of total ω3 fatty acids, palmitic acid (16:0) and oleic acid (18:1) were comparatively unaffected by increasing tissue fat content.

Only one sample of mackerel in brine, sample 10, was examined. Unlike the tuna, mackerel contained relatively large amounts of 20- and 22- carbon monoenoic fatty acids.

Tuna or sardines in oil

It is difficult to obtain accurate data for all ω3 fatty acids in tuna or sardines canned in edible oil (Table 2). The quantity of added vegetable oil usually exceeds that of the natural fish oils present, and the fatty acid characteristics of the fish oils are obscured. Thus for tuna samples 11 and 14, the percentage of EPA was reduced to the extent of being recorded only as a trace during g.l.c. The data for our set of samples suggested that tuna samples 11, 12 and 14 were packed in a high-linoleic vegetable oil (linoleic to linolenic acid ratio exceeds 10). Tuna 13 and 15 probably contained soyabean oil, as did sardines 17 and 19 (linoleic to linolenic ratio between 6 and 10). Sardines 18 contained only fish oil (sild sardine oil) as claimed on the label. Sardines 16 contained vegetable oil as well as fish oil, despite the label claim to be packed in sild sardine oil only.

TABLE 1

Fatty acid content of canned fish — tuna in brine and mackerel in brine

Product type	Tuna	Tuna	Tuna	Tuna	Tuna	Tuna	Tuna	Tuna	Tuna	Mackerel
Sample number	1	2	3	4	5	6	7	8	9	10
Country of origin	Japan	Thailand	Thailand	Thailand	Aust.[A]	Aust.	Aust.	Aust.	Aust.	Denmark
Can contents (stated, g)	95	185	185	185	425	185	425	425	180	125
Fat content (% w/w)	0.8	0.8	1.0	1.1	1.5	1.5	1.7	2.2	9.0	14.0
Major fatty acids (mg/100 g)										
14:0	17	10	22	27	52	45	51	162	638	1223
16:0	189	162	266	225	324	264	463	454	1766	1788
18:0	49	58	91	85	113	102	118	77	371	269
Total Saturates[B]	281	249	401	352	533	433	710	743	2863	3508
16:1	35	23	35	42	61	49	96	137	733	739
18:1	111	97	125	132	219	210	223	273	1397	1559
20:1	—	2	—	2	20	7	—	4	112	1290
22:1	—	—	—	—	—	—	—	—	95	2003
Total Monoenes	146	122	160	176	300	266	319	414	2337	5591
18:2 ω6	27	6	15	12	23	20	13	50	95	282
20:4 ω6	21	27	35	48	27	27	30	42	69	40
22:5 ω6	18	19	20	33	—	16	30	—	—	—
Total ω6[B]	96	104	74	93	53	71	84	129	181	538
18:3 ω3	1	1	5	5	11	10	3	33	60	228
18:4 ω3	3	1	4	7	16	16	10	54	224	699
20:5 ω3 (EPA)	26	36	41	78	83	99	64	243	1328	726
22:5 ω3	—	—	7	—	—	23	—	—	181	121
22:6 ω3 (DHA)	176	221	211	284	400	457	403	414	940	1693
Total ω3[B]	206	259	268	374	516	609	480	750	2811	3628
Ratio ω6/ω3	0.5	0.4	0.3	0.3	0.1	0.1	0.2	0.2	0.1	0.2
Ratio EPA/DHA	0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.6	1.4	0.4

[A] Australia

[B] Total includes minor fatty acids not listed above.

TABLE 2

Fatty acid content of canned fish — tuna in oil and sardines in oil

Product type	Tuna	Tuna	Tuna	Tuna	Tuna	Sardines	Sardines	Sardines	Sardines
Sample number	11	12	13	14	15	16	17	18	19
Country of origin	Thailand	Thailand	Aust.[A]	Aust.	Aust.	Norway	Canada	Norway	Scotland
Can contents (stated, g)	185	185	185	185	185	106	100	106	110
Fat content (% w/w)	15.8	17.9	19.3	22.4	22.9	21.0	24.3	30.5	34.7
Major fatty acids (mg/100 g)									
14:0	61	69	74	43	66	1230	1236	2460	1299
16:0	3109	3351	3409	1742	2594	3044	2846	4538	5530
18:0	334	378	686	946	835	444	443	468	966
Total saturates[B]	3640	3918	4225	2774	3627	5001	4712	7993	7962
16:1	61	52	37	43	66	1572	1003	3309	899
18:1	6416	7338	3872	6924	5144	3891	3056	5915	5963
20:1	61	69	—	—	66	1452	2333	2694	866
22:1	—	—	—	—	—	1089	3476	1845	1332
Total monoenes	6538	7459	3909	6967	5276	8004	9868	13763	9060
18:2 ω6	4626	5533	8968	11483	11278	2782	4246	556	12259
Total ω6[B]	4656	5533	8968	11483	11300	2782	4246	556	12259
18:3 ω3	152	103	1112	43	1253	464	653	322	1832
18:4 ω3	—	—	—	—	—	504	630	849	333
20:5 ω3 (EPA)	—	69	56	—	66	1169	1330	2108	766
22:5 ω3	—	—	—	—	—	121	—	322	—
22:6 ω3 (DHA)	152	86	259	172	352	1512	1236	2401	766
Total ω3[B]	304	258	1427	215	1671	3871	3942	6148	3697
Ratio ω6/ ω3	15.3	21.5	6.3	53.4	6.8	0.7	1.1	0.1	3.3
Ratio EPA/DHA	—	0.8	0.2	—	0.2	0.8	1.1	0.9	1.0
Type of oil (stated)	NS[C]	NS	Vegetable	NS	Vegetable	sild (fish)	soya	sild	soya

[A,B]See footnotes for Table 1.

[C]NS = Not stated.

TABLE 3

Fatty acid content of canned fish — sardines drained of oil

Sample number	20	21	22 (cf.17)	23 (cf.16)	24	25 (cf.18)	26	27 (cf.19)
Country of origin	Thailand	Thailand	Canada	Norway	Portugal	Norway	Japan	Scotland
Can contents (stated, g)	130	100	100	106	125	106	110	110
Fat content (% w/w)	8.0	9.5	12.3	14.4	16.9	18.1	19.2	22.7
Major fatty acids (mg/100 g)								
14:0	61	119	815	843	681	1095	1198	1634
16:0	1183	1450	1748	2336	2774	2624	3355	3617
18:0	300	429	224	235	617	400	461	414
Total saturates[A]	1605	2134	2916	3607	4331	4328	5308	5992
16:1	46	109	590	1299	844	990	737	1177
18:1	1958	1933	1535	3746	2482	2971	2820	3617
20:1	54	27	1193	760	146	921	1051	1939
22:1	—	—	1511	373	65	1286	498	3421
Total monoenes	2058	2069	4829	6178	3537	6168	5106	10154
18:2 ω6	3325	3767	1913	470	4332	2693	2359	2354
Total ω6[A]	3371	3822	1913	637	4429	2780	2524	2376
18:3 ω3	184	274	260	235	552	539	387	392
18:4 ω3	8	—	224	290	243	400	442	349
20:5 ω3 (EPA)	84	137	697	926	1428	1147	1714	806
22:5 ω3	—	—	—	111	97	—	240	87
22:6 ω3 (DHA)	215	429	638	1369	1022	1616	2064	1133
Total ω3[A]	491	840	1854	3000	3407	3806	5013	2854
Ratio ω6/ ω3	6.9	4.5	1.0	0.2	1.3	0.7	0.5	0.8
Ratio EPA/DHA	0.4	0.3	1.1	0.7	1.4	0.7	0.8	0.7
Type of oil (stated)	Vegetable	Vegetable	Soya	Sild	Vegetable	Sild	Vegetable	Soya

[A]See footnote (B) for Table 1.

TABLE 4

Fatty acid content of canned fish — salmon.

Type of salmon	Pink	Pink	Pink	Pink	Red	Red	Red	Aust.[A]	Aust.
Sample number	28	29	30	31	32	33	34	35	36
Country of origin	Korea	U.S.A.	Canada	Canada	U.S.A.	Canada	Korea	Aust.	Aust.
Can contents (stated, g)	220	210	210	210	210	105	220	450	450
Fat content (% w/w)	4.3	4.8	8.9	12.1	6.6	7.9	9.9	7.3	8.0
Major fatty acids (mg/100 g)									
14:0	254	210	299	604	252	425	408	328	498
16:0	758	625	1546	2056	977	1138	1510	1747	1945
18:0	152	109	333	372	113	174	171	349	436
Total saturates[B]	1245	1031	2307	3252	1455	1866	2231	2592	3116
16:1	307	223	521	639	284	319	465	503	544
18:1	852	511	1871	1696	1072	1176	1661	1614	1516
20:1	279	470	410	1080	719	1115	1149	84	46
22:1	197	606	436	894	630	925	1301	—	—
Total monoenes	1635	1810	3238	4309	2705	3535	4576	2201	2106
18:2 ω6	53	64	111	209	107	129	123	84	115
Total ω6[B]	81	128	214	465	170	212	161	189	207
18:3 ω3	33	46	85	163	63	91	76	63	138
18:4 ω3	66	169	197	302	290	182	294	77	115
20:4 ω3	37	73	120	186	107	121	133	28	31
20:5 ω3 (EPA)	398	433	735	1045	630	607	854	335	421
22:5 ω3	70	91	162	70	101	61	104	63	46
22:6 ω3 (DHA)	504	638	1162	1301	637	675	921	1341	1401
Total ω3[B]	1108	1450	2461	3079	1828	1752	2382	1907	2152
Ratio ω6/ ω3	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Ratio EPA/DHA	0.8	0.7	0.6	0.8	1.0	0.9	0.9	0.3	0.3

[A]Australian/Australia
[B]See footnote (B) for Table 1.

Sardines drained of oil

Sardines packed in soyabean oil or sild sardine oil are rich sources of ω3 fatty acids. Table 3 shows data obtained for samples of sardines from which most of the packing oil had been drained. Four of these samples were fresh cans of products previously tested (Table 2). Thus, 22 was the same type of product as 17, 23 the same as 16, 25 the same as 18, and 27 the same as 19. It is evident from Table 3 and the g.l.c. analysis of the packing oil and of the drained sardines that the fish oil migrates into the packing oil and vice versa. It is not possible to remove all the packing oil from the fish. In each case the EPA/DHA ratio of the drained oil was much higher than that of the oil left in the fish, suggesting that EPA was more readily transferred from the fish into the packing oil than DHA.

Our data show that sardines 20 and 21 were packed in a high-linoleic vegetable oil, whereas sardines 22, 24, 26 and 27 contained soyabean oil. Sardines 23 were packed in sild sardine oil as claimed on the label, but sardines 25 contained vegetable oil as well as the sild oil claimed on the label. Samples 20 and 21 possibly contained a different species of sardine from the others, as indicated by the low levels of 22:1 in their fatty acids and low EPA/DHA ratios.

Canned salmon

Data for canned salmon of various species are given in Table 4. The so-called Australian salmon (samples 35 and 36) has little 22:1 in its fatty acids and higher levels of DHA than the other species, with a lower EPA/DHA ratio. Despite species differences, the other salmon samples 28 to 34 had fairly similar percentage fatty acid compositions, which are broadly similar to those quoted for tissue lipids of four commercial species by Gruger (1967).

According to the labels on the cans, nearly all of the products examined contained added salt. Consumers who have been advised to reduce their salt intake but wish to eat canned fish may now find sardines, tuna, pink salmon and Australian salmon, all containing no added salt, available at some retail outlets.

Fish oil preparations

Table 5 shows what additional fatty acids would be ingested if the maximum daily recommended doses of various fish oil preparations were taken. These preparations can be subdivided into two types, namely cod liver oils, possibly containing added vitamins A and D, or refined fish oils with a standardized composition of EPA and DHA, such as

TABLE 5

Maximum daily intake of fatty acids from fish oil preparations

Product code	A	B	C	D
Product type	CLO[A]	CLO	EPA-conc.[B]	EPA-conc.
Maximum recommended daily dosage (as fish oil, g)	9	0.3	3	3
Major fatty acids (mg in maximum daily dose)				
14:0	361	22	225	239
16:0	843	44	475	504
18:0	172	6	86	95
Total saturates[C]	1514	77	866	919
16:1	877	25	288	268
18:1	2021	43	438	409
20:1	1066	26	72	66
22:1	705	24	63	37
Total monoenes	4669	118	861	780
Total ω6	191	7	86	144
18:3 ω3	43	3	17	17
18:4 ω3	163	7	66	66
20:4 ω3	52	2	20	23
20:5 ω3 (EPA)	826	26	469	463
22:5 ω3	77	3	58	58
22:6 ω3 (DHA)	920	20	311	268
Total ω3	2081	61	941	895
Ratio EPA/DHA	0.9	1.3	1.5	1.7

[A]Cod liver oil (contains vitamins A and D)
[B]Refined fish oil enriched in EPA and DHA
[C]See footnote (B) for Table 1.

MaxEPA (Seven Seas Health Care, Hull, UK). The recommended doses of the cod liver oil types are based on the levels of natural or supplementary vitamins present, and not on the content of ω3 fatty acids. To avoid vitamin toxicity, care should be taken not to consume more than the maximum recommended dose of such products.

There is still considerable scientific controversy about the amounts and types of ω3 fatty acids which might produce beneficial effects if included in our diets. In regard to the ω3 fatty acids of fish oils the question for the layman is how much and what sort of fish should be eaten. Greenland Eskimos, who have a very low incidence of heart disease, consume about 40 g fish lipids, (400 to 500 g of fish) per day (Dyerberg 1981). Japanese from fishing villages who also have a low incidence of heart disease, consume 5 to 10 g of fish lipids (200 g of fish) per day (Kinsella 1986). Other workers have suggested that more modest intakes of fish could be beneficial. Kromhout *et al.* (1985) on the basis of a 20-year study, suggested that fish consumption of 30 g per day reduced mortality from heart disease in Dutch males. Direct consumption of fish oils circumvents the need to eat fish; Sanders (1983) suggested that 5 g of fish oil per day is effective in lowering serum triglycerides. However, caution must be exercised in selecting the type and amount of oil for consumption.

Consumers who wish to supplement their diets with fish oils should realise that cod liver oil cannot be taken *ad libitum* due to its high content of vitamin D, which can produce toxic side effects when excess is ingested (see review by Dyerberg 1986). The more expensive fish oil preparations such as MaxEPA (Seven Seas Health Care, Hull, UK), have been refined to concentrate EPA and DHA, and to reduce the levels of Vitamin D, sterols, and 20- and 22-carbon monounsaturated fatty acids. Whatever type of product is used, the consumer should never exceed the dosage recommended on the label.

A point that is often overlooked in assessing the effects of ω3 fatty acids is that it may not be necessary to obtain pre-formed 20- or 22-carbon ω3 fatty acids such as EPA or DHA from fish or fish oils. As Hornstra *et al.* (1979) pointed out, there is no reason why EPA could not be biosynthesized from linolenic acid, obtained for example from soyabean oil in the diet. This suggestion was queried by Dyerberg *et al.* (1980) on the basis of a study involving only one patient. The patient was fed cod liver oil for 8 days, then a similar dose of linseed oil two months later. The observed increase in EPA of plasma lipids after linseed oil consumption was regarded as insignificant. A much more comprehensive study by Sanders and Younger (1981) showed that dietary linseed oil led to an increase of EPA in the fatty acids of human platelets and plasma phosphatidyl cholines, although the increase was less than that produced by dietary fish oil. The DHA levels, unlike the EPA levels, did not increase when linseed oil was fed, suggesting that Δ4-desaturase activity (see Fig. 1) is low in humans. In a long term study, the use by French farmers of a linolenic-rich margarine increased the content of EPA in plasma and platelet lipids (Renaud *et al.* 1980, 1983) and resulted in marked alterations in platelet aggregability. More recently, after a study involving young female adults, Adam *et al.* (1986) concluded that biosynthesis of prostaglandins, but not the conversion of linoleic acid to arachidonic acid, is suppressed by ingestion of linolenic acid.

The effects of dietary ω3 fatty acids are dependent on a number of variables. Firstly, the types and amounts of both ω6 and ω3 fatty acids in the diet are important. Suggestions have been made (Budowski and Crawford 1985) that Western diets are unbalanced in favour of ω6 fatty acids. Lasserre *et al.* (1985) have suggested optimum dietary intakes for human adults of 5 to 6% of total calories for linoleic acid and 0.5 to 1% of total calories for linolenic acid.

A second factor influencing the effects of dietary polyunsaturated fat is the status of the existing fatty acids in the tissues. The half-life of fatty acids in human adipose tissues is of the order of 600 days, so the effects of changes in dietary fatty acids are not necessarily immediate (Sanders and Younger 1981).

The final influences on the effects of dietary ω6 and ω3 fatty acids are the extremely complex ones involving differences in rates of absorption of fatty acids, inhibition and competition between ω6 and ω3 fatty acids and their eicosanoids, and other metabolic considerations.

Conclusion

In view of the complexity of the above considerations, it would appear that much research needs to be done before clear guidelines can be established for the use of dietary ω3 fatty acids. Six specific areas of further study have already been suggested by Kinsella (1986) in his splendid review.

The canned fish used in this study are good sources of the ω3 fatty acids EPA and DHA, with those packed in fish oil providing an additional quantity of EPA and DHA if the oil is eaten. Fish packed in soyabean oil also provide an excellent source of linolenic acid, the primary ω3 fatty acid, providing the oil is consumed. Most of the canned fish contain added salt, which should be taken into account if dietary salt restriction has been advised, but canned fish with no added salt is now becoming available.

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News from the Division

Retirements

There has been a number of retirements from FRL — details of which will appear in the next issue of FRQ. As Sandy Henderson was the Chief's Secretary and Gordon Walker was Divisional Editor, their retirements have been noted in this issue.

Vegetarian diet, blood pressure and cardiovascular disease

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Introduction

Epidemiological studies and randomized controlled trials clearly show that vegetarians have lower blood pressure (Rouse and Beilin 1984), lower total and low density lipoprotein (LDL) cholesterol levels (Masarei *et al.* 1984), and a reduced risk of coronary heart disease (Phillips *et al.* 1978) than appropriately matched omnivores.

These observations are certainly not new. Donaldson (1926) reported that the mean blood pressure of vegetarian college students increased markedly within two weeks of adding meat to the diet. Saile (1930) reported that German vegetarian monks had lower blood pressures at all ages than monks who ate meat. Subsequent reports of lower blood pressures in vegetarian populations have been based principally on religious groups such as Trappist monks and Seventh Day Adventists, or on those living a commune-type existence such as Macrobiotic vegans who eschew dairy products as well as meat, fish and poultry (Rouse and Beilin 1984). These reports raise a number of issues, primarily whether the observed blood pressure differences were due to the diet alone, or to other aspects of lifestyle characterizing that population.

This question has been addressed recently in cross-sectional epidemiological studies and in controlled experimental studies. Seventh Day Adventist vegetarians were found to have significantly lower blood pressures than Mormon omnivores — both groups share the characteristics of religiosity, abstention from alcohol, tobacco and caffeine but have contrasting dietary patterns.

Blood pressure differences were of the order

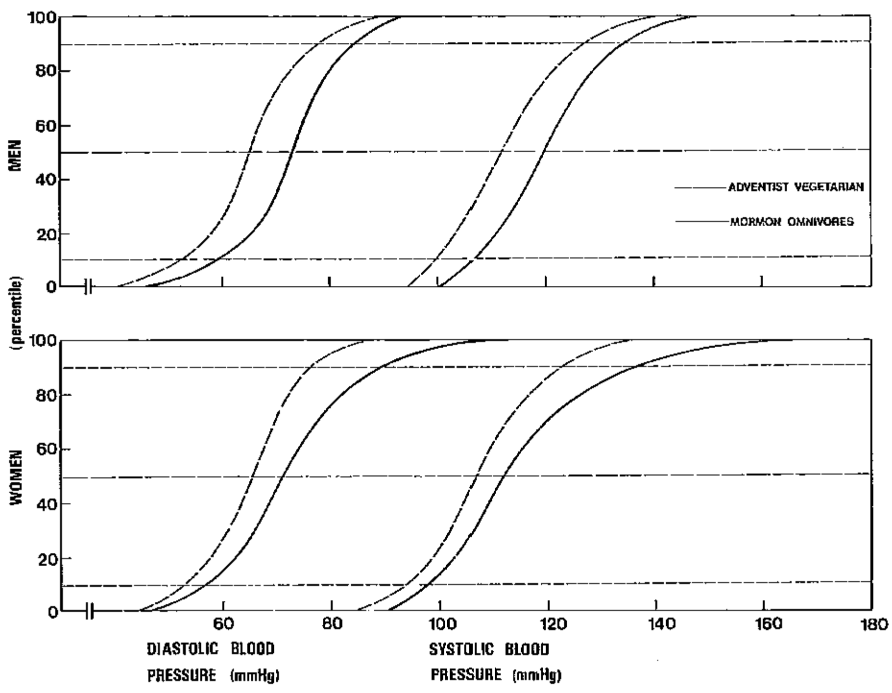

Fig. 1. Cumulative frequency distributions of systolic and diastolic blood pressure (BP) in Seventh Day Adventist vegetarians (----) and Mormon omnivores (————) aged 25-44 years. From Rouse and Beilin (1984).

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of 6-8 mmHg systolic and 3-5 mmHg diastolic. These effects were seen in both men and women and were accompanied by a shift to the left in the frequency distribution curves for blood pressure (Fig. 1). The prevalence of mild systolic or diastolic hypertension was 2% in the Adventist vegetarians and around 10% in the Mormon meat eaters. The Mormons were also heavier but the difference in blood pressure took this into account.

The observed lower blood pressures of vegetarians has led to a number of experimental studies designed to assess the short-term effect on blood pressure of changing to a vegetarian diet. One such study involved 59 healthy omnivore hospital employees in Western Australia. They were randomly allocated to either a control group who ate an omnivore diet for 14 weeks, or to one of two intervention groups whose members ate an omnivore diet for the first two weeks, followed by an ovo-lacto-vegetarian diet for one of two six-week experimental periods.

The mean changes in blood pressure during each experimental period are shown in Fig. 2. There was no appreciable blood pressure change in the control group during either experimental period, nor during the first experimental period (omnivore diet) in experimental group 2. However, there were significant falls in mean systolic and diastolic blood pressures in both experimental groups during the period on the vegetarian diet. Mean blood pressure in experimental group 1 rose after resumption of the omnivore diet in the second experimental period to the same level as that preceding the vegetarian diet. Considering both experimental groups together, the mean fall in blood pressure associated with a vegetarian diet was 6.8 mmHg systolic (s.d. = 8.8) and 2.7 mmHg diastolic (s.d. = 6.3; both falls, $P < 0.01$, paired t-test, 36 df).

Detailed analyses demonstrated that the change in blood pressure was associated with eating a vegetarian diet and was independent of age, sex, Quetelet's index (measure of overweight), blood pressure before dietary modification and change in body weight.

How does a vegetarian diet lower blood pressure?

Almost without exception, the vegetarian dietary pattern which has been studied is that described more correctly as 'ovo-lacto-vegetarian' and is characterized by a high intake of wholegrain cereals, fruit, vegetables and vegetable oils, and moderate use of eggs and dairy products. A well balanced ovo-lacto-vegetarian diet differs from that of an omnivore for intake of many foods other than meat, and many nutrients besides the amount and type of protein. Furthermore, despite the absence of red meat, fish and poultry in the ovo-lacto-vegetarian diet, the diet complies with the dietary guidelines established for most affluent countries.

In the intervention trials discussed above, changes in the major nutrients corresponded to the diets of Seventh Day Adventist vegetarians, including substantial increases in dietary fibre, polyunsaturated to saturated fat ratio, vitamins C and E; smaller increases in calcium, potassium and magnesium; and reductions in total fat, saturated fat, cholesterol, protein, iron and vitamin B_{12}. However, there was no change in sodium intake (or excretion). This

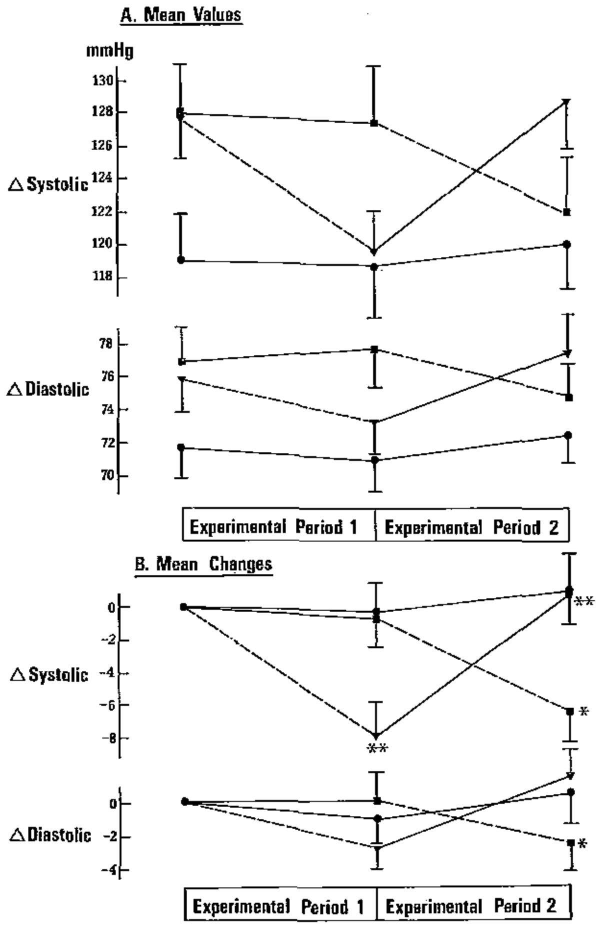

Fig. 2. Mean changes in resting blood pressure (BP) measured in the laboratory. • = Control group; ▼ = experimental group I; ■ = experimental group II.
--- = Vegetarian diet; —— = omnivore diet. Vertical bars = s.e.m. *P <0.05; **P<0.01 for significance of difference in response of experimental groups in comparison with control group (protected least significant difference test). From Rouse *et al.* (1983). Blood-pressure-lowering effect of a vegetarian diet: controlled trial in normotensive subjects. *Lancet* 1, 5-10.

observation supports other studies which indicate that the blood pressure lowering effects of vegetarian diets in "accultured" populations is independent of dietary sodium.

Exactly what nutrient (or combination of nutrients) is important in lowering blood pressure, is not known. Although many studies have looked at the effects of changing various dietary components on blood pressure, the nutrients responsible have not been identified clearly, nor has a mechanism of action been established (Rouse and Beilin 1984). The observation that an ovo-lacto-vegetarian diet significantly reduces blood cholesterol levels (Masarei *et al.* 1984) is less surprising than the observed effect on blood pressure. Using equations derived from metabolic studies (Keys *et al.* 1965) one could predict that someone eating a 'typical Australian diet' (high in saturated fat and cholesterol, and low in fibre) would experience a fall of approximately 0.5-1.0 mmol/l in plasma total-cholesterol if they changed to a diet containing less saturated fat and cholesterol, and significantly more polyunsaturated fat (i.e. a vegetarian diet).

For the majority of accultured omnivores, changing to an ovo-lacto-vegetarian diet may not seem particularly appealing. Therefore, it is important to establish whether there are any health benefits in consuming an ovo-lacto-vegetarian diet rather than a "prudent" diet which includes lean meat, fish and poultry.

This question is currently being investigated by scientists in the CSIRO Division of Human Nutrition. A randomized study is being conducted in which volunteers are given well-defined menus (calculated carefully to approximate healthy diets) that provide similar types and amounts of fat, fibre and cholesterol and similar P:S ratios. However, one of the diets has 70% of the protein derived from lean meats and dairy products, and the other 70% from vegetable sources (30% from eggs and dairy products). It is hoped that this study will provide answers to questions outlined here, and thereby enable more widespread adoption of dietary practices likely to reduce the prevalence of hypertension and dependence on antihypertensive drugs, and through changes in blood pressure and blood lipids, ameliorate the natural history of cardiovascular disease.

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News from the Division

Retirement

Gordon Walker

Gordon Walker joined the Division of Food Research in September, 1968 as Editor.

Initially all editorial responsibility had devolved upon the first Chief of the Division, Dr J.R. Vickery. The growth of the Division and the concomitant growth of editorial duties led to the formal appointment of the Division's first editor Dr G.C. Cunningham. Gordon Walker thus inherited an already established habit of editorial excellence.

Gordon possessed in full measure those qualities of patience and tolerance required for success in dealing with authors and with management. As well, he was a skilful author in his own right and several of his expositions on food and related topics were issued in the thousands in response to public demand.

No divisional editor has the absolute power of a computer editor, ie, the power to refuse to compile a programme (publication) unless it is 'immaculate'. I think this lack was sometimes regretted by Gordon. It is often not sufficiently recognized that editors who aim to help others achieve high standards for their publications require support and moral backing from management and authors alike.

Gordon was always concerned with standards and fearful of their erosion and debasement. It may bring him a wry smile to reflect that in this State (NSW) the government is currently concerned to re-emphasize the 3-R's in the State education system.

In the climate of his time Gordon Walker did all in his power to maintain and strengthen a tradition of quality in Divisional publications. Those in the Division who respected and valued his assistance, counsel and friendship wish him well in his future career.