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Meat consumption, cancer risk and population groups within New Zealand

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Abstract

In comparison with other OECD countries with good cancer registries, New Zealand has the highest mortality rate of colon cancer, second highest of breast cancer and third highest of prostate cancer. A possible association with heterocyclic amine consumption has been suggested for each of these cancers. Studies of locally cooked meat suggest that the main contributors to heterocyclic amines in the New Zealand diet would be well-cooked beef, chicken and pork. Well-cooked beef steak, and the specific heterocyclic amine, IFP, showed a weak positive correlation with prostate cancer risk in the New Zealand population, but no studies thus far have considered the role of meat cooking practices or heterocyclic amines in the development of other cancers. The Maori and Pacific Island people, despite a superficially similar diet, have a substantially lower incidence of colon cancer than people of Caucasian origin. These differences are particularly intriguing in view of a report that a very high percentage of these people have a fast acetylator phenotype—a factor suggested to augment the effect of well-cooked red meat in other populations. The three population groups are known to differ in their preferences for meat type (including processed meats), and there are anecdotal suggestions that they may differ in preferred cooking methods. More detailed population studies are warranted to establish the role of meat, meat processing, cooking methods and the interaction with food plants and/or with genotype and phenotype in New Zealand.
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Keywords: Cancer risk; Meat; Cooking methods; Meat processing; Heterocyclic amines

1. Introduction

New Zealand has an agricultural based economy, with current estimated numbers of just over 3.5 million people, 9 million cows and 45 million sheep [1]. A relatively unpolluted environment and abundance of fresh food has been traditionally believed to provide the New Zealand population with a healthy lifestyle and diet. Thus, it is of major concern that diseases associated with inappropriate diets, such as heart disease and cancer, are at high levels. Data for deaths from major cancer types [2] show that overall the New Zealand cancer data rank third highest in the world, with individual comparisons of colon cancer as top ranked for 1995, breast cancer second and prostate third (Fig. 1). Deaths from cancers of the lung are also high.

Muscle foods, including red meat (beef, lamb or pork) and poultry, provide an important protein source in most diets of developed countries. On a worldwide average, meat and poultry contribute 9% to the total energy of the diet [3]. However, in Denmark this figure reaches 24%, while in New Zealand, Australia,

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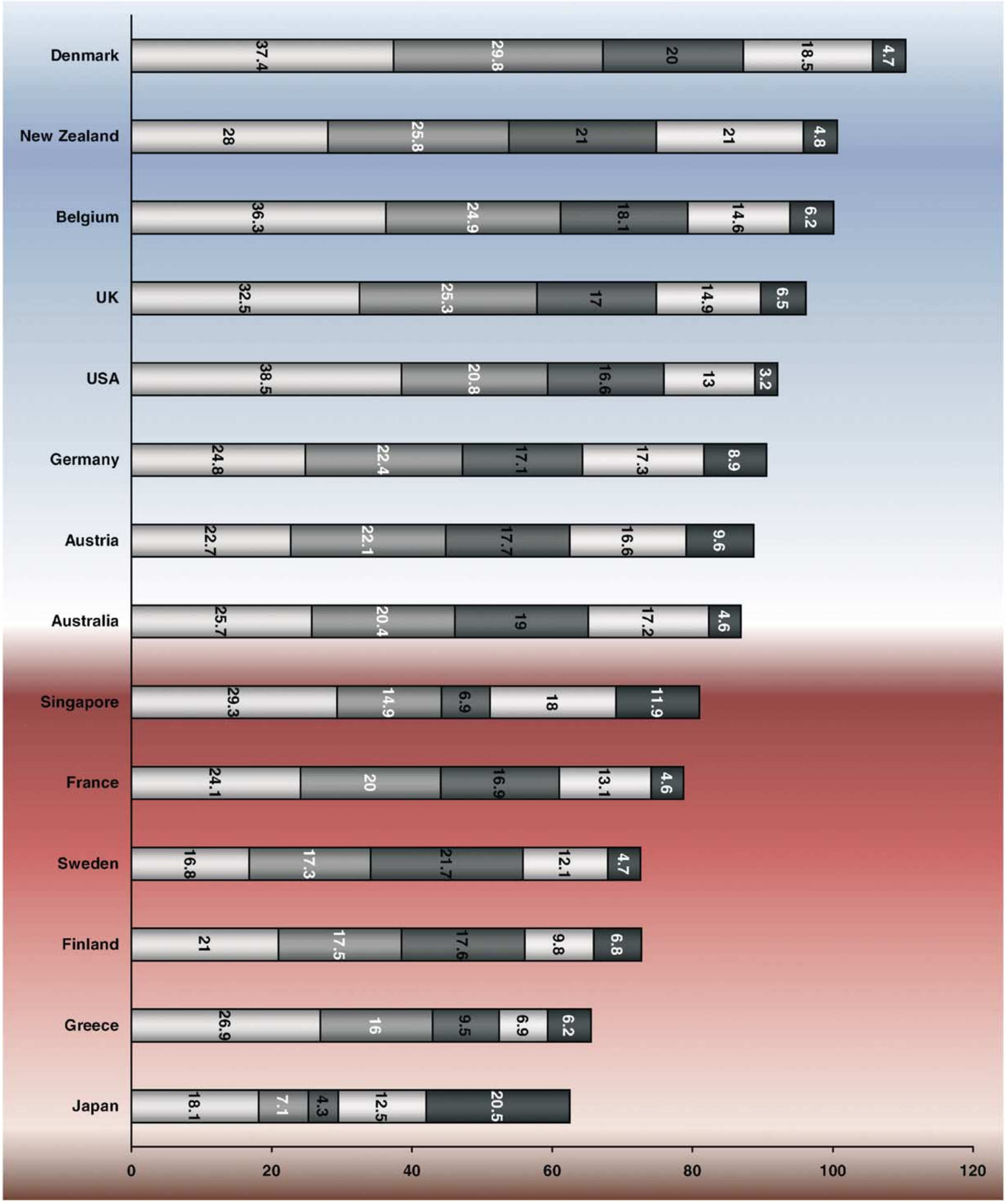

Fig. 1. Age-standardised rates (per 100,000 population) for deaths in 1995 due to lung, breast, prostate, colon and stomach cancer, in that order, in selected OECD countries. Data from [2].

Argentina and Bermuda, meat and poultry provide around 20% of the total energy. Meat and poultry are rich sources of Vitamins B_6 and B_{12}, zinc, selenium and fatty acids, and beef and lamb are especially rich sources of readily absorbable haem iron [4]. On average, New Zealand women eat 39 g and men 74 g of beef or lamb per day. However, there is considerable variation within the population and it seems that an average serve size of beef or lamb for men is 114 g, but 82 g for women [5]. Meat pies and pastries provide 6% and processed meats 5% of the saturated fat in the average New Zealand diet [5].

A critical evaluation of international epidemiologic studies up to 1997 concluded that high red meat consumption was probably associated with a high risk of cancers of the colon and rectum, and possibly associated with cancers of the pancreas, breast, prostate and kidney [3]. There has been considerable debate as to whether it is meat per se, its high fat content, carcinogens generated during cooking (heterocyclic amines and polycyclic aromatic hydrocarbons) [6,7] or *N*-nitroso compounds generated in processing [8] that are the potential risk factors. There were no New Zealand studies included in that database. In this review, we consider whether meat consumption or meat cooking methods might provide a possible explanation for some of the high cancer death rates in New Zealand.

2. Population groups

Although, the bulk of the New Zealand population are Caucasians of European descent, there are also two population groups that have Polynesian origins. The Maori are the indigenous New Zealanders, thought to have been in this country for around 1000 years [9], while there is also a substantial and continuing immigration of Pacific Island people into the country. The incidence of several cancers has been recognised to be lower for Polynesians living a traditional lifestyle in the Pacific Islands, as compared with the European population in New Zealand [10]. Although, changes in diet and lifestyle occur upon immigration to New Zealand, the population groups retain some substantial differences in the incidence of different types of cancer [2]. Cancer of the liver, stomach and (possibly) breast appear lower for the European groups, while that of the colon and prostate are higher (Fig. 2). This very low incidence of colon cancer has been maintained [10–13], and on current data, males of Polynesian descent could expect to have one-third the death rate from colon cancer as compared with Caucasians in New Zealand [2].

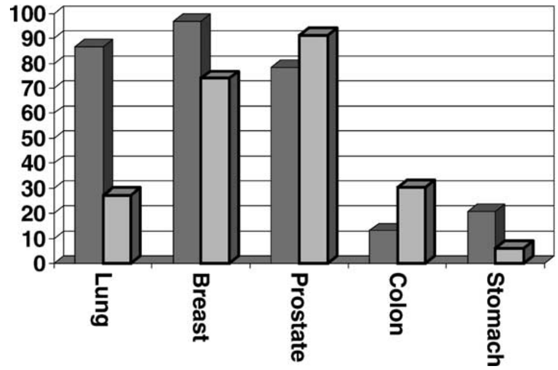

Fig. 2. Comparative data on the incidence of five major cancers for two different New Zealand population groups [2]. Bars represent age-standardised rates (per 100,000 population) for deaths in 1995 due to lung, breast, prostate, colon and stomach cancer in Maori (darker bars) as compared with non-Maori (lighter bars) groups.

Attempts to relate the cancer incidences in these groups to dietary differences have been surprisingly unsuccessful thus far. Dietary surveys have generally suggested higher overall caloric intakes in the Polynesian groups, but otherwise somewhat similar patterns of consumption of major recognised dietary cancer risk factors including total fat, meat, and beer, or of suggested protective factors such as total fruit and vegetable consumption or dietary fibre [11–13]. However, where more detailed side-by-side comparisons have been done, they have tended to suggest that the Polynesian groups have a poorer diet than the Europeans. For example, Tongan and Tokelauan children living in New Zealand consume a diet that is larger in amount but lower in nutrient density compared to that of non-Pacific Islands New Zealand children. The Pacific Island children obtain most of their nutrients from meat, bakery products, fast foods and dairy products, and eat lower amounts of fruits and vegetables [14]. Clearly, these data do not explain the cancer protection seen in the different population groups. One factor worth considering could be either meat itself, or meat cooking practices.

3. Meat cooking and cancer risk

Heterocyclic amines (HCAs) are formed during the high-temperature cooking of meat and fish, from amino acid, creatine and polysaccharide pre-cursors [6]. Although, their potencies vary, all of these compounds have been shown to be mutagenic in the Ames *Salmonella* assay and carcinogenic in experimental animal studies [6,15,16]. The HCAs that have been described most commonly in cooked meats are 2-amino-3, 8-dimethylimidazo[4,5-*f*]quinoxaline (MeIQx), 2-amino-3,4,8-trimethylimidazo[4,5-*f*]quinoxaline (DiMeIQx) 2-amino-1-methyl-6-phenylimidazo[4,5-*b*] pyridine (PhIP). In animal studies the different HCAs have different target sites, causing cancers of the liver, colon, breast and prostate [15–17].

Heterocyclic amine formation is promoted by high cooking temperatures (>150 °C) and extended cooking times (>2 min). It is also dependent upon meat type and on the method of cooking, so that direct exposure to heat, as occurs with frying, grilling and barbecuing, is more likely to lead to HCA formation than baking or steaming. Approximately, one-third of the meat consumed regularly in New Zealand is cooked in such a way that HCAs are likely to form [18]. Preferred methods of cooking include roasting and baking, pan-frying and grilling for most cuts of meat, with barbequing being especially common for beef and sausages. It seems that only a small proportion of New Zealanders will microwave their meat, or otherwise cook in methods unlikely to encourage HCA formation [18].

Estimation of HCAs from epidemiologic studies requires details of cooking methods and estimates of meat doneness, as in recent American studies [19]. However, it is important to recognise that data on meat from one country cannot simply be extrapolated to another. Winters in New Zealand generally show fewer extremes of temperature than in Northern European cities or the United States, and the animals are purely pasture-fed as compared with grain-fed, leading to differences in nutrient composition. For example, the levels of omega-3 polyunsaturated fatty acids are claimed to be higher in New Zealand sheep and cattle as compared with estimated values from overseas animals [20]. For these reasons, we have established our own database for HCAs based upon analysis of meat samples from local sources, cooked under controlled conditions to states of doneness which are considered typical in the New Zealand population [21]. Although, differing in exact detail, the range of estimated values of individual HCAs from New Zealand meats were similar to those found in foods cooked in Sweden [22] or in restaurants in the United States [23], ranging from undetectable levels to 28.6 ng/g for a well-done chicken sample (Fig. 3). As well as identifying the commonly-reported HCAs in New Zealand meats, we also reported the presence of a further compound, IFP (2-amino-1,6-dimethylfuro[3,2-*e*]imidazo[4,5-*b*] pyridine) [23].

Epidemiological studies have suggested that the consumption of well-done meat is associated with an increased risk of breast cancer [24] and of colorectal cancer [25,26], although conflicting studies have also been published [27,28]. The only data from New Zealand are from our case-control study which compared 317 prostate cancer cases with 480 controls [21]. These men were predominantly European (96%), with 2% Maori, 1% Pacific Island and 1% other ethnic groups. Cases and controls showed a similar age structure and similar median intake of energy and fat. Although, cases reported a higher median intake of meat, age-adjusted and multivariate analyses did not confirm a statistically significant increase in prostate cancer risk with increasing quartiles of either total or red meat consumption. The doneness of beef steak was positively associated with prostate cancer risk, with well-done beef steaks showing a relative risk of 1.8. No association was observed for the other meats or for the composite meat doneness score. A weak gradient of increasing risk was observed over increasing quartiles of exposure to IFP and PhIP, the major HCAs derived from beef and chicken sources. However, this correlation was not statistically significant at the usually accepted level, and there was no clear association between prostate cancer risk and either estimated total or other individual heterocyclic amines.

4. Population groups, meat type and cooking preferences

A national nutrition survey conducted in 1997 revealed differences in eating patterns between the main New Zealand population groups [5]. Although, the number of Pacific Island people in this study was too low to allow meaningful comparisons, data are

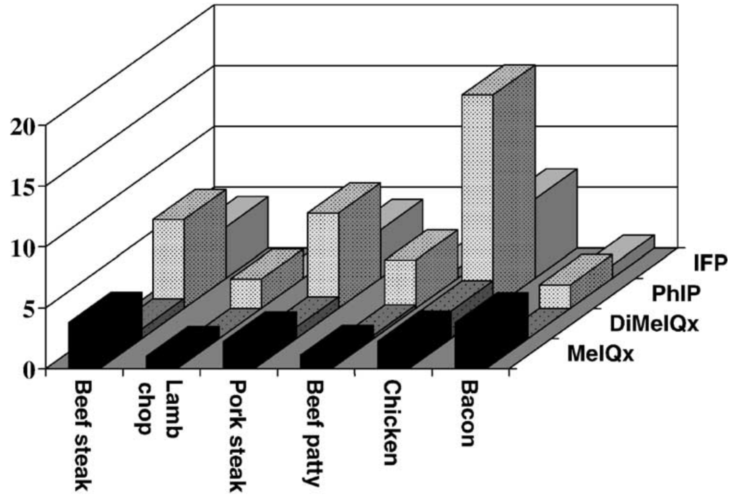

Fig. 3. Heterocyclic amine composition of commonly-eaten New Zealand meats [21]. (■): MeIQx; (■): DiMeIQx; (▨): PhIP; (■): IFP.

available for Maori versus non-Maori (New Zealand Europeans and others) groups. In general, the intake of total energy, protein and fat is higher in men than in women, and higher for Maori than for non-Maori groups (Fig. 4). This overall greater energy intake is not compensated for by greater exercise and there is considerable concern about the level of obesity in the Polynesian groups within New Zealand [5].

The selection of meat also differs between the population groups (Fig. 5). Maori eat more meat than their European counterparts [5,29]. Although, beef, chicken and pork are regularly eaten by all groups, the Maori people eat more lamb, hogget or mutton, either alone or as part of mixed dishes. They will also eat more shellfish and more fried fish in batter. Only limited data are available on the relative consumption of

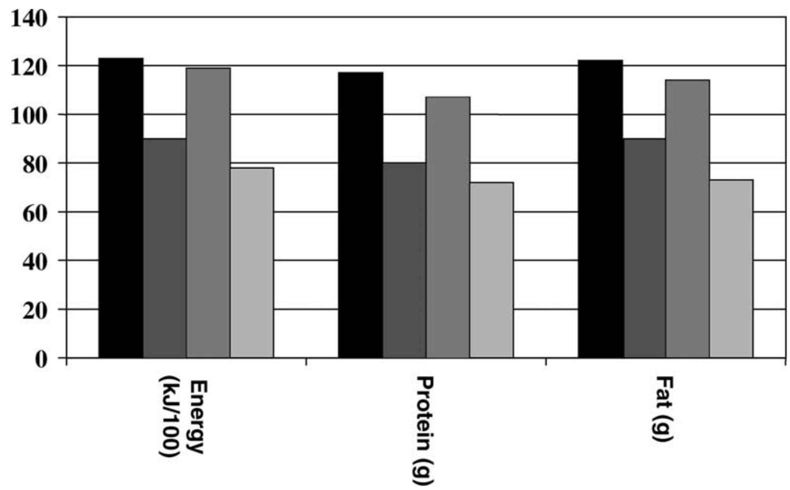

Fig. 4. Mean daily total energy, protein and fat consumption by New Zealand Maori as compared with New Zealand Europeans and other groups (non-Maori) [5]. Data are derived from repeat 24 h diet recalls. (■): Maori male; (■): Maori female; (■): non-Maori male; (■): non-Maori female.

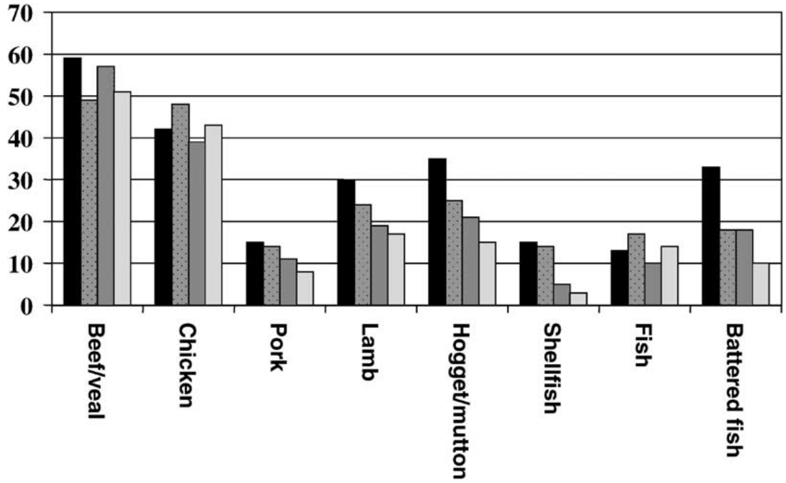

Fig. 5. Mean daily consumption (grams per day) of main meats eaten in New Zealand (excluding mixed dishes) by New Zealand Maori as compared with New Zealand Europeans and other groups (non-Maori) [5]. Method of collection and key as for Fig. 4.

processed meats (Fig. 6). Although, the European groups eat slightly more bacon and ham, Maori eat slightly more sausage meats, but significantly more corned beef. Quantitative data are not available for other processed meats such as pickled pork or smoked mutton, although there is a perception that these are most commonly eaten by Maori and Pacific Island groups.

There were insufficient Maori or Pacific Island people represented in either the analysis of cooking methods [18] or the prostate cancer study [21] to be able to quantify the role of heterocyclic amines in cancer formation in this group. However, at least anecdotally, there are substantial differences in preferred cooking methods used either for day-to-day food preparation or for festive occasions.

"Boil-ups" are commonly eaten by both Polynesian groups, and there were highly statistically significant preferences for boiling meat in Maori and Pacific Island groups [29,30]. Boil-ups involve long cooking

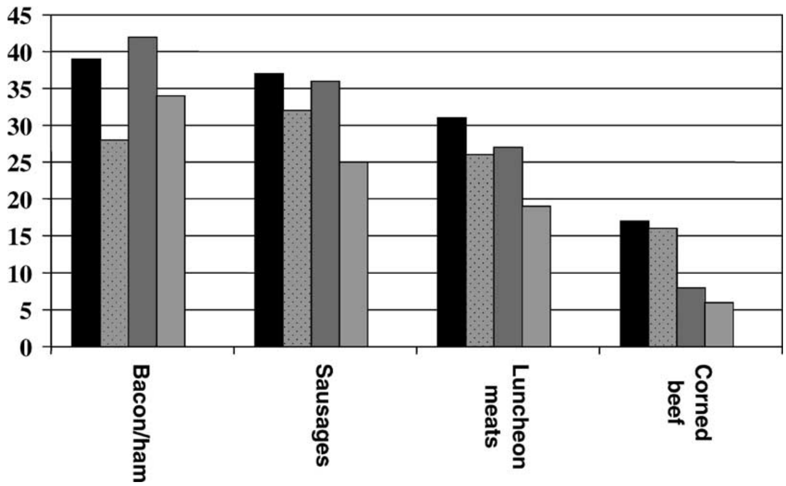

Fig. 6. Mean daily consumption (grams per day) of processed meats eaten in New Zealand (excluding mixed dishes) by New Zealand Maori as compared with New Zealand Europeans and other groups (non-Maori) [5]. Method of collection and key as for Fig. 4.

times at low temperatures, of mixtures of meat and vegetables. They typically use using cheaper cuts of meat especially corned beef, beef brisket or mutton flaps, combined with a range of vegetables that may also be distinctive [31]. Thus a typical "boil-up" as illustrated by the New Zealand Beef and Lamb Marketing Bureau would combine trimmed brisket with potato, kumara (sweet potato; *Ipomeae batatis*), puha (sowthistle, *Sonchus aster* and other species) and kamokamo (a type of vegetable squash), with a variety of herbs [30].

Whereas social occasions are often accompanied by a barbeque in the Caucasian groups, Maori people and to a lesser extent the Pacific Island people would invite friends and relations to a hangi. This again involves a slow cooking process, this time with an all-day preparation. Wood, stacked above and below a group of large stones, is set on fire. When the fire has essentially burned to ashes and the stones are hot, they are shovelled into a large pit. The food is wrapped, traditionally in baskets woven from the native flax, although more typically nowadays into tinfoil (meat) or cheesecloth (vegetables). Water is hosed over the stones, the wrapped food (in large baskets) lowered onto the rocks, and water again hosed over the baskets. Wet sacks, and sometimes also a sheet of corrugated iron, are placed on top. Finally, earth is shovelled on top to seal in the steam, and the food is left for the rest of the day to cook. It would seem unlikely that heterocyclic amines would be generated to any extent by this cooking method.

5. Modifying factors in heterocylic amine carcinogenesis

A considerable number of factors may modify the formation of heterocyclic amines; including the fat, water or iron content of meat [32] and the use of precooking treatments [33]. We have no information on the way in which these could be acting in New Zealand meats.

There are various ways in which the genotoxic and carcinogenic effects of heterocyclic amines can be reduced or eliminated by other dietary components [34]. Mechanisms include inactivation of the compound itself or its metabolites by direct binding, inhibition of enzymes involved in the metabolic activation of the amines, induction of detoxifying enzymes, and/or interaction with DNA repair processes. For example, we have shown prevention of mutations and/or aberrant crypt formation by various dietary fibres and dietary fibre sources [35,36]. Some but not all dietary fibres have the ability to adsorb heterocyclic amines, leading to their enhanced excretion from the body [37,38]. Additionally, the dietary fibre source, wheat bran, can modulate the expression and activity of various hepatic xenobiotic metabolising enzymes, leading to reduced potential for formation of the genotoxic metabolite [39]. Although, overall fruit and vegetable intake is similar, the selection of the major dietary fibre sources (fruits, vegetables and cereals) preferred by Maori or Pacific Island people in New Zealand tends to be different from that of European groups [31]. We have some evidence that the nature of the dietary fibres eaten differs between these groups [40], and we also found significant antimutagenic activities in various food plants eaten preferentially by the Maori Pacific Island groups [41]. Tea consumption differs between the groups, and could also play a role [42,43]. It would be of considerable interest to relate food plant consumption, meat intake and cooking methods to cancer risk in the various population groups.

The probability of carcinogenesis by heterocyclic amines is also modulated by host factors such as individual acetylator phenotype [44,45]. Lang et al. found that the cancer risk from well-cooked red meat was significantly increased in individuals who were rapid acetylators [44]. Given this finding, the low colon cancer risk of Polynesians in New Zealand is even more perplexing, since approximately 93% of New Zealand Polynesians have been reported to have a rapid acetylator phenotype, while most groups of European descent tend to have around 40% of this phenotype [46].

6. Meat processing and cancer risk

Salted, cured and smoked foods have been inconsistently linked to cancer in various studies [3]. High salt levels in various products have been identified as potential risk factors in heart disease and cancer [47,48]. Processed foods may also contain high levels of nitrate, that may combine with secondary or tertiary amino compounds from food or medicines to form *N*-nitroso compounds in vivo [8]. Cured meats,

especially bacon, may contain significant levels of potentially carcinogenic nitrosoamines, although these levels have been reduced in recent years. Nitrosamines have been shown experimentally to induce tumours in various organs including liver, lung, kidney, bladder, pancreas and tongue, but not skin, brain, colon or bone [8]. Nevertheless, preliminary findings of an association of colorectal cancer risk with processed meats in the European collaborative (EPIC) study, have rekindled interest in the possibility that *N*-nitroso compounds may be important in human cancer [49].

Many of the cheaper cuts of meat in New Zealand are subjected to various processing methods. Maori have a higher consumption of corned beef, sausages and luncheon meats, but a similar consumption of bacon, compared with those of European descent (Fig. 6). However, we have no quantitative consumption data on the available range of other processed meats.

CYP4502D6 is a polymorphic human enzyme that is involved in the activation of some, but not all, nitrosamines [50]. Wanwimolruk et al. compared genetic oxidation polymorphisms of debrisoquine (CYP2D6) in South Pacific Polynesian volunteers compared with Caucasian volunteers [51,52] from New Zealand. They found that the Polynesian groups appeared to extensively metabolize debrisoquine, and showed a lower incidence of the poor metaboliser phenotype than New Zealanders of European descent. The low incidence of colon cancer risk in Polynesian groups would appear inconsistent with a strong involvement of processed meats or of *N*-nitroso compounds in colon cancer risk within New Zealand.

7. Why should New Zealand be a focus for further studies on meat consumption and cancer risks?

Although, New Zealand is a high meat-eating nation, this factor alone could not justify the selection of this country for further studies above others such as Australia, Argentina, Bermuda or Denmark. Indeed, the existence of ongoing cohort studies [53] might lead to the selection of Denmark, Belgium or the United Kingdom for further studies on meat consumption and cancer risk. What is so distinctive about New Zealand is the enigmatic differences in cancer incidence between population groups living side-by-side, with superficially similar dietary preferences. As pointed out by several authors including Smith [11], the major etiological hypotheses do not explain the differences in incidence of colorectal cancer between Maoris and Europeans within New Zealand. The present summary shows that there are considerable differences between the various populations in meat preferences and meat cooking methods. However, these differences have not yet been connected to cancer risk in any epidemiological study. Cooking methods, and/or cancer risk modulation through the specific selection of food plants may provide testable hypotheses. The limited data available on metabolic phenotypes only add to the complexity, the interest and the potential research strength, of such a study.

Acknowledgements

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