Kangaroo meat for human consumption

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Summary

The harvesting of kangaroos for human consumption has become a significant domestic and export industry in the past 30 years. There is evidence that the current harvest of about 3 million animals annually is an essential tool to manage the grazing pressure in Australian rangelands, where the total population of kangaroos now exceeds 20 million animals. Data exist to show that kangaroos are healthy and that the overall rejection rate of carcasses for pathological reasons is low, especially in comparison with domestic animals. Kangaroo meat is highly regarded as a game meat and is now available in restaurants and in supermarkets throughout the country, with market research revealing that more than half those surveyed had eaten kangaroo meat. Kangaroo meat is low in fat and contains both n-6 and n-3 polyunsaturated fatty acids. Studies in subjects consuming 500 g of kangaroo meat per day for up to 2 weeks when on low fat diets showed beneficial effects on plasma cholesterol levels and increases in long chain n-3 polyunsaturated fatty acid levels. There was no evidence of increased platelet aggregation on diets rich in kangaroo meat. These data suggest that kangaroo meat can be included in diets safely and can contribute to the diversity of the Australian diet.

Introduction

In the last 30 years a significant industry has developed producing kangaroo for domestic and export markets. Kangaroo is available for human consumption in every State and exported to over 15 countries on a regular basis. All kangaroos are field harvested from the wild population and are taken by professional harvesters who must pass stringent accreditation testing by the relevant State's Meat Hygiene Authorities (1).

Over the last 25 years the kangaroo population has increased, despite the annual harvest of approximately 3 million animals. The estimated national population of kangaroos has risen steadily from about 10 million animals in 1984 to greater than 20 million in 1993 (2). Indeed many consider the kangaroo harvest to be an essential tool in managing the total grazing pressure in the Australian rangelands and thereby contributing to the sustainable management of these fragile environments (3, 4). The Australasian Wildlife Management Society supports the current industry as being sustainable (5). Similarly the CSIRO have also assessed the kangaroo harvest against a set of criteria it has published and concluded 'kangaroo harvesting clearly meets most of the criteria for sustainable utilisation of wildlife' (6). The Australian Veterinary Association believes that the 'Australian kangaroo population is a unique and valuable resource and that harvesting is a legitimate use of that resource' (7).

Health status of kangaroos

There are considerable data to show that kangaroos are remarkably healthy. Since many of the zoonotic diseases (those transmitted to humans from animals) are contracted by the animals from faecal matter or inter-animal contact, wild animals running at lower densities than domestic animals are exposed to considerably less disease transmission risk. Further since disease contraction is invariably fatal to wild animals (8), the background levels of infection are lower than in domestic animals in which diseases are treated and thereby maintained in the population (9, 10). Examination of the rejection rates at post mortem inspection for disease conditions of animals processed under Australian Quarantine Inspection Service (AQIS) inspection provides further evidence of the relative disease-free status of kangaroos. In one study of over 200,000 kangaroos processed for export, overall rejection rate for pathological conditions was 0.7% (11). By comparison rejection rates for similar conditions in studies of domestic animals have been shown to be 2.7% in cattle (12) and 1.6% in sheep (AQIS 1997, pers comm).

Acceptance of kangaroo meat consumption in Australia

Recent market research conducted across five Australian capital cities has indicated that 51% of Australians have tried kangaroo and that 85% of these were more than happy to eat it regularly (13). Whilst most is still consumed in restaurants where it is highly regarded as a game meat, the product is appearing increasingly in supermarkets in all States.

The composition of kangaroo meat

Our interest in meat from indigenous animals first arose as a result of studies being conducted by Kerin O'Dea with Aborigines near Derby in Western Australia in the early 1980's, examining the effect on diabetes control of consuming diets rich in indigenous foods, such as fish (14) or kangaroo meat (15). These studies contributed to the understanding that the lipid content and fatty acid composition of indigenous foods were different to fish or animal foods consumed in large urban cities in Australia. For example, many of the fish from the north west of Australia were relatively enriched in long chain polyunsaturated fatty acids (LCP) from the omega 6 series such as arachidonic acid (20:4n-6) compared with fish from southern Australia (16, 17), as shown in Table 1. The lipid content of the kangaroo meat examined was low in fat and also appeared to be relatively rich in 20:4n-6 and LCP n-3 compared with beef (15, 18). Subsequent studies have shown that the concentration of 20:4n-6 and n-3 PUFA in kangaroo meat is higher than in beef (19).

Table 1 Comparison of the lipid content and PUFA levels in kangaroo, wallaby and fish muscle

Species	Lipid %[1]	18:2 n-6[2]	20:4 n-6	18:3 n-3	20:5 n-3	22:5 n-3	22:6 n-3	n6/n3	20:4/ LCPn-3
Barramundi flesh (n=2) [3]	0.6	2.0	12.3	0.8	2.8	3.0	18.1	0.8	0.5
Kangaroo (n=4) [4]	1.1	22.7	7.7	6.0	1.9	2.9	0.9	2.6	1.4
Beef (lean) (n=2) [4]	2.6	9.9	4.4	1.7	1.5	1.6	0.2	2.8	1.4
Antelope Kangaroo (n=5) [5]	1.2	22.1	7.7	6.1	2.0	2.7	0.8	2.7	1.4
Black-footed Rock Wallaby(n=1) [5]	2.0	18.0	5.5	3.5	0.9	1.5	0.3	3.8	2.0
Antelope Kangaroo (n=1) [5]	2.5	13.2	5.3	1.9	2.7	3.4	1.9	1.9	0.7
Eastern Grey Kangaroo (n=5) [5]	ND[6]	18.3	7.5	4.8	2.0	2.4	0.8	2.5	1.4
Eastern Wallaroo (n=1) [5]	ND	33.2	8.5	1.6	0.4	1.1	0.6	9.6	2.1
Red Kangaroo (n=2) [5]	ND	19.1	5.5	3.2	0.7	1.2	0.5	3.9	2.3
Black-tailed Wallaby (n=2) [5]	ND	31.6	19.3	0.8	0.8	3.1	0.8	8.8	4.1

[1]Lipid % = grams lipid per 100 grams meat (raw weight); [2]% of total fatty acids; [3]from ref 14; [4]from ref 15; [5]from ref 20; [6]ND = not determined.

Following this work, we set out to examine in more detail the lipid content and fatty acid composition of a wide variety of indigenous animal foods from three regions of Australia — Kimberley/Arnhem Land, Central Australia and Victoria (20). This study revealed that many of the 34 species were low in lipid, with muscle tissue being below 2.6%, liver from 5-10%, and adipose 5-40%. In simple terms, the meats were low in fat, saturated fat and polyunsaturated fat, however the meat was relatively enriched in PUFA due to the higher proportion of structural lipids (18).

These data highlight the differences in meat composition between the current western diet and that of the 'hunter-gatherer'. The wild animal carcass contained much less fat, both in the meat itself and on the carcass as discrete depots (21). Thus, the foods most readily available in the largest quantities for the hunter-gatherer (muscle from wild animals, fish and shellfish) were low in fat with a wide range of PUFA, rather than being rich in linoleic acid as in the present western diet. The high fat foods were either less readily available (witchetty grubs, perente eggs) or were present only in small quantities on the animal (mangrove ray liver, depot fat).

What is the effect of consuming diets rich in kangaroo meat?

In the O'Dea studies with diets rich in indigenous foods such as kangaroo meat and fish, the subjects' plasma triglycerides fell, bleeding time increased and the plasma cholesterol levels, which were not high initially, were not significantly affected by the diets (14, 15). These observations implied that diets rich in meat did not raise plasma cholesterol levels, and furthermore, that diets rich in indigenous foods increased plasma arachidonic acid levels. This finding was of interest in the context of the debate about dietary n-6 to n-3 ratios and western life style diseases.

Based on these observations we decided to examine, under controlled conditions, the effects on plasma lipoprotein lipids, plasma fatty acid composition, bleeding time and thromboxane production of four diets similarly low in fat. The first diet involved subjects consuming 500 g/day of kangaroo meat (rich in linoleic, arachidonic acid and LCP n-3), the second 500 g/day of barramundi fish (rich in arachidonic and docosahexaenoic acids), the third diet 500 g/day of Victorian fish (rich in docosahexaenoic acid), and the fourth diet was vegetarian, with a similar low fat content but containing no long chain (≥20 carbon) PUFA (22, 23). The four experimental diets were designed to meet two objectives, namely, to provide a minimum of fat (<10% of total energy intake), in this way approximating the conditions of the two field studies (above) and to be isoenergetic such that no loss of body weight occurred over the 4-week period of the study. Thirteen healthy, weight-stable subjects (seven women and six men) participated. Each diet study ran for 4 weeks, with the subjects consuming their usual diets in weeks 1 and 4 and the very low fat test diets in weeks 2 and 3. All food and beverages consumed over each 2-wk diet period plus the pre- and post-control weeks were weighed and recorded. Fasting blood samples were taken before the study began and at weekly intervals for the measurement of plasma lipoprotein lipid, fatty acid compositions, platelet aggregation, thromboxane formation and bleeding times.

The subjects estimated daily dietary intake of saturated, monounsaturated and linoleic acid in the baseline periods was 31, 30 and 12 g/day, respectively (Table 2). In all experimental periods, the levels of each of these three groups of fatty acids declined to about 2-4 g/day. Cholesterol intake was extremely low on the vegetarian diet, but unchanged on the other three diets relative to the baseline periods.

Table 2 Estimated fatty acid intakes (grams/day) of baseline and very low fat diets

Diet	Sat[1]	Mono[2]	18:2n-6	18:3n-3	20:4n-6[3]	20:5n-3	22:5n-3	22:6n-3
Baseline	30.7	29.5	11.42	0.86	0.07	0.04	0.04	0.09
Kangaroo meat	3.2	3.7	3.55	0.58	0.49	0.14	0.14	0.07
Barramundi	2.5	2.3	2.40	0.26	0.56	0.11	0.11	0.51
Victorian fish	2.1	2.4	2.64	0.24	0.14	0.25	0.07	1.08
Vegetarian	2.2	2.4	3.14	0.37	0	0	0	0

[1]Sat = saturated fatty acids; [2]Mono=monounsaturated fatty acids; [3]Values for the LCP calculated from the total lipid content and the fatty acid composition of the foods used in the study (ref 22)

A consistent finding on all diets was the substantial reduction in the percentage of linoleic acid in both the plasma cholesteryl ester (CE) and phospholipid (PL) fractions and the increase in the palmitic acid percentage in the PL and CE fractions and palmitoleic acid percentage in the CE fraction. We have consistently observed alterations in the palmitic/palmitoleic acid ratios in the plasma CE on very low fat diets (24 - 27); the increase in the palmitoleic acid possibly indicating increased fatty acid synthesis and delta-9 desaturation. Following the resumption of the normal high fat diets the percentage of plasma linoleate returned to the pre-diet values. There were also changes in plasma lipid fatty acid profiles in this study that were quite diet-dependent. For example, despite very low levels of the dietary 20:4n-6 and LCP n-3 (0.14-1.08 g per day), there was a significant increase in the proportion of these fatty acids in the plasma lipids, as shown in Table 3. These data show that red meat such as kangaroo meat can be a significant dietary source of 20:4n-6 and LCPn-3. There were no increases in the percentage of 20- and 22-carbon PUFA on the vegetarian diet, suggesting that the increase in the plasma lipids on the other low fat diets was due to their presence in the diet and not due to in vivo formation. There was a reduction in the 20:5n-3 level in the plasma phospholipids in the subjects consuming the vegetarian diet, a finding we have consistently observed in vegetarian diet studies (24 - 27) and one that presumably reflects the high linoleic acid and low intakes of n-3 PUFA in strict vegetarians (28).

Table 3 Effect of very low fat diets (VLF) on plasma lipid and plasma phospholipid PUFA levels[1]

Diet	Baseline, day 7	VLF[2] Diet, day 14	VLF Diet, day 21	Post-diet, day 28
Total plasma cholesterol (mM)				
Kangaroo (10)[3]	5.22	4.42***[4]	4.17***	4.86
Victorian Fish (10)	4.54	3.83***	3.51***	4.20
Barramundi (11)	4.75	4.08***	3.86***	4.13
Vegetarian (7)	4.54	3.59	3.44**	4.12
Plasma PL - 20:4n-6 %				
Kangaroo	10.8	ND[5]	15.1***	12.4***
Victorian Fish	10.8	ND[3]	12.0	9.2**
Barramundi	9.8	ND	15.7***	10.4
Vegetarian	9.2	ND	9.7	9.0
Plasma PL - 20:5n-3 %				
Kangaroo	1.1	ND	1.4*	1.4*
Victorian Fish	1.0	ND	2.8***	1.4*
Barramundi	0.8	ND	1.2*	0.8
Vegetarian	0.9	ND	0.6**	1.4*
Plasma PL - 22:5n-3 %				
Kangaroo	1.1	ND	1.5***	1.4
Victorian Fish	0.9	ND	1.2*	0.9
Barramundi	1.1	ND	1.2	0.8***
Vegetarian	0.8	ND	0.8	0.9
Plasma PL - 22:6n-3 %				
Kangaroo	3.5	ND	4.0	3.8
Victorian Fish	4.0	ND	9.1***	5.4***
Barramundi	3.9	ND	6.6***	4.3
Vegetarian	3.4	ND	3.8	3.2

[1]From reference (22); [2]VLF=very low fat; [3]number of subjects;
[4]statistically significant differences from baseline, * $p<0.05$, ** $p<0.01$, *** $p<0.001$; [5]ND = not determined

In this study, the changes in lipoprotein composition in response to all four very low fat diets were similar. There was a rapid reduction in total cholesterol (LDL and HDL) within 1 week and a slower return toward baseline values 1 week after resuming the normal diet (Table 3). This appears to be explained entirely by the very low fat (and saturated fat) content of the diets used, rather than to specific cholesterol-lowering properties of the main protein sources (kangaroo meat or fish). We have also reported that lean beef, lamb, pork and chicken included in low fat diets can lead to reductions in plasma cholesterol levels (27, 29).

Kangaroo meat as a source of long chain n-6 and n-3 fatty acids

Concerns have been expressed that diets which elevate arachidonic acid levels might lead to an increased thrombosis risk through increased production of thromboxane A_2 and therefore an increase in platelet aggregation (30).

In the present study, diets containing 20:4n-6 (barramundi and the kangaroo meat) did elevate the plasma 20:4n-6 levels by about 50%, however there were no changes in platelet aggregation or bleeding times, although there were significant increases in ex-vivo platelet thromboxane production in response to adrenaline on all diets except the Victorian fish diet. In a repeat of this study with 7 subjects consuming a very low fat diet containing kangaroo meat for 7 days, we showed that there was a significant rise in the serum 20:4n-6, 20:5n-3 and 22:5n-3 and in prostacyclin production (measured as a urinary metabolite), but no change in thromboxane production or the prostacyclin/thromboxane ratio (31). Perhaps the short duration of the diets or the relatively low intakes of dietary 20:4n-6 (300 mg/day) might have been insufficient to alter the platelet 20:4n-6 levels; in addition, the n-3 PUFA content of the kangaroo meat might have down-regulated platelet thromboxane production without adversely affecting arterial prostacyclin production which seems to parallel serum 20:4n-6 increases (29).

Platelet 20:4n-6 levels are relatively high in subjects consuming typical western diets (20-30% of total PL) and a recent study by Nelson et al (32) showed that feeding 1.5 g/day of 20:4n-6 (as a triglyceride) significantly elevated the platelet 20:4n-6 levels over a 50 day period from 21 to 23% of total fatty acids. There were no changes in platelet aggregation although there were significantly raised levels of thromboxane A_2 (by 41%) and prostacyclin I_2 metabolites (by 27%) in urine (33).

In conclusion, these studies on kangaroo meat showed that it does not raise blood cholesterol levels when consumed as part of a low fat diet and that it is a source of n-3 fatty acids, readily incorporated into plasma lipids. These findings together with its low fat content make it a nutritionally desirable product. Short and long-term studies do not reveal any adverse thrombotic effects of dietary 20:4n-6 using kangaroo meat as a source of 20:4n-6. Since there are sound arguments for the harvesting of kangaroos, inclusion of kangaroo meat in the diet can make a useful contribution to the diversity of our food supply.

References

1. ARMCANZ. Meat Hygiene Standards for Game Meat Production. Agriculture and Resource Management Committee of Australia and New Zealand, 1997.
2. ANCA. Kangaroo Harvest Data, Australian Nature Conservation Agency, 1997.
3. Grigg G. Kangaroo harvesting and the conservation of the sheep rangelands. Australian Zoologist 1988;24:124-8.
4. Caughley GJ, Shepard R, Short J. Kangaroos, their ecology and management in the rangelands of Australia, 1987, Cambridge Uni Press.
5. Australasian Wildlife Management Society. Submission to Senate Reference Enquiry on Wildlife Utilisation, 1997.
6. CSIRO. Submission to Senate Reference Enquiry on Wildlife Utilisation, 1997.
7. AVA. Submission to Senate Reference Enquiry on Wildlife Utilisation, 1997.
8. Readcliff CL, Hartley WJ, Dubey JB, Cooper DW. Pathology of experimentally induced acute toxoplasmosis in macropod. Aust Vet J 1993;70:4-6.
9. Johnson AM, Roberts H, Statham P, Munday BL. Serodiagnosis of acute toxoplasmosis in macropods. Vet Parasitol 1989;34:25-33.
10. Munday BL. Prevalence of toxoplasma in Tasmanian meat animals. Aust Vet J 1975;51:315-6.

11. Andrew AE. Kangaroo meat, public health aspects. Australasian Zoologist 1988;24:138-40.
12. Hopwood P, Martin P. A report to the NSW Meat Industry Authority on zoonoses of pigs and lambs and their implications for public health, 1991.
13. RIRDC. Improving consumer perceptions of kangaroo products. Rural Industries Resource and Development Corporation, 1997.
14. O'Dea K, Sinclair AJ. Increased proportion of arachidonic acid in plasma lipids after two weeks on a diet of tropical seafood. Amer J Clin Nutr 1982;36: 868-72.
15. O'Dea K, Sinclair AJ. The effects of low fat diets rich in arachidonic acid on the composition of plasma fatty acids and bleeding time in Australian aborigines. Int J Nutr & Vitaminol 1985:31: 441-53.
16. Sinclair AJ, O'Dea K, Naughton JM. Elevated levels of arachidonic acid in fish from northern australian coastal waters. Lipids 1983:18: 877-81.
17. Fogerty AC, Evans AJ, Ford GL, Kennett BH. Distribution of omega 6 and omega 3 fatty acids in lipid classes in Australian fish. Nutrition Reports International 1986;33:777-86.
18. Sinclair AJ, Slattery WJ, O'Dea K. The analysis of polyunsaturated fatty acids in meat by capillary gas liquid chromatography. J Sci Fd Agric 1982;33:771-6.
19. Mann NJ, Johnson LJ, Warrick G, Sinclair AJ. The arachidonic acid content of the Australian diet is lower than previously estimated. J Nutr 1986;125:2528-35.
20. Naughton JM, O'Dea K, Sinclair AJ. Animal foods in traditional Australian aboriginal diets: polyunsaturated and low in fat. Lipids 1986;21:684-90.
21. Crawford MA. Lancet 1968;1:1329-33.
22. Sinclair AJ, O'Dea K, Dunstan G, Ireland PD, Niall M. Effects on plasma lipids and fatty acid composition of very low fat diets enriched with fish or kangaroo meat. Lipids 1987;22:523-9.
23. Butcher LA, O'Dea K, Sinclair AJ, Parkin JD, Smith IL, Blombery P. The effects of very low fat diets enriched with fish or kangaroo meat on cold-induced vasoconstriction and platelet function. Prostaglandins Leuk and EFA 1990;39:221-6.
24. O'Dea K, Traianedes K, Chisholm K, Leyden H, Sinclair AJ. Cholesterol-lowering effect of a low fat diet enriched with lean beef is reversed by addition of beef fat. Am J Clin Nutr 1990;52:491-4.
25. Morgan SA, Sinclair AJ, O'Dea, K. Low-fat diets rich in lean beef: the effects of the addition of safflower and olive oil. J Amer Diet Assocn 1993;93:644-8.
26. Sanders K, O'Dea K, Sinclair AJ. Impact on lipoprotein lipids of the addition of safflower oil, olive oil or butter to a very low fat vegetarian diet containing one egg daily. Lipids 1994;29:129-38.
27. Sinclair AJ, Johnson, L, O'Dea K, Holman RT. Diets rich in lean beef increase the eicosatrienoic, arachidonic, eicosapentaenoic and docosapentaenoic acid content of plasma phospholipids. Lipids 1994;29: 337-43.
28. Roshani F, Sanders TAB. Assessment of fatty acid intakes in vegans and omnivores. Human Nutr: Applied Nutr 1984;38A:345-54.
29. Mann NJ, Johnson LJ, Warrick G, Sinclair AJ. The effect of short-term diets rich in fish, red meat or white meat on thromboxane and prostacyclin levels in humans Lipids 1997;33:635-44.
30. Berner LA. Roundtable discussion on milk fat, dairy foods and coronary heart disease risk. J Nutr 1993;123:1175-84.
31. Sinclair AJ, Mann NJ. Short-term diets rich in arachidonic acid influence plasma phospholipid PUFA levels and prostacyclin and thromboxane production in humans. J Nutr 1996;126:1110S-14S.
32. Nelson GJ, Schmidt PC, Bartolini G, Kelley DS, Kyle D. The effect of dietary arachidonic acid on platelet function, platelet fatty acid composition and blood coagulation in humans. Lipids 1997;32:421-6.
33. Ferretti A, Nelson GJ, Schmidt PC, Bartolini G, Kelley DS, Flanagan VP. Increased dietary arachidonic acid enhances the synthesis of vasoactive eicosanoids. Lipids 1997;32:435-40.