National Centre of Excellence in Functional Foods

FOOD, HEALTH AND NUTRITION: WHERE DOES CHICKEN FIT?

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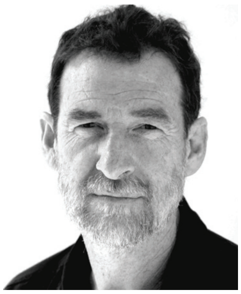

The Australian population suffers from a range of diet related diseases, particularly obesity and type 2 diabetes, which GPs and health care professionals need to help address.

High protein diets may play a significant role in helping overweight and obese subjects lose weight and maintain weight loss. Chicken is a key component of today's diet, with about 33 per cent of Australians who eat chicken doing so at least three times a week, and can contribute significantly to a high protein diet. Lean chicken can also contribute to a healthy eating pattern even if weight loss is not required.

Chicken can be very low in fat and provides essential vitamins and minerals, particularly niacin, vitamin A and vitamin E and magnesium, which should encourage GPs to recommend it to patients in their practices when reviewing and discussing an overall balanced diet.

This report aims to broaden the understanding of where chicken fits, nutritionally, in the Australian diet and what that means to the health of Australians. Chicken is generally recognised as a low fat protein source. The fact that it also provides a range of other valuable nutrients is less well known and this report fills this information gap.

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Competing Interests
None identified.

ABSTRACT

FOOD, HEALTH AND NUTRITION: WHERE DOES CHICKEN FIT?

The link between diet and health is important, given the prevalence of diet related disease, including obesity, in the Australian population. Consumers need to be able to discriminate between foods based on the nutritional contribution of each to a healthy diet. They also need to be able to discriminate between foods in a broader context, considering issues such as food safety, how the food is produced and the environmental consequences of its production. This review outlines the position of chicken in the Australian diet from a health, consumer and environmental perspective.

Chicken can contribute to a healthy eating pattern. It is an important source of protein. The predominant cut consumed, breast meat, is low in fat, with its fat profile favouring polyunsaturated, rather than saturated, fatty acids. Chicken meat delivers essential vitamins and minerals and is the most affordable meat source. As with all meats, care is required with preparation but consumers find it easy to use. The Australian chicken industry is a significant contributor to the economy and, of the land based animal production systems, chicken meat production creates the least environmental burden.

Keywords: Chicken meat, health, consumers, food safety, environmental sustainability

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This work was supported by a project grant funded by the Australian Chicken Meat Federation. The Australian Chicken Meat Federation (ACMF) is the peak coordinating body for participants in the chicken meat industry. It was formed in 1964 and is recognised by the Australian Government. It works to develop and promote the industry's capabilities and represents the industry's interests at the national level in matters regarding international trade, quarantine, animal health, biosecurity, food standards and food safety, and animal welfare.

INTRODUCTION

As science exposes the fine detail of the food-health relationship, practitioners need information to help guide patients in making healthy food choices. With the exception of breast milk in infancy, no single food provides all the nutritional requirements to sustain and protect the human body. The answer lies in the total diet, but achieving a balanced diet requires an ability to discriminate between foods. From a nutritional perspective this means appreciating the health and disease impacts of dietary patterns, individual foods, and specific food components. From a consumer perspective it also means addressing personal and cultural values, ranging from taste preferences to environmental issues. Moving from an individual to a broader social context brings industry into perspective, as the provider of food. This review considers the case of chicken and the health of Australians, and, in moving through the various perspectives, addresses the question: where does chicken fit?

CHICKEN, HEALTH AND DIETARY PATTERNS

The links between health and dietary patterns are studied by various means, with intervention studies providing the highest level of evidence for dietary recommendations. Food choice remains at the heart of the research, but the focus can shift from a positive stance (ensuring adequate nutrition) to a negative one (reducing disease risk). Obesity is arguably the most significant food related health issue for Australians today. Overweight and obesity are major predisposing factors for diseases such as diabetes, hypertension, coronary heart disease and certain forms of cancer [1]. Management of overweight, especially before the development of these complications, is particularly relevant for Australians, with more than half of the adult population [2] and over a fifth of children aged 5–17 years being overweight or obese [3].

THE ROLE OF CHICKEN IN HEALTHY DIETS

Chicken delivers important nutrients

Lean chicken meat is an excellent source of protein, has a favourable ratio of unsaturated to saturated fatty acids and delivers essential vitamins and minerals. The health impact of chicken is linked to its nutritional composition and the interactions of those nutrients within the food. The nutrient composition of stir-fried chicken breast meat is compared with stir-fried cuts of other meats in Table 1. Furthermore, the nutrient composition of different cuts of lean Australian chicken meat, raw and cooked, is shown in Appendix 1.

Compared to other meat sources, stir-fried lean chicken breast has the lowest total fat content. The type of fatty acids contributing to this total fat profile should be noted. Stir-fried lean chicken breast contains more than 55% unsaturated fatty acids (monounsaturated and polyunsaturated) and one of the lowest levels of saturated fatty acid when compared with other stir-fried meat sources. Stir-fried chicken breast also appears to be higher in a number of micronutrients, although removal of the skin from the meat reduces these figures considerably. Stir-fried lean chicken breast is an excellent source of niacin equivalents, providing higher amounts than each of the other lean stir-fry cuts of meat. For other macro- and micronutrients, stir-fried lean chicken breast has a similar nutrient profile to lean stir-fried cuts of beef, lamb, pork and veal [4], although it contains relatively little iron and less zinc than the cuts of beef, lamb, pork and veal used in this comparison.

The nutrient profile of chicken meat has been shown to be amenable to manipulation by different feeding practices. For example, dietary supplements such as garlic, copper, omega-3 fatty acids and dehydrated alfalfa have been used in an attempt to change the fat and cholesterol content of poultry meat [5-9]. It is possible to change the fatty acid profile of chicken meat to increase its omega-3 fatty acid content by feeding chickens either linseed or rapeseed grain extract (tenfold increase in alpha-linoleic acid, ALA), or fish extract or algae oils (seven-fold increase in long chain docosahexaenoic acid, DHA) [10].

Such innovations in the production system may further increase the potential benefits of chicken meat in the diet in years to come. The nutrient composition of Australian chicken meat is also affected to some extent by the type (breed) of chicken, butchering technique (for example, the amount of trim), age and sex of the bird.

At present there appears to be no conclusive body of data demonstrating significant differences between the nutritional composition of conventional, organic, free-range and kosher chicken meat.

Chicken contributes to nutrient requirements

To establish how chicken can contribute nutritionally in the context of a whole diet, the nutritional values for a serve of chicken meat can be compared with the recommended dietary intakes of Australians [11]. When this was done for all age groups and for both genders, baked lean chicken breast alone was found to provide between 110 and 147% of daily niacin requirements (Table 2; with Appendix 2 providing further information regarding each of the main chicken cuts). Lean chicken breast was also found to be an important source of protein, providing more than 50% of the recommended dietary intake (RDI) for all ages except 14-18 year old males who have higher protein requirements. For pre-pubescent children, lean chicken breast is a good source of magnesium (11.5-18.8%) and zinc (10-13.3%), and provides reasonable amounts of riboflavin (9.2-12.2%).

Thus, from a nutritional perspective, chicken can fulfil a valuable role in the Australian diet. Lean chicken meat is a good source of protein, and its high protein content may support efforts at weight management. It is also a low cholesterol meat choice that contains essential fatty acids and is a source of minerals and essential vitamins, particularly vitamin E, vitamin A equivalents and thiamin, and delivers significant amounts of niacin equivalents, an important nutrient for energy metabolism [11].

Review of research on potential health benefits

An initial literature search conducted in PubMed using the search terms "chicken and health" identified 361 abstracts. Of these, most were not related to health benefits of chicken in humans, but referred to topics such as bacterial contamination and microbiological safety (n=84 abstracts), parasites, viral agents and environmental toxins (n=35), avian influenza (n=37), livestock production (n=28), food security and food choices (n=36), food safety and food handling (n=17), chicken eggs (n=13), embryonic development (n=8), while the majority were not related to chicken per se (n=84). Only 19 abstracts were selected from this search and six full papers included in the review. The search was then refined to include the terms "chicken intake" and "health or diabetes or cancer or obesity or weight control or cholesterol or cardiovascular disease." This strategy identified 101 abstracts of which 46 were selected, and N=32 full papers included in the review. A summary of the papers is shown in Appendix 3.

Research published in the scientific literature between 1996 and 2007 relating to the potential health benefits of chicken meat identified that major research activity relates to the role of chicken in weight loss and reduction of cardiovascular risk factors as well as the chicken consumption and risk of cancer, particularly colorectal cancer.

Weight loss and cardiovascular disease risk factors

High protein diets have proven effective in weight loss, both in the short [12-14] and longer term [15-17], suggesting a role for foods that deliver high quantities of protein, such as chicken.

Two studies examining the specific effect of chicken on weight loss were identified by the current literature search. Both studies were randomized controlled trials of high quality and validity. In one study of 54 postmenopausal women comparing hypocaloric diets of high protein (provided mainly by chicken or beef) and high carbohydrate diets, a similar reduction in mean energy intake was achieved between the groups over nine weeks [18].

Table 1: Nutrient composition of stir-fried (cooked) lean chicken breast meat compared with stir-fried cuts of beef, lamb, pork and veal. Based on 100g serve

		Chicken breast**	Beef stir-fry strips*	Trim lamb stir-fry strips**	Pork leg strips*	Veal stir-fry strips**
Energy	kJ	520.00	644.00	770.00	557.00	620.00
Total Protein	g	28.60	30.90	28.00	29.50	29.90
Total fat***	g	0.90	3.20	7.90	1.50	3.00
Total SFA[a]	g	0.30	1.00	2.80	0.60	1.20
Total MUFA[b]	g	0.40	1.40	3.10	0.60	0.90
Total PUFA[c]	g	0.10	0.40	0.90	0.20	0.50
C18:2 n–6 (linoleic acid)	g	0.11	0.15	0.46	0.15	0.18
C18:2 n–3 (alpha-linolenic acid)	g	0.01	0.03	0.14	0.01	0.04
C22:6 n–3 (docosahexanoic acid)	mg	3.00	8.00	25.00	3.00	15.00
Cholesterol	mg	62.00	77.00	96.00	70.00	99.00
Vitamin E[d]	mg	0.50	0.70	0.20	0.00	0.30
Vitamin A[e]	μg	5.00	2.00	8.00	0.00	2.00
Iron	mg	0.40	2.80	3.70	1.00	2.10
Magnesium	mg	33.0	23.00	27.00	27.00	37.00
Niacin equivalents	mg	20.60	9.40	11.80	12.10	15.10
Riboflavin	mg	0.09	0.11	0.34	0.26	0.20
Thiamin	mg	0.12	0.03	0.15	0.96	0.10
Zinc	mg	0.70	7.20	2.60	2.40	5.80

[a] Saturated fatty acids, [b] Monounsaturated fatty acids, [c] Polyunsaturated fatty acids, [d] Alpha-tocopherol equivalents, [e] Retinol equivalents. Data sourced from NUTTAB 2006 online [4]
*Separable lean, **Lean, ***Total fat ≠ SFA + MUFA + PUFA; this may be the result of not including meat juices from the cooking in the chemical analysis and rounding factors.

Table 2: Percentage contribution of 100g lean baked chicken breast to nutrient requirements for Australians [11] (50g portion in the case of children up to the age of 8)

	All		Males				Females							
Nutrient	1-3yrs[a]	4-8yrs[a]	9-13yrs	14-18yrs	19-70yrs	>70 yrs	9-13yrs	14-18yrs	19-70yrs	19-30yrs	31-70yrs	19-50yrs	51-70yrs	>70yrs
Total protein [b]	103.71	72.60	72.60	44.68	45.38	35.85	82.97	64.53	63.13					50.95
Essential fatty acids														
Linoleic acid (omega 6) [c]	4.84	3.03	4.84	4.03	3.72	3.72	6.05	6.05	6.05					6.05
Alpha-linolenic acid (omega 3) [c]	3.50	2.19	3.50	2.92	2.69	2.69	4.38	4.38	4.38					4.38
Minerals														
Potassium [c]	8.00	6.96	10.67	8.89	8.42	8.42	12.80	12.31	11.43					11.43
Magnesium [b]	18.75	11.54	12.50	7.32	7.50 [a] 7.14 [b]	7.14	12.50	8.33		9.68 [d]	9.38 [e]			9.38
Iron [b]	2.78	2.5	6.25	4.55	6.25	6.25	6.25	3.33				2.78 [f]	6.25 [g]	6.25
Zinc [b]	13.33	10.00	13.33	5.71	5.71	5.71	13.33	11.43	10.00					10.00
Vitamins														
Vitamin E [c,h]	2.20	1.84	2.44	2.20	2.20	2.20	2.75	2.75	3.14					3.14
Niacin equivalents [b]	147.50	110.63	147.50	110.63	110.63	110.63	147.50	126.43	126.43					126.43
Riboflavin [b]	11.00	9.17	12.22	8.46	8.46	6.88	12.22	10.00	10.00					8.46
Thiamin [b]	5.00	4.17	5.56	4.17	4.17	4.17	5.56	4.55	4.55					4.55

[a] 50g portion, [b] Recommended Dietary Intake (RDI), [c] Adequate intake (AI), [d] 19-30, [e] 31-70 years, [f] 19-50 years, [g] 51-70 years, [h] Alpha-tocopherol equivalents

Here, the chicken diet (but not the beef diet) showed a significantly higher weight and body mass index loss than the high carbohydrate diet ((representing losses of 7.9 (SD = 2.6) and 5.6 (1.8)kg respectively (P<0.05)). However, the weight loss was not statistically different between the chicken and beef diet groups. These findings were confirmed in a similar 12-week study in which weight loss did not differ according to allocation to a diet where the predominant protein source was either lean beef or chicken [19]. This group concluded that weight loss and improved lipid profile effects were best achieved by high dietary protein regardless of the comparative food source. Anecdotally, red meat is often perceived to be more filling than white meat (chicken and fish). However, an older appetite study also supports the finding of a lack of difference by demonstrating that the postprandial satiety response to either beef or chicken did not differ [20].

Chicken has a role, within the context of a low fat eating plan, in cholesterol-lowering diets. Incorporation of either chicken, lean beef or lean fish in an American Heart Association diet showed that plasma total and LDL cholesterol can be reduced by 7–9% over a short period of time (26 days) in hypercholesterolaemic men, irrespective of the protein source [21]. These findings confirm the findings of earlier research [22].

Whole dietary models are also of interest in determining the position of individual foods in protecting cardiovascular health. The DASH diet, for example, has been shown to be effective in lowering blood pressure, particularly in people with hypertension and in African Americans [23]. This diet emphasises chicken and fish, and includes nuts and low-fat dairy products, alongside high proportions of fruits and vegetables.

From a more general perspective, further information on the position of individual foods can be considered in terms of other dietary relationships. In a large US cross-sectional survey of children (n=4,802) and adults (n=9,460), for example, the inclusion of an average intake of less than 28g of chicken over two days was associated with lower discretionary fat intakes compared to non-consumers or consumers of larger portions (≥28g cooked lean chicken equivalent per two days) [24] (P<0.05). This highlights the importance of portion size, a key component of guidance on food choice.

Chicken and cancer risk

In 2007, the World Cancer Research Fund (WCRF) published a recommendation that intake of red meat (beef, pork, lamb and goat) should be limited, and in those who consume red meat, less than 500g a week is the dietary target [34]. WCRF also recommended that processed meats should be avoided. Links between diet and cancer are difficult to ascertain because by nature there is a reliance on associations reported in observational studies. The WCRF report determined that the evidence was too limited in amount, consistency or quality to draw any conclusions regarding poultry consumption and cancer risk [25]. A brief indication of why this is the case can be seen from a summary of published studies (accessed on PubMed) in the period 1996-2007 (see Table 3).

Of seven papers identified in a systematic search on colorectal cancer risk, five found a protective association with increased chicken consumption [26-30], one found no association [31], while another found a positive association between cooking method for chicken (i.e. preferring darkly browned surfaces) and cancer risk [32]. For breast cancer, increased chicken consumption was either associated with no additional risk [33] [34] or was found to be protective [35] [36], regardless of cooking method [37]. One case-control study found that postmenopausal women with oestrogen receptor-positive tumours were more likely to consume a dietary pattern that included chicken, along with other foods, than controls without cancer [38]. For bladder cancer, an increased risk was associated with skinless chicken consumption of more than five times per week, but this was not found for chicken consumed with skin [39]. It was hypothesised that chicken without skin contains more heterocyclic amines than chicken cooked with skin. A large prospective cohort study (N=110,792) from Japan found a significant inverse association between hepatocellular mortality and chicken consumption in men [40], and another case-control study from China also reported protective effects of chicken consumption on hepatocellular cancer risk [41]. Two studies on gastric cancer found either a decreased mortality risk associated with chicken intake [42] or no association between chicken intake, including cooking method, and risk of adenocarcinoma of the stomach and oesophagus [43]. No association has been shown in a study investigating chicken consumption and ovarian cancer risk [44].

Despite a number of studies suggesting some protective effects of chicken meat against cancer, the overall evidence is not conclusive.

There is emerging evidence that the cooking method of meat is possibly more important than frequency of consumption of specific foods in determining risk of various cancers. In a study of pancreatic cancer risk, more cases than controls showed a preference to well-done meats, including bacon, grilled and pan-fried chicken [45]. Similarly, Norrish [46] and colleagues reported a weak and inconsistent association between meat doneness and increased risk of prostate cancer, but this was not significant for chicken. Thus while there is no conclusive evidence linking chicken meat with cancer or its prevention, cooking methods that generate carcinogenic compounds such as heterocyclic amines (HCA) and polycyclic hydrocarbons (produced when meats are cooked over an open flame or charred) deserve some attention. Reduced levels of HCA have been found in chicken that has been marinated before grilling [47]. Meats (beef patties) that are partially cooked in a microwave oven before being cooked by higher temperature methods also have lower levels of these compounds [48]. A review by Thomson [49] reported that the most important variables contributing to HCA formation are: cooking temperature (>150°C), cooking time (>2 min), cooking method (frying, oven grilling/broiling, barbecuing), and meat type. However, much of the evidence relating to the formation of HCAs and polycyclic hydrocarbons in various meats prepared using different cooking methods is inconsistent and reported absolute amounts of these compounds are highly variable between studies. Undoubtedly, further well-controlled studies are required to inform consumers of the best way to prepare meat in order to minimise health risks.

Table 3: Summary evidence table of studies identified in PubMed (1996–2007) on chicken and health

Health outcome	Study	In support of association?	Quality of study	Type of study/Comments	Classification of evidence
Weight loss	Mahon et al., 2007	No	High	RCT. Chicken vs. beef vs. CHO	Insufficient evidence
	Melanson et al., 2003	No	High	RCT. Chicken vs. beef; no control group	
Cancer					
Colorectal cancer	Sato et al., 2006	No association	High	Cohort study	Insufficient evidence
	Hu et al., 2007	Protective for chicken intake in men only	High	Case-control study	
	Navarro et al., 2004	Increased risk for chicken according to cooking method	Medium	Case-control study	
	Chiu et al., 2004	Decreased risk for chicken/turkey intake	Medium	Case-control study	
	Le Marchand et al., 1997	Decreased risk for chicken/turkey intake without skin	Medium	Case-control study	
	Phinney, 1996	Decreased risk for chicken intake	Medium	Review of epidemiological studies	
	Robertson et al., 2005	Decreased risk for chicken intake	High	Secondary analysis of dietary data in RCTs (cross-sectional)	
Pancreatic cancer	Li et al., 2007	Increased risk with increasing HCAs from meat, including chicken	Medium	Case-control study	Insufficient evidence
Breast cancer	Cui et al., 2007	Increased risk associated with chicken as part of "meat-sweet" pattern (shrimp, chicken, beef, pork, candy, desserts), but only in postmenopausal women with estrogen receptor-positive tumours	Medium	Case-control study	Insufficient evidence
	Delfino et al., 2000	Decreased risk for chicken intake, including well done, pan fried and barbecued chicken	Medium	Case-control study	
	Gertig et al., 1999	No risk associated with increased frequency of chicken intake	Medium-high	Case-control study	
	Ambrosone (30)et al., 1998	Decreased risk with higher poultry consumption in post-menopausal women only	Medium-high	Case-control study	
	Potischman et al., 1998	Slight increase (borderline significance) in risk for intake of chicken	High	Case-control study	
	Djuric et al., 1998	Suggests inverse association between poultry intake and oxidative DNA damage.	Low	Cross sectional survey	
Bladder cancer	Michaud et al., 2006	Elevated risks with chicken consumption without skin ≥ 5 times/wk compared to non-consumers of skinless. No associations for chicken with skin	High	Two large cohort studies	Probable evidence
Hepatocellular cancer (liver)	Kurozawa et al., 2004	Decreased risk in men without history of liver diseases. but not women (no risk)	High	Cohort study	Insufficient evidence
	Yu et al., 2002	Decreased risk	Could not obtain paper	Case-control study	
Ovarian cancer	Pan et al., 2004	No association of risk with chicken intake.	Medium	Case-control study	Insufficient evidence
Gastric cancer	Huang et al., 2000	Decreased mortality risk with chicken intake	Medium	Prospective prognostic study	Insufficient evidence
	Ward et al., 1997	Broiling or frying not associated with risk; too few data for roasted/BBQ chicken	Medium-low	Case-control study	
HCA intake and chicken	Bogen et al., 2007	PhIP intake attributable mostly to chicken. Increased risk for PhIP intake and highly elevated PSA	High	Clinic based cohort study (prostate cancer biomarker not disease outcome)	Insufficient evidence
	Knize et al., 2002	Higher excretion of PhIP metabolites from chicken after broccoli consumption, implying cancer protective effect of broccoli.	Low	Quasi-experimental	
	Thomson, 1999	BBQ chicken provided highest concentration of PhIP of all meats, but variable levels according to cooking method.	Medium	Review	
	Wong et al., 2005	Pan-fried and deep-fried chicken contributed significantly to HCA intake.	High	Cross-sectional	
	Byrne et al., 1998	Large variation in HCA intake	Low	Cross-sectional analysis of cohort dietary data	
Cardiovascular outcomes	Pala et al., 2006	Chicken consumption (included in "olive oil and salad" eating pattern) highest in hyper-lipidaemic and suggesting awareness of the (beneficial) dieting subjects, health consequences of these patterns	High	Cohort study	Insufficient evidence
	Sacks et al., 1999	DASH study which includes chicken reduces blood pressure	High	Mulitcentre randomised controlled parallel group feeding trial.	
	Sperber et al., 1996	Increased chicken consumption associated with total cholesterol decrease at community level	Low	2-year quasi-experimental study	
Immunity	Brian et al., 2006	Declines in interleukin-2 production with a chicken diet; the clinical significance of this finding is not known.	High	Randomised controlled trial	Insufficient evidence

FOOD SAFETY IS AN IMPORTANT CONSIDERATION

Safe food handling is a concern for all foods. From 1995 through 2000, 214 outbreaks of food borne disease were identified in Australia, affecting a total of 8,124 people [50]. Seventy-four of these outbreaks, involving 6,472 people, had a known aetiology. Bacterial disease was responsible for 61% of the outbreaks, with *Salmonella* being the most common pathogen (35% of outbreaks), followed by *Clostridium perfringens* (14%), ciguatera toxin (11%), scombrotoxin (3%) and norovirus (3%). There were 20 deaths attributed to food borne illness; salmonellosis and listeriosis were each responsible for eight (40%) of the deaths. Restaurants and commercial caterers were associated with the highest number of outbreak reports and cases, followed by hospitals and aged care facilities. The most frequently implicated vehicles in the 173 outbreaks with known vehicles were meats (30%), fish (16%), seafood (6%), salad (6%), sandwiches (5%) and eggs (4%). Chicken, the most frequently implicated meat, was associated with 27 (13%) of the outbreaks.

Food safety risks can be minimised by following some basic storage, preparation and cooking practices [51], as bacteria can become a problem if food is not stored and handled correctly. Chicken meat is a 'perishable' food, and therefore should not be kept at room temperature for more than two hours. Raw meats should be stored at a maximum temperature of 4°C or kept frozen below -15°C. Frozen chicken meat should always be thawed completely prior to cooking. Separate utensils should be used in preparation and cooking should ensure 75°C at the centre of the thickest part of the meat, producing clear juice at the end. Stuffing should be inserted loosely before, and removed immediately after cooking.

Chicken that is to be kept hot should be kept above 60°C and leftovers should be stored in the fridge for one to two days only or be frozen. Leftovers should be heated to at least 70°C for a minimum of two minutes. Although listeriosis is not rated a significant risk from chicken meat [52], in pregnancy chicken is best consumed hot immediately after cooking, and any leftovers stored in the fridge and used within a day of cooking or purchase [53].

INDUSTRY FACTS

Food safety and chicken

Food safety is paramount to both healthy eating and consumer confidence. The chicken meat industry participates in research and tracks best practice in animal husbandry and food handling with the aim of improving food safety. Through its participation in the government's Rural Industries Research and Development Corporation, industry is active in developing research strategies and priorities and funding research and development to address food safety issues.

Campylobacter and Salmonella are food-borne bacterial pathogens that can be found on chicken meat and are a potential risk with all types of meat. Any risk from these bacteria is completely eliminated if meat is cooked properly and care is taken not to contaminate other cooked foods or those to be eaten raw, such as salad.

On farm, sound husbandry practices in collecting, transporting and handling birds enhance both bird health and welfare and food safety for consumers.

During processing, audited quality assurance programs which identify and manage risk in food handling, such as the internationally recognised HACCP and quality assurance programs run by major chicken processors, help ensure consistency and high standards.

For consumers, industry supports communication initiatives to encourage safe food handling in the home, as well as providing information directly to consumers.

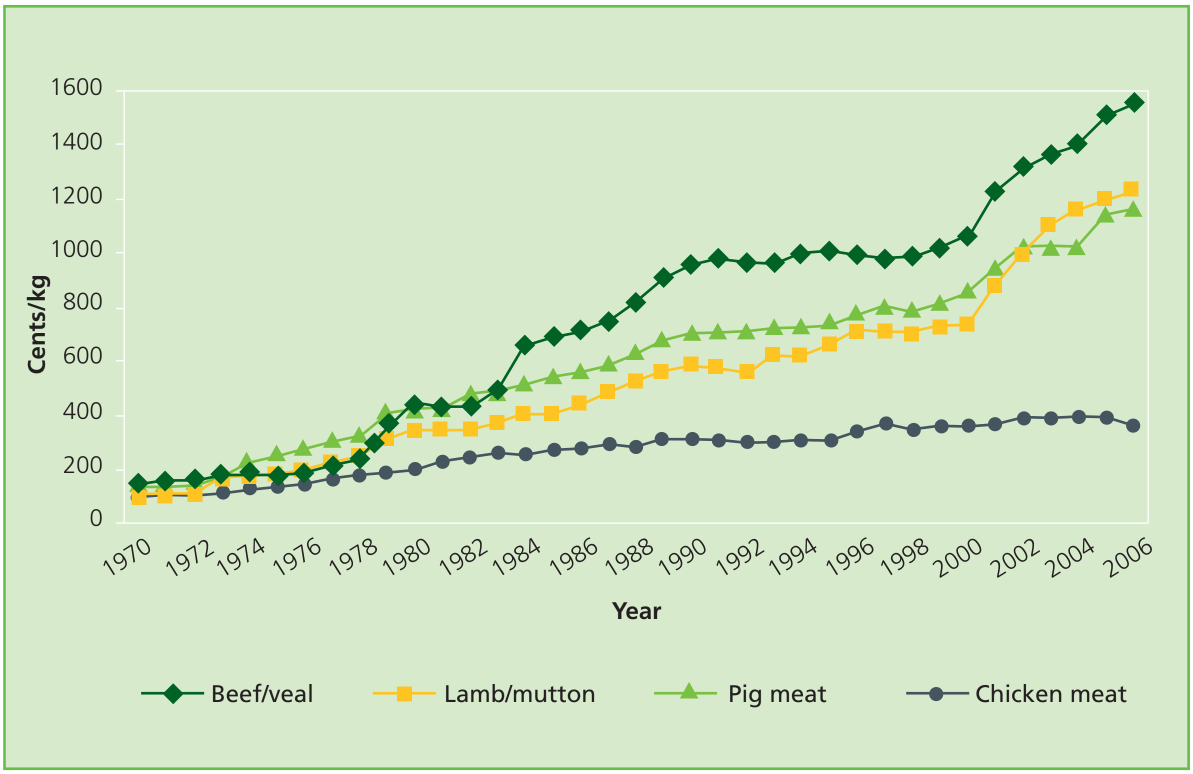
CONSUMER PERSPECTIVES ON CHICKEN

When it comes to meat, qualitative studies have found that freshness, sensory factors and perceived 'healthfulness' are the most important drivers of product choice [54]. Poultry tends to be perceived more favourably than beef or pork in terms of these attributes [54]. In Australia, producer efficiency has helped to keep wholesale prices low and some observers credit the success of chicken relative to other meats to its affordability. While the retail cost of beef, lamb and pork has steadily increased, particularly since 2000, the cost of chicken has remained remarkably stable (Figure 1) [55].

and, above all, chicken is versatile, which extended to its acceptance by vegetarian family members. Chicken is perceived as a particularly 'family friendly' food which contributes to easing the pressures on the family cook [56].

With increasing time pressures due to longer working hours and more women in the workforce, consumer demand for highly processed and convenience goods has driven chicken meat to be rapidly absorbed by the value-adding sector of the food industry, more so than other meats [57].

Figure 1: Retail prices of meat in Australia, 1970 – 2006 Source: Australian Bureau of Agricultural and Resource Economics, ABARE Australian Commodity Statistics, 2007 [55]



However, Dixon [56] argues that the reasons for the popularity of chicken are far more complex than being merely a pricing issue. Her focus group research showed that chicken is held in high esteem by Australian consumers. Among the explanations provided were: a personal liking of chicken meals; it is healthier than red meat; it is easy to prepare and easy to chew, which was a particularly important attribute with children;

The success of chicken meat with consumers also appears to be determined by its health image [54]. Compared to other meat types, chicken is perceived as healthier in terms of fat content and is considered to be a lean, low-fat food, particularly in the case of chicken breast fillets [58]. Consumers perceive that leanness of chicken meat can be assessed when purchasing it raw, enabling any skin or extraneous fat to be removed prior to cooking.

Chicken consumption also appeared to be motivated by a perceived need for weight loss. Australian consumers often express concerns about the chicken industry relating to their perception that growth hormones are used (whereas no hormones whatsoever are used in chicken meat production in Australia) and the conditions under which chickens are grown [56], with free range systems being seen as a more animal welfare friendly farming method.

These concerns are often enhanced by the misconception that meat chickens are raised in cages, which has never been the case.

INDUSTRY FACTS

Busting the myths behind today's chicken

Through generations of selective breeding and careful attention to optimal nutrition, today's meat chickens are a faster growing, larger and stronger bird.

No added hormones – hormones are not administered in any form; the use of added hormones in growing chickens in Australia has been banned for many decades.

Responsible use of antibiotics – antibiotics are used to prevent and treat disease and their use is carefully managed to minimise the development of resistance and to ensure that no residues are detectable in meat (i.e. any residue level must be below the very low level set in the Australian Standards published in the Australia New Zealand Food Standards Code). While some antibiotics used in human medicine are used to treat ill birds, antibiotics important to human health are not used for routine disease prevention. In addition, avoparcin and vancomycin, two antibiotics which have been identified as of particular concern in terms of antibiotic resistance development, are never used by the Australian chicken meat industry.

No cages – Meat chickens live on the floor of large sheds – they are never caged.

Organic and free range production – Free range and organic chickens are also housed in sheds but may also roam outside the shed for part of the day. Organic and free range chickens are not given antibiotics (i.e. birds that require antibiotic treatment can no longer be sold as free range or organic) and organic chickens are only given feed which has not been treated with agricultural chemicals.

Australian grown – Except for a small amount of fully cooked tinned or retorted product, all chicken eaten in Australia is grown in Australia.

Chickens for egg production – these are quite different birds to those raised for meat due to different breeding priorities. The egg industry operates as a separate industry with different production systems.

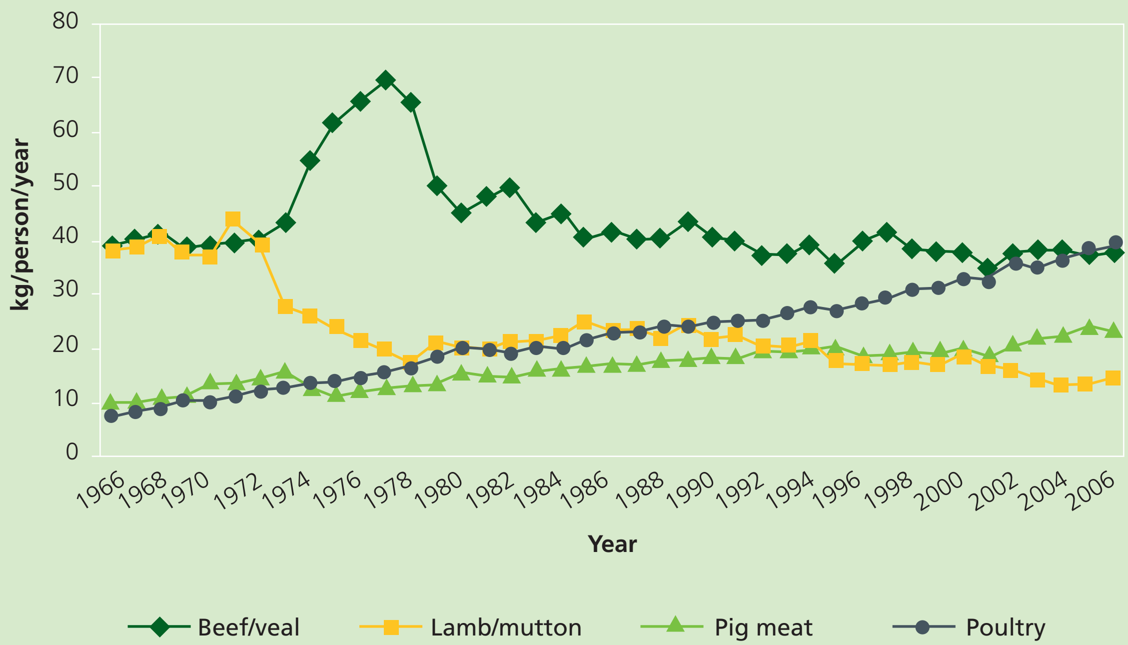
Consumers are choosing more chicken

Over the past 40 years chicken consumption has increased, elevating chicken meat from a position of marginal importance in Australian diets to rivalling beef as Australian consumers' favourite meat choice. The main changes in consumer preferences for meat sources of protein relate to an increased consumption of poultry and a gradual fall in consumption of sheep meat and beef [58] (Figure 2).

Australia is now one of the highest per capita consumers of chicken meat in the world [59]. In 2006, per person consumption of chicken meat was estimated by the ACMF to be 37.4kg, based on ABARE's poultry production statistics [55].

As well as an increased consumption of chicken in the Australian diet, there is a change in consumer demand regarding the type of chicken product. There is a rapid shift away from unprocessed raw chicken towards value-added products and cooked chicken products [60].

Figure 2: Consumption trends of poultry and other meats in Australia, 1966–2006 Source: Australian Bureau of Agricultural and Resource Economics, ABARE Australian Commodity Statistics, 2007 [55].



THE AUSTRALIAN CHICKEN MEAT INDUSTRY

It is thought that intensive poultry production began in the 1950s, although records only date back to the mid 1960's. Chicken meat production in Australia is a highly intensive industry; chickens are raised in large sheds which provide the birds with a stable environment protected from the elements; no meat chickens are grown in cages. The chicken meat industry is an important contributor to the national economy, with a Gross Value of Production (GVP) of $1.442 billion in 2006/07 (55).

The Australian Chicken Meat Federation (62) estimates that Australian consumers spend around $4.4 billion on chicken meat per annum. Australian chicken meat production was estimated to be 816,166 tonnes for 2007 (63). The Australian chicken meat industry has experienced rapid growth over past decades(61). Trends in chicken meat production (63) show a ten-fold increase between 1967 and 2007 (see Table 4).

Most chicken meat produced in Australia is consumed locally. Under Australian quarantine regulations, raw chicken meat cannot be imported. While importation of cooked chicken meat is permitted under very strict conditions and cooking protocols from a small number of countries, in practice importation of cooked chicken meat products is virtually zero (64).

Table 4: Trends in chicken meat production, poultry consumption and price of chicken meat in Australia

Year	Chicken meat produced (tonnes carcass weight/year)[a]	Consumption of poultry meat (kg/person/year)*[b]	Price (cents/kg chicken meat)[b]
1967	82,540	8.4	Not available
1977	205,524	15.6	174.5
1987	354,633	23.2	288.6
1997	512,244	29.3	365.9
2006		39.5†	357.1†
2007	816,166#		

* Chicken meat constitutes approx. 94.6% of all poultry meat (ACMF)

\# 2007 figures

† 2006 figures (2007 figures not available at time of publication)

a Chicken meat production statistics are sourced from the Australian Bureau of Statistics (ABS) Publication "Livestock Products, Australia" Catalogue No 7215.0 (63).

b Consumption and Price statistics are extracted from Australian Bureau of Agricultural and Resource Economics, ABARE Australian Commodity Statistics, 2007. Price estimates are formed by indexing forward from actual average prices of beef, lamb, mutton, pork and chicken during December quarter 1973, based on meat subgroup indexes of the consumer price index. These indexes are based on average retail prices of selected cuts (weighted by expenditure) in state capitals.

PRODUCTION SYSTEMS ARE SENSITIVE TO ENVIRONMENTAL ISSUES

Nutrient efficiency is regarded as an important criterion to describe the sustainability and the environmental impact of animal production systems [65]. The efficiency in converting feed into meat is commonly expressed as the feed conversion ratio (FCR). Simply expressed, this is the kilograms of feed consumed to produce one kilogram of live weight.

Through careful breeding and selection processes (90% of the improvement) and improved nutrition (10% of the improvement) the chicken meat industry has made great strides in improving the feed conversion ratio [66]. Compared to chicken meat production in 1957, a bird reared in 2001 required approximately one-third of the time (32 vs. 101 days) and less than one third of the amount of feed (FCR of 1.47 vs. 4.42) to reach a weight of 1.85kg [66].

While there are many ways of measuring environmental impact, two means – nutrient balance and life cycle assessment (LCA) – have emerged in recent times as methods of choice [67] [68]. Nutrient balance studies have shown that the nutrient gain in birds per unit of nutrient intake (i.e. the retention of nutrients) is higher for intensive poultry production than for free range and organic production systems [65]. LCA analyses a production system in a systematic manner – accounting for all inputs and outputs that cross the specified system boundary [68]. LCA has been extensively used in industrial processes but can be useful when applied appropriately to agricultural systems [68]. An LCA study of animal production systems in England and Wales has shown that poultry production is more environmentally efficient than pig, sheep and beef production systems [68]. The greater environmental efficiency of poultry production systems is attributed to the low overheads of poultry breeding (each hen produces around 250 progeny per year), the very efficient feed conversion of broilers and the high daily weight gain of the broiler. An LCA study of agricultural production systems in the US also demonstrated that chicken meat is the most energy and water efficient land-based animal protein production system [69].

There is considerable research investment devoted to ensuring that nutrients provided in the feed of meat chickens are at levels that are not only beneficial for the chicken, but that are not likely to cause environmental problems when poultry manure or litter is applied to agricultural land. For example, phosphorous is a key mineral in animal feeds[70], however excess phosphorous in the environment can potentially be transported to aquatic systems and cause problems such as excessive plant growth, reduction in oxygen levels and fish die-offs [71]. The use of phytase enzymes in broiler diets reduces the need for supplemental phosphorous by around 15% [72] [73]. Similarly, research has shown that the use of highly bioavailable mineral proteinates, as opposed to inorganic salts, as a source of trace minerals [74] allows a major reduction in supplementation levels of minerals such as zinc. The research has shown that the reductions may be as high as 80% with no adverse consequences on the health, welfare or growth of the broilers [74].

The Australian chicken meat industry is committed to both maintaining and improving the environmental footprint of the industry, as demonstrated at several levels (Box 1).

INDUSTRY FACTS

What are the main differences between conventional, certified free-range and certified organic chicken?

All meat chickens, be they conventional, free range or organic, are raised in barns where they live on the floor; never in cages

Free range chickens have to have access to an outdoor space during the day once they reach 3 weeks of age. They cannot be treated with antibiotics. They have more space available per bird than at conventional chicken farms. They are the same strain of chicken than used in conventional production and they are fed the same feed. They are 35 to 55 days old when harvested, the same age as conventionally raised chickens.

Organic chickens are fed only organic feed (no synthetic fertiliser, herbicide or pesticide used in its production). They are given access to an outdoor space during the day after 10 days of age. They cannot be treated with antibiotics. They are provided with more space than conventional and free range chickens. They grow more slowly and are between 65 and 80 days old when harvested.

PRODUCTION SYSTEMS ARE SENSITIVE TO ENVIRONMENTAL ISSUES CONTINUED

Box 1- Industry commitment to maintaining and improving the environmental footprint of the chicken meat industry

- At the producer level, the industry has been pro-active in identifying opportunities for improving the eco-efficiency of the industry. For example, the Queensland Chicken Growers Association has been a partner, along with the Queensland Environmental Protection Agency and the UNEP Working Group for Cleaner Production, in a project that has identified potential savings in lighting, ventilation, heating and water use [75]. In Victoria, chicken meat growers have, in partnership with the Victorian Department of State and Regional Development and the Mornington Peninsula Shire Council, developed the Chicken Care Program – a comprehensive program which amongst other activities has identified best practices in environmental management and provided tools to assist in the implementation of these best practices [76].

- At the national level, the industry has a National Environmental Management System that comprises a detailed Manual of Good Environmental Practice and tools to enable the development of a farm-specific Environmental Management Plan [77].

- Research investment of the industry is facilitated through two research mechanisms – The Rural Industries Research and Development Corporation (RIRDC) Chicken Meat Program (http://www.rirdc.gov.au/programs/cm.html) and the Australian Poultry CRC (http://www.poultrycrc.com.au).

  The Poultry CRC has a major sub-program of research on the impact of poultry production on the environment - specifically developing strategies to ensure that dust and odour emissions are managed appropriately. The RIRDC Chicken Meat Program has a major focus on ensuring that litter is recognised as a valuable by-product that can be used in a safe and sustainable manner.

CONCLUSION

Perhaps more then ever today, consumers need to be able to discriminate between foods based on health and wellbeing values. This review has shown that chicken is an excellent source of protein, low in fat and is nutrient dense. Nutrient dense protein foods are important in Australian diets today, not only for growth and development, but possibly also in weight management. As with similar foods, safe handling is important, but chicken is easy to prepare and liked by consumers. The Australian chicken meat industry has experienced rapid growth over the past forty years and continues to invest in research to ensure production systems work with greatest environmental efficiency. These positive attributes will ensure that chicken maintains its strong position in the Australian diet, supporting the health and wellbeing of Australian families.

INDUSTRY FACTS

Avian influenza – it's not in your food

Two very different diseases are often referred to as avian influenza (or bird flu) – a 'real' one which infects chickens and other birds (and only on very rare occasions infects humans), and a 'hypothetical' human disease which is more correctly referred to as a human influenza pandemic.

Bird disease: In recent years a highly pathogenic strain, H5N1, has spread widely among poultry in Asia and some other countries, but not in Australia. While it has infected a small number of humans under exceptional circumstances, it is not easily transmitted between humans. The likelihood of an outbreak of this strain of avian influenza in Australian poultry is extremely low. Furthermore, a high level of preparedness and past experience with AI outbreaks provide confidence that should the H5N1 strain, or any other AI strain, get into a local flock, it would be identified and eradicated quickly.

In the event of an outbreak in Australian poultry, chicken meat from infected birds would not reach consumers. It is also reassuring to know that even if chicken meat was contaminated, the virus would be destroyed during normal cooking.

Human disease: There are concerns about a hypothetical human influenza pandemic, which may occur if an animal influenza virus mutates to one that transmits easily between humans. As humans would have very limited or no immunity to such a new strain it is anticipated that this could lead to a human influenza pandemic. At this point, it would no longer be a bird disease. A human influenza pandemic still remains a hypothetical risk; there is no evidence that the bird virus has mutated to a virus transmissible by humans at any time since the H5N1 virus emerged over 10 years ago.

There is only a remote possibility of a human pandemic influenza originating in Australia. International travel by infected people is the more likely route for the introduction of a hypothetical human pandemic influenza virus into Australia.

REFERENCES

1. World Health Organization WHO/FAO. Diet, Nutrition and the Prevention of Chronic Diseases. Report of a Joint WHO/FAO Expert Consultation. WHO Technical Report Series 916. Geneva; 2003.
2. Barr E, Magliano D, Zimmet P, Polkinghorne K, RC RA, Dunstan D, et al. AusDiab 2005. The Australian Diabetes, Obesity and Lifestyle Study. Melbourne: International Diabetes Institute; 2006.
3. Magarey A, Daniels L, Boulton J. Prevalence of overweight and obesity in Australian children and adolescents: reassessment of 1985 and 1995 data against new standard international definitions. . Medical Journal of Australia. 2001;174:561-4.
4. Food Standards Australia New Zealand. NUTTAB 2006 Online version. 2008 [cited 2008 1 February]; Available from: http://www.foodstandards.gov.au/monitoringandsurveillance/nuttab2006/onlineversionintroduction/onlineversion.cfm
5. Ayerza R, Coates W, Lauria M. Chia seed (Salvia hispanica L.) as an -3 fatty acid source for broilers: Influence on fatty acid composition, cholesterol and fat content of white and dark meats, growth performance and sensory characteristics. Poult Sci. 2002;81:826-37.
6. Chowdhury S, Chowdhury S, Smith T. Effects of dietary garlic on cholesterol metabolism in laying hens. Poult Sci 2002;81:1856-62.
7. Konjufca V, Pesti G, Bakalli R. Modulation of cholesterol levels in broiler meat by dietary garlic and copper. Poult Sci. 1997;76:1264-71.
8. Matsuura H. Saponins in garlic as modifiers of the risk of cardiovascular disease. J Nutr. 2001;131:1000S -5S.
9. Pesti G, Bakalli R. Studies on the feeding of cupric sulfate pentahydrate and cupric citrate to broiler chickens. Poult Sci. 1996;75:1086-91.
10. Bourre J. Where to find omega-3 fatty acids and how feeding animals with diet enriched in omega-3 fatty acids to increase nutritional value of derived products for human: what is actually useful ? J Nutr Health Aging. 2005;9(4):232-42.
11. National Health and Medical Research Council. Nutrient Reference Values for Australia and New Zealand, including recommended dietary intakes. Canberra; 2006.
12. Astrup A. The satiating power of protein–a key to obesity prevention? Am J Clin Nutr. 2005; 82(1):1-2.
13. Halton T, Hu F. The effects of high protein diets on thermogenesis, satiety and weight loss: a critical review. J Am Coll Nutr. 2004;23:373-85.
14. Hu F, Stampfer M, Manson J. Dietary protein and risk of ischemic heart disease in women. Am J Clin Nutr. 1999;70:221-7.
15. Clifton P, Keogh J, Noakes M. Long-term effects of a high-protein weight-loss diet. Am J Clin Nutr. 2008;87:23-9.
16. Due A, Toubro S, Skov A, Astrup A. Effect of normal-fat diets, either medium or high in protein, on body weight in overweight subjects: a randomised 1-year trial. Int J Obes Relat Metab Disord. 2004;28:1283-90.
17. McAuley K, Smith K, Taylor R, McLay R, Williams S, Mann J. Long-term effects of popular dietary approaches on weight loss and features of insulin resistance. . Int J Obes (Lond) 2006;30:342-9.
18. Mahon A, Flynn M, Stewart L, McFarlin B, Iglay H, Mattes R, et al. Protein intake during energy restriction: effects on body composition and markers of metabolic and cardiovascular health in postmenopausal women. J Am Coll Nutr. 2007; 26(2):182-9.
19. Melanson K, Gootman J, Myrdal A, Kline G, Rippe J. Weight Loss and Total Lipid Profile Changes in Overweight Women Consuming Beef or Chicken as the Primary Protein Source. Nutrition. 2003;19:409-14.
20. Uhe A, Collier G, O'Dea K. A comparison of the effects of beef, chicken and fish protein on satiety and amino acid profiles in lean male subjects. J Nutr. 1992;122:467-72.
21. Beauchesne-Rondeau E GA, Bergeron J, Jacques H. Plasma lipids and lipoproteins in hypercholesterolaemic men fed a lipid-lowering diet containing either lean beef, lean fish or poultry. . Am J Clin Nutr. 2003;77:579-93.
22. Scott L, Dunn J, Pownall H. Effects of beef and chicken consumption in plasma lipid levels in hypercholesterolaemic men. Arch Intern med 1994;154:1261-7.
23. Sacks F, Appel L, Moore T, Obarzanek E, Vollmer W, Svetkey L, et al. A dietary approach to prevent hypertension: a review of the Dietary Approaches to Stop Hypertension (DASH) Study. Clin Cardiol 1999;22(7 Suppl):III6-10.
24. Guenther P, Jensen H, Batres-Marquez S, Chen C. Sociodemographic, knowledge, and attitudinal factors related to meat consumption in the United States. J Am Diet Assoc. 2005;105(8):1266-74.
25. WCRF. Food, Nutrition, Physical Activity and the Prevention of Cancer: a Global Perspective. .Washington DC: AICT: World Cancer Research Fund / American Institute for Cancer Research; 2007.
26. Chiu B, Gapstur S. Changes in diet during adult life and risk of colorectal adenomas. Nutr Cancer. 2004;49(1):49-58.
27. Hu J, Mery L, Desmeules M, Macleod M. Canadian Cancer Registries Epidemiology. Diet and vitamin or mineral supplementation and risk of rectal cancer in Canada. Acta Oncol 2007;46(3):342-54.
28. LeMarchand L, Wilkens L, Hankin J, Kolonel L, Lyu L. A case-control study of diet and colorectal cancer in a multiethnic population in Hawaii (United States): lipids and foods of animal origin. Cancer Causes Control. 1997;8(4):637-48.
29. Phinney S. Metabolism of exogenous and endogenous arachidonic acid in cancer. Adv Exp Med Biol. 1996;399:87-94.
30. Robertson D, Sandler R, Haile R, Tosteson T, Greenberg E, Grau M, et al. Fat, fiber, meat and the risk of colorectal adenomas. Am J Gastroenterol. 2005;100(12):2789-95.
31. Sato Y, Nakaya N, Kuriyama S, Nishino Y, Tsubono Y, Tsuji I. Meat consumption and risk of colorectal cancer in Japan: the Miyagi Cohort Study. Eur J Cancer Prev. 2006;15(3):211-8.
32. Navarro A, Muñoz S, Lantieri M, Diaz MdP, Cristaldo P, Fabro Sd, et al. Meat cooking habits and risk of colorectal cancer in Córdoba, Argentina. Nutrition 2004;20(10):873-7.
33. Gertig D, Hankinson S, Hough H, Spiegelman D, Colditz G, Willett W, et al. N-acetyl transferase 2 genotypes, meat intake and breast cancer risk. Int J Cancer. 1999;80(1):13-7.
34. Potischman N, Weiss H, Swanson C, Coates R, Gammon M, Malone K, et al. Diet during adolescence and risk of breast cancer among young women. J Natl Cancer Inst. 1998;90(3):226-33.
35. Ambrosone C, Freudenheim J, Sinha R, Graham S, Marshall J, Vena J, et al. Breast cancer risk, meat consumption and N-acetyltransferase (NAT2) genetic polymorphisms. Int J Cancer. 1998;75(6):825-30.
36. Djuric Z, Depper J, Uhley V, Smith D, Lababidi S, Martino S, et al. Oxidative DNA damage levels in blood from women at high risk for breast cancer are associated with dietary intakes of meats, vegetables, and fruits. . J Am Diet Assoc. 1998;98(5):524-8.
37. Delfino R, Sinha R, Smith C, West J, White E, Lin H, et al. Breast cancer, heterocyclic aromatic amines from meat and N-acetyltransferase 2 genotype. Carcinogenesis. 2000;(4):607-15.
38. Cui X, Dai Q, Tseng M, Shu X, Gao Y, Zheng W. Dietary patterns and breast cancer risk in the shanghai breast cancer study. Cancer Epidemiol Biomarkers Prev 2007;16(7):1443-8.
39. Michaud D, Holick C, Giovannucci E, Stampfer M. Meat intake and bladder cancer risk in 2 prospective cohort studies. Am J Clin Nutr. 2006;84(5):1177-83.
40. Kurozawa Y, Ogimoto I, Shibata A, Nose T, Yoshimura T, Suzuki H, et al. Dietary habits and risk of death due to hepatocellular carcinoma in a large scale cohort study in Japan. Univariate analysis of JACC study data. Kurume Med J. 2004;51(2):141-9.
41. Yu S, Huang X, Koide T, Cheng G, Chen G, Harada K, et al. Hepatitis B and C viruses infection, lifestyle and genetic polymorphisms as risk factors for hepatocellular carcinoma in Haimen, China. Jpn J Cancer Res. 2002;93(12):1287-92.

42. Huang X, Tajima K, Hamajima N, Kodera Y, Yamamura Y, Xiang J, et al. Effects of dietary, drinking, and smoking habits on the prognosis of gastric cancer. Nutr Cancer 2000;38(1):30-6.
43. Ward M, Sinha R, Heineman E, Rothman N, Markin R, Weisenburger D, et al. Risk of adenocarcinoma of the stomach and esophagus with meat cooking method and doneness preference. Int J Cancer. 1997;71(1):14-9.
44. Pan S, Ugnat A, Mao Y, Wen S, Johnson K. A case-control study of diet and the risk of ovarian cancer. Cancer Epidemiol Biomarkers Prev 2004;13(9):1521-7
45. Li D, Day R, Bondy M, Sinha R, Nguyen N, Evans D, et al. Dietary mutagen exposure and risk of pancreatic cancer. Cancer Epidemiol Biomarkers Prev. 2007;16(4):655-61.
46. Norrish A, Ferguson L, Knize M, Felton J, Sharpe S, Jackson R. Heterocyclic amine content of cooked meat and risk of prostate cancer. J Natl Cancer Inst. 1999;91(23):2038-44.
47. Salmon C, Knize M, Felton J. Effects of marinating on heterocyclic amine carinogen formation in grilled chicken. Food Chem Toxcol. 1997;35:433-41.
48. Felton J, Fultz E, Dolbeare F, Knize M. Effect of microwave pretreatment on heterocyclic aromatic amine mutagens/carcinogens in fried beef patties. Food Chem Toxicol. 1994;32(10):897-903.
49. Thomson B. Heterocyclic amine levels in cooked meat and the implication for New Zealanders. Eur J Cancer Prev. 1999;8(3):201-6.
50. Dalton C, Gregory J, Kirk M, Stafford R, Givney R, Kraa E, et al. Foodborne disease outbreaks in Australia, 1995 to 2000. Commun Dis Intell. 2004;28(2):211-24.
51. Australian Chicken Meat Federation (ACMF). Food safety. [cited 2008 31 January]; Available from:
http://www.chicken.org.au/page.php?id=9
52. Food Standards Australia and New Zealand. Primary production and processing standard for poultry meat. Draft assessment report of proposal P282 7 December 2005.
53. http://www.foodstandards.gov.au/newsroom/factsheets/factsheets 2001/listeriaandpregnancy630.cfmFSAaNZFLapbAAa.[cited (accessed 4th February 2008)];
54. Verbeke W, Viane J. Beliefs, attitude and behaviour towards fresh meat consumption in Belgium; empirical evidence from a consumer study. Food Quality and Preference. 1999;Vol. 10:437-45.
55. Australian Bureau of Agricultural and Resource Economics, ABARE Australian Commodity Statistics, 2007.
56. Dixon J. The Changing Chicken. Chooks, Cooks and Culinary Culture: Sydney UNSW Press; 2002.
57. Gatfield T. Australia's gone chicken! An examination of consumer behaviour and trends related to chicken and beef meats in Australia. J Food Products Marketing. 2006;12:29-43.
58. Australian Bureau of Statistics. Agriculture Australia, cat. No. 7113.0. Canberra
59. United States Department of Agriculture, Foreign Agricultural Service. Livestock and Poultry: World Markets and Trade. November 2007 also available as
http://www.fas.usda.gov/psdonline/circulars/livestock_poultry.pdf page 24 of 32 pages
60. Australian Chicken Meat Federation (ACMF). Personal communication. 2008.
61. Australian Bureau of Statistics. Year Book Australia 2007. No. 89. ABS Catalogue No. 1301.0. Canberra; 2007.
62. Australian Chicken Meat Federation (ACMF). Estimations on retail value. [cited 2008 5 February]; Available from:
http://www.chicken.org.au/page.php?id=4
63. Australian Bureau of Statistics. ABS Livestock Products, Australia, Cat. No. 7215.0. Canberra.
64. Department of Agriculture Fisheries and Forestry (DAFF). [cited 2008 29 January]; Available from:
http://www.daff.gov.au/agriculture-food/meat-wool-dairy/ilg/industries/chicken_meat
65. Kratz S, Halle I, Rogasik J, Schnug E. Nutrient balances as indicators for sustainability of broiler production systems. British Poultry Science. 2004;45:149-57.
66. Havenstein G, Ferket P, Qureshi M. Growth, livability, and feed conversion of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets. Poultry Science. 2003;82:1500-8.
67. Koelsch R. Evaluating livestock system environmental performance with whole-farm nutrient balance. Journal of Environmental Quality. 2005;34:149-55.
68. Williams A, Audsley E, Sandars D. Determining the environmental burdens and resource use in the production of agricultural and horticultural products. Main Report. Defra Research Project IS0205: Bedford: Cranfield University and Department of Environment, Food and Rural Affairs, 97 pp.; 2006.
69. Pimental D, Pimental M. Sustainability of meat-based and plant-based diets and the environment. Am J Clin Nutr. 2003;78:660S-3S.
70. McDonald P, Edwards R, Greenhalgh J, Morgan C. Animal Nutrition 5th edn.: Harlow: Addison Wesley Longman Limited; 1995.
71. Smith D, Moore P, Jr DM, Haggard B, Daniel T. Decreasing Phosphorus Runoff Losses from Land-Applied Poultry Litter with Dietary Modifications and Alum Addition. Journal of Environmental Quality. 2004;33:2210-6.
72. Kies K. Phytase - mode of action. In Phytase in animal nutrition and waste management. Edited by MB Coelho and ET Kornegay Ludwisghafen, Germany: BASF.; 1996.
73. Huff W, Moore P, Jr PW, Waldroup A, Balog J, Huff G, et al. Effect of dietary phytase and high available phosphorus corn on broiler chicken performance. Poultry Science. 1998;77:1899-904.
74. Leeson S. Defining and predicting changes in nutrient requirements of poultry. In The XII European Poultry Conference; 2006; Verona, Italy; 2006.
75. Prasad P. Eco-efficiency for Queensland Chicken Growers. 12th Australian Poultry and Feed Convention; 2002; Gold Coast; 2002.
76. Smith J. Sustainability Improvements in the Victorian Chicken Meat Industry (Phase 1). In: Rural Industries and Development Corporation Publication no 03/035. Canberra; 2003.
77. McGahan E, Tucker R. National Environmental Management System for the Meat Chicken Industry. In: Rural Industries and Development Corporation Publication no 03/038. Canberra; 2003.

APPENDIX 1:

NUTRIENT COMPOSITION OF LEAN AUSTRALIAN CHICKEN MEAT CUTS FROM NUTTAB 2006 AND AGAL 1998

Nutrient		Breast		Leg		Wing		Thigh		Skin	
		Raw	Baked	Raw	Baked	Raw	Baked	Raw	Baked	Raw	Baked
Moisture	g	74.70	67.60	75.20	63.90	74.80	60.50	75.00	65.60	53.30	36.00
Energy	kcal	104.65	152.64	117.85	179.06	112.19	193.85	118.51	175.43	362.14	435.00
Energy	kJ	437.45	638.04	492.63	748.49	468.96	810.31	495.36	733.30	1514.75	1818.29
Total fat	%E	13.53	22.62	36.05	37.57	32.35	35.16	37.35	43.90	85.79	79.16
Total fat	g	1.60	3.90	4.80	7.60	4.10	7.70	5.00	8.70	35.10	38.90
Protein	%E	86.47	77.38	63.95	62.43	67.65	64.84	62.65	56.10	14.21	20.84
Protein	g	22.25	29.04	18.53	27.49	18.66	30.91	18.26	24.20	12.65	22.29
Total SFA [a]	% fat	32.80	34.00	30.80	32.40	32.00	32.20	31.90	32.80	32.40	32.20
Total SFA	g	0.53	1.33	1.48	2.46	1.31	2.48	1.60	2.85	11.37	12.53
Total MUFA [b]	% fat	47.00	50.40	50.50	52.20	51.00	53.10	50.80	52.30	23.20	53.80
Total MUFA	g	0.75	1.97	2.42	3.97	2.09	4.09	2.54	4.55	8.14	20.93
Total PUFA [c]	% fat	19.70	15.40	18.50	15.10	16.70	14.60	17.10	14.70	13.90	13.90
Total PUFA	g	0.32	0.60	0.89	1.15	0.69	1.12	0.86	1.28	4.88	5.41
C18:2 n-6 (Linoleic acid)	g	0.21	0.46	0.64	0.89	0.51	0.93	0.65	1.04	4.18	4.60
C18:3 n-3 (alpha-linolenic acid)	g	0.01	0.03	0.04	0.06	0.04	0.07	0.05	0.08	0.36	0.43
Sodium	mg	41.00	46.00	71.00	84.00	66.00	84.00	62.00	76.00	43.00	78.00
Potassium	mg	300.00	320.00	260.00	290.00	230.00	270.00	280.00	290.00	120.00	220.00
Magnesium	mg	28.00	30.00	22.00	26.00	22.00	24.00	24.00	26.00	8.40	25.00
Calcium	mg	12.00	8.60	9.60	18.00	13.00	13.00	10.00	18.00	13.00	54.00
Iron	mg	0.40	0.50	0.60	0.85	0.40	0.70	0.70	0.90	0.70	1.20
Zinc	mg	0.70	0.80	1.70	2.30	1.10	1.90	1.50	2.00	0.70	1.50
Alpha-tocopherol equivalents	mg	2.20	0.22	0.31	0.37	0.30	0.35	0.64	0.36	0.78	2.10
Niacin equivalents	mg	16.20	17.70	9.30	11.40	12.30	16.10	10.20	11.60	4.10	9.70
Riboflavin	mg	0.19	0.11	0.13	0.28	0.13	0.17	0.27	0.33	0.10	0.19
Thiamin	mg	0.11	0.05	0.14	0.00	0.06	0.00	0.11	0.06	0.00	0.00

[a] Saturated fatty acids, [b] Monounsaturated fatty acids, [c] Polyunsaturated fatty acids

APPENDIX 2:

PERCENTAGE CONTRIBUTIONS OF DIFFERENT CUTS OF CHICKEN MEAT TO THE NUTRIENT REFERENCE VALUES (NRV) FOR ALL AGE GROUPS AND GENDER

Breast Baked				% contribution to NRVs (50g portion) RDI (all)		% contribution to NRVs (100g portion) RDI (males)					% contribution to NRVs (100g portion) RDI (females)					
				1-3yrs	4-8yrs	9-13yrs	14-18yrs	19-70yrs	19-30yrs	>70 yr	9-13yrs	14-18yrs	19-70yrs	19-30yrs	51-70yrs	>70 yrs
Essential fatty acids																
Linoleic acid (omega 6) [c]	**18:2 n-6**	% fat	0.46	4.60	2.88	4.60	3.83	3.54			5.75	5.75	5.75			
Alpha-linolenic acid (omega 3) [c]	**18:3 n-3**	% fat	0.03	3.00	1.88	3.00	2.50	2.31			3.75	3.75	3.75			
Mineral																
Sodium		mg	46.00	11.50	7.67	11.50	10.00	10.00		10.00	11.50	10.00	10.00			10.00
Potassium [c]		mg	320.00	8.00	6.96	10.67	8.89	8.42		8.42	12.80	12.31	11.43			11.43
Magnesium [b]		mg	30.00	18.75	11.54	12.50	7.32	7.14	7.50	7.14	12.50	8.33	9.38	9.68		9.38
Calcium		mg	8.60	0.86	0.61	0.86	0.66	0.86		0.66	0.86	0.66	0.86		0.66	0.66
Iron [b]		mg	0.50	2.78	2.50	6.25	4.55	6.25		6.25	6.25	3.33	2.78		6.25	6.25
Zinc [b]		mg	0.80	13.33	10.00	13.33	6.15	5.71		5.71	13.33	11.43	10.00			10.00
Vitamins																
Vitamin E [c,h]		mg	0.22	2.20	1.83	2.44	2.20	2.20		2.20	2.75	2.75	3.14			3.14
Niacin equivalents [b]		mg	17.70	147.50	110.63	147.50	110.63	110.63		110.63	147.50	126.43	126.43			126.43
Riboflavin [b]		mg	0.11	11.00	9.17	12.22	8.46	8.46		6.88	12.22	10.00	10.00			8.46
Thiamin [b]	**Vitamin B1**	mg	0.05	5.00	4.17	5.56	4.17	4.17		4.17	5.56	4.55	4.55			4.55

Leg Baked				% contribution to NRVs (50g portion) RDI (all)		% contribution to NRVs (100g portion) RDI (males)					% contribution to NRVs (100g portion) RDI (females)					
				1-3yrs	4-8yrs	9-13yrs	14-18yrs	19-70yrs	19-30yrs	>70 yr	9-13yrs	14-18yrs	19-70yrs	19-30yrs	51-70yrs	>70 yrs
Essential fatty acids																
Linoleic acid (omega 6)[c]	**18:2 n-6**	% fat	0.94	9.42	5.89	9.420	7.850	7.246			11.775	11.775	11.775			
Alpha-linolenic acid (omega 3)[c]	**18:3 n-3**	% fat	0.07	6.80	4.25	6.800	5.667	5.231			8.500	8.500	8.500			
Mineral																
Sodium		mg	84.00	21.00	14.00	21.000	18.261	18.261		18.261	21.000	18.261	18.261			18.261
Potassium [c]		mg	380.00	9.50	8.26	12.667	10.556	10.000		10.000	15.200	14.615	13.571			13.571
Magnesium [b]		mg	26.00	16.25	10.00	10.833	6.341	6.190	6.500	6.190	10.833	7.222	8.125	8.387		8.125
Calcium		mg	47.00	4.70	3.36	4.700	3.615	4.700		3.615	4.700	3.615	4.700		3.615	3.615
Iron [b]		mg	0.85	4.72	4.25	10.625	7.727	10.625		10.625	10.625	5.667	4.722		10.625	10.625
Zinc [b]		mg	2.60	43.33	32.50	43.333	20.000	18.571		18.571	43.333	37.143	32.500			32.500
Vitamins																
Vitamin E [c,h]		mg	0.37	3.70	3.08	4.111	3.700	3.700		3.700	4.625	4.625	5.286			5.286
Niacin equivalents [b]		mg	5.00	41.67	31.25	41.667	31.250	31.250		31.250	41.667	35.714	35.714			35.714
Riboflavin [b]		mg	0.28	28.00	23.33	31.111	21.538	21.538		17.500	31.111	25.455	25.455			21.538
Thiamin [b]	**Vitamin B1**	mg	0.00	0.00	0.00	0.000	0.000	0.000		0.000	0.000	0.000	0.000			0.000

APPENDIX 2:

PERCENTAGE CONTRIBUTIONS OF DIFFERENT CUTS OF CHICKEN MEAT TO THE NUTRIENT REFERENCE VALUES (NRV) FOR ALL AGE GROUPS AND GENDER

Wing Baked				% contribution to NRVs (50g portion) RDI (all)		% contribution to NRVs (100g portion) RDI (males)					% contribution to NRVs (100g portion) RDI (females)					
				1-3yrs	4-8yrs	9-13yrs	14-18yrs	19-70yrs	19-30yrs	>70 yr	9-13yrs	14-18yrs	19-70yrs	19-30yrs	51-70yrs	>70 yrs
Essential fatty acids																
Linoleic acid (omega 6) [c]	**18:2 n-6**	% fat	0.99	9.86	6.16	9.86	8.22	7.58			12.33	12.33	12.33			
Alpha-linolenic acid (omega 3) [c]	**18:3 n-3**	% fat	0.08	7.70	4.81	7.70	6.42	5.92			9.63	9.63	9.63			
Mineral																
Sodium		mg	84.00	21.00	14.00	21.00	18.26	18.26		18.26	21.00	18.26	18.26			18.26
Potassium [c]		mg	370.00	9.25	8.04	12.33	10.28	9.74		9.74	14.80	14.23	13.21			13.21
Magnesium [b]		mg	24.00	15.00	9.23	10.00	5.85	5.71		5.71	10.00	6.67	7.50	7.74		7.50
Calcium		mg	13.00	1.30	0.93	1.30	1.00	1.30		1.00	1.30	1.00	1.30		1.00	1.00
Iron [b]		mg	0.70	3.89	3.50	8.75	6.36	8.75		8.75	8.75	4.67	3.89		8.75	8.75
Zinc [b]		mg	1.90	31.67	23.75	31.67	14.62	13.57		13.57	31.67	27.14	23.75			23.75
Vitamins																
Vitamin E [c,h]		mg	0.35	3.50	2.92	3.89	3.50	3.50		3.50	4.38	4.38	5.00			5.00
Niacin equivalents [b]		mg	9.00	75.00	56.25	75.00	56.25	56.25		56.25	75.00	64.29	64.29			64.29
Riboflavin [b]		mg	0.17	17.00	14.17	18.89	13.08	13.08		10.63	18.89	15.45	15.45			13.08
Thiamin [b]	**Vitamin B1**	mg	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00			0.00

Thigh Baked				% contribution to NRVs (50g portion) RDI (all)		% contribution to NRVs (100g portion) RDI (males)					% contribution to NRVs (100g portion) RDI (females)					
				1-3yrs	4-8yrs	9-13yrs	14-18yrs	19-70yrs	19-30yrs	>70 yr	9-13yrs	14-18yrs	19-70yrs	19-30yrs	51-70yrs	>70 yrs
Essential fatty acids																
Linoleic acid (omega 6) [c]	**18:2 n-6**	% fat	1.11	11.05	6.91	11.05	9.21	8.50			13.81	13.81	13.81			
Alpha-linolenic acid (omega 3) [c]	**18:2 n-3**	% fat	0.09	8.70	5.44	8.70	7.25	6.69			10.88	10.88	10.88			
Mineral																
Sodium		mg	76.00	19.00	12.67	19.00	16.52	16.52		16.52	19.00	16.52	16.52			16.52
Potassium [c]		mg	390.00	9.75	8.48	13.00	10.83	10.26		10.26	15.60	15.00	13.93			13.93
Magnesium [b]		mg	26.00	16.25	10.00	10.83	6.34	6.19	6.50	6.19	10.83	7.22	8.13	8.39		8.13
Calcium		mg	18.00	1.80	1.29	1.80	1.38	1.80		1.38	1.80	1.38	1.80		1.38	1.38
Iron [b]		mg	0.90	5.00	4.50	11.25	8.18	11.25		11.25	11.25	6.00	5.00		11.25	11.25
Zinc [b]		mg	2.00	33.33	25.00	33.33	15.38	14.29		14.29	33.33	28.57	25.00			25.00
Vitamins																
Vitamin E [c,h]		mg	0.36	3.60	3.00	4.00	3.60	3.60		3.60	4.50	4.50	5.14			5.14
Niacin equivalents [b]		mg	6.00	50.00	37.50	50.00	37.50	37.50		37.50	50.00	42.86	42.86			42.86
Riboflavin [b]		mg	0.33	33.00	27.50	36.67	25.38	25.38		20.63	36.67	30.00	30.00			25.38
Thiamin [b]	**Vitamin B1**	mg	0.06	6.00	5.00	6.67	5.00	5.00		5.00	6.67	5.45	5.45			5.45

APPENDIX 2:

PERCENTAGE CONTRIBUTIONS OF DIFFERENT CUTS OF CHICKEN MEAT TO THE NUTRIENT REFERENCE VALUES (NRV) FOR ALL AGE GROUPS AND GENDER

Skin Baked				**% contribution to NRVs (50g portion)**		**% contribution to NRVs (100g portion)**					**% contribution to NRVs (100g portion)**					
				RDI (all)		**RDI (males)**					**RDI (females)**					
				1-3yrs	**4-8yrs**	**9-13yrs**	**14-18yrs**	**19-70yrs**	**19-30yrs**	**>70 yr**	**9-13yrs**	**14-18yrs**	**19-70yrs**	**19-30yrs**	**51-70yrs**	**>70 yrs**
Essential fatty acids																
Linoleic acid (omega 6) [c]	**18:2 n-6**	% fat	4.86	48.63	30.39	48.63	40.53	37.41			60.79	60.79	60.79			
Alpha-linolenic acid (omega 3) [c]	**18:2 n-3**	% fat	0.43	42.80	26.75	42.80	35.67	32.92			53.50	53.50	53.50			
Mineral																
Sodium		mg	78.00	19.50	13.00	19.50	16.96	16.96		16.96	19.50	16.96	16.96			16.96
Potassium [c]		mg	220.00	5.50	4.78	7.33	6.11	5.79		5.79	8.80	8.46	7.86			7.86
Magnesium [b]		mg	25.00	15.63	9.62	10.42	6.10	5.95	6.25	5.95	10.42	6.94	7.81	8.06		7.81
Calcium		mg	54.00	5.40	3.86	5.40	4.15	5.40		4.15	5.40	4.15	5.40		4.15	4.15
Iron [b]		mg	1.20	6.67	6.00	15.00	10.91	15.00		15.00	15.00	8.00	6.67		15.00	15.00
Zinc b		mg	1.50	25.00	18.75	25.00	11.54	10.71		10.71	25.00	21.43	18.75			18.75
Vitamins																
Vitamin E [c,h]		mg	2.10	21.00	17.50	23.33	21.00	21.00		21.00	26.25	26.25	30.00			30.00
Niacin equivalents [b]		mg	6.00	50.00	37.50	50.00	37.50	37.50		37.50	50.00	42.86	42.86			42.86
Riboflavin [b]		mg	0.19	19.00	15.83	21.11	14.62	14.62		11.88	21.11	17.27	17.27			14.62
Thiamin [b]	**Vitamin B1**	mg	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00			0.00

[a] 50g portion, [b] Recommended Dietary Intake (RDI), [c] Adequate intake (AI), [d] 19-30, [e] 31-70 years, [f] 19-50 years, [g] 51-70 years, [h] Alpha-tocopherol equivalents

APPENDIX 3:
SUMMARY TABLES OF ARTICLES IDENTIFIED IN LITERATURE SEARCH (PUBMED, 1996–2007)

Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Weight loss and appetite control						
Mahon AK, Flynn MG, Stewart LK, McFarlin BK, Iglay HB, Mattes RD, Lyle RM, Considine RV, Campbell WW. Protein intake during energy restriction: effects on body composition and markers of metabolic and cardiovascular health in postmenopausal women. *J Am Coll Nutr 2007* Apr; 26(2): 182-9.	Randomised controlled parallel group trial for 9 weeks (2-wk weight maintenance run-in).	54 postmenopausal women, 50 – 80 y, BMI <25 and > 34 kg/m2.	Three energy restricted (ER) lacto-ovo vegetarian diets of 1000 kcal/d plus 250 kcal/d of either beef (BEEF; 25 % E Protein, n = 14), chicken (CHICK; 25 % E Protein, n = 15), or carbohydrate/fat foods (CARB (lacto-ovo), 17 % E Protein, n = 14), Control group (CON, n = 11) consumed their habitual diets.	Body fat (DEXA), BMI, total and LDL cholesterol, Triacylglycerol, HDL cholesterol, C-reactive protein (CRP), glucose, insulin, leptin, and adiponectin.	5-day fixed rotation menu of 3 meals and 2 snacks daily. 250 kcal/day provided of either cooked beef tenderloin, (BEEF) chicken breast plus 2.5 tsp butter to match the saturated fatty acid content of the beef) (CHICK) or shortbread cookies and sugar coated chocolates (CARB),	Energy intake was lower in the ER groups compared to CON but not different among ER groups. For all ER subjects combined, body mass (-6.7 ± 2.4 kg, 9 %), fat mass (-4.6 ± 1.9 kg, 13 %), and fat-free mass (-2.1 ± 1.1 kg, 5 %) decreased. Responses not different between ER groups, except for body mass (CHICK -7.9 ± 2.6 kg(a); BEEF -6.6 ±2.7 kg(a,b); CARB -5.6 ±1.8 kg(b); CON -1.2 ± 1.2 kg(c); values with a difference superscript differ, P < 0.05). Total and LDL cholesterol decreased 12%, with no differences among groups. Triacylglycerol, HDL-C, C-reactive protein (CRP), glucose, insulin, leptin, and adiponectin not changed over time or by diet group.
Melanson K, Gootman J, Myrdal A, Kline G, Rippe JM. Weight Loss and Total Lipid Profile Changes in Overweight Women Consuming Beef or Chicken as the Primary Protein Source. *Nutrition* 2003;19:409–414 Not identified in PubMed search (Red meat is keyword, not chicken)	12-wk, randomized, controlled trial,	N = 81 overweight sedentary non-smoking females 21 – 59 y, 120 – 150 % Ideal Body Weight.	Hypocaloric (-500 kcal/day) diet with lean beef or chicken as the primary protein source (19.2 – 22.6 % E) , plus fitness walking program		Body weight, body composition (by hydrodensitometry), and blood lipid profiles	Weight loss similar between beef (5.6± 0.6 kg) and the chicken (6.0 ± 0.5 kg) groups. Both groups had similar and significant reductions in % body fat and total and LDL cholesterol,. HDL-C did not change in either group. Weight loss and improved lipid profile can be accomplished through diet and exercise, whether the dietary protein source is lean beef or chicken.

APPENDIX 3:

SUMMARY TABLES OF ARTICLES IDENTIFIED IN LITERATURE SEARCH (PUBMED, 1996–2007)

Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Cancer						
Colorectal cancer						
Hu J, Mery L, Desmeules M, Macleod M; Canadian Cancer Registries Epidemiology Diet and vitamin or mineral supplementation and risk of rectal cancer in Canada. *Acta Oncol* 2007;46(3): 342-54.	Case-control study.	The study examines the relation of diet and vitamin or mineral supplementation with risk of rectal cancer in 1380 newly diagnosed patients with histologically confirmed rectal cancer and 3 097 population controls. Mail survey, 1994 - 1997 in 7 Canadian provinces.	No intervention		Mailed questionnaires included information on socio-economic status, lifestyle, diet (FFQ)and vitamin or mineral supplementation. Odds ratios and 95% confidence intervals derived through unconditional logistic regression.	Consumption of vegetables, fruit and whole-grain products did not reduce risk of rectal cancer. Consumption of cruciferous vegetables inversely associated with risk among women only, as did chicken intake among men (adjusted OR for high vs low chicken intake = 0.4 (0.2 – 0.8; P = 0.01). The strongest dietary association with increased risk appeared in males with increasing total fat intake and in females with bacon intake. Vitamin and mineral supplementation inversely associated with rectal cancer in women only.
Sato Y, Nakaya N, Kuriyama S, Nishino Y, Tsubono Y, Tsuji I. Meat consumption and risk of colorectal cancer in Japan: the Miyagi Cohort Study. Eur J Cancer Prev. 2006 Jun;15(3): 211-8.	Prospective cohort study	N = 47,605 residents, aged 40-64 years, of northern Japan. Recruited June - August 1990,	Cox proportional hazards model to estimate the relative risk of colorectal cancer (colorectum, colon, rectum and proximal colon and distal colon) according to each of the categories of meat intake (total meat, beef, pork, ham or sausage, chicken and liver), with adjustment for sex, age and other confounding variables.		Self-administered food frequency questionnaire	474 incident cases of colorectal cancer during 11 years of follow-up, to March 2001. Multivariate RR of colorectal cancer in the highest category of total meat consumption compared with the lowest was 1.14 [95% CI=0.85-1.53; P=0.22]. Chicken not significant. No association between total meat consumption and the risk of sub-site of colorectal cancer. The data do not support the hypothesis that meat consumption (including chicken) is a risk factor for colorectal cancer.

APPENDIX 3:
SUMMARY TABLES OF ARTICLES IDENTIFIED IN LITERATURE SEARCH (PUBMED, 1996–2007)

Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Colorectal cancer						
Robertson DJ, Sandler RS, Haile R, Tosteson TD, Greenberg ER, Grau M, Baron JA. Fat, fiber, meat and the risk of colorectal adenomas. *Am J Gastroenterol.* 2005 Dec; 100(12):2789-95.	Two randomized controlled trials.. Secondary analyses of dietary intake (not assigned supplemental intervention)	N = 1,520 participants in the Antioxidant Polyp Prevention Study (B-carotene, placebo, Vit C + Vit E, N = 709) and Calcium Polyp Prevention Study (1.2g elemental calcium carbonate, N = 811).			Colorectal adenoma recurrence (colonoscopy at baseline, 1 and 4 years). Dietary intake estimated with a validated semiquantitative food frequency questionnaire.. Pooled risk ratios for adenoma recurrence were obtained by generalized linear regression, with adjustment for age, sex, clinical center, treatment category, study, and duration of observation.	No association between fat or total red meat intake and risk of adenoma or advanced adenoma recurrence. Considering other meats, risk (quartile 4 vs quartile 1) for advanced adenoma was increased for processed meat (RR=1.75, 95% CI 1.02-2.99) and decreased for chicken (RR=0.61, 95% CI 0.38-0.98). The data indicates that intake of specific meats may have different effects on risk. Note: no chicken intervention despite RCT nature of two trials – secondary analyses of dietary data.
Navarro A, Muñoz SE, Lantieri MJ, del Pilar Diaz M, Cristaldo PE, de Fabro SP, Eynard AR. Meat cooking habits and risk of colorectal cancer in Córdoba, Argentina. *Nutrition* 2004 Oct;20(10):873-7.	Case-control retrospective study (1994 – 2000)	296 colorectal cancer patients and 597 control subjects, 23 – 83 y men and women	Meat consumption and cooking methods for meat.	Average consumption 5 y before diagnosis or hospitalization	Food-frequency questionnaire by interview, on meat consumption and preferred cooking procedures. Fish and chicken classified together as white meat.	Chicken was preferentially barbecued or roasted. Multivariate relative risks (adjusted by age, sex, social stratum, and total energy intake) for preferring darkly browned surfaces associated with an increased risk for all cooking procedures (OR = 4.57; 95% CI = 3.10 - 6.73. For white meat (chicken and fish), preferring darkly browned surfaces: Barbecued OR = 1.91 (1.33 – 2.74; Roasted: OR = 2.19 (1.53 – 3.12); Fried: OR = 1.42 (1.00 – 2.02).
Chiu BC, Gapstur SM. Changes in diet during adult life and risk of colorectal adenomas. *Nutr Cancer.*2004;49(1):49-58.	Case-control study	N = 146 colorectal adenoma patients and 226 controls.	Dietary habits during the year before sigmoidoscopy and when subjects were 30 yr old, collected using a food-frequency questionnaire.		Change in frequency of consumption during adulthood was calculated (Frequency of consumption of specific foods/food groups during the previous year minus frequency of consumption at age 30 yr (recent consumption)).	No association for foods/food groups consumed at age 30 yr. Frequent consumption of fish, vegetables and chicken/turkey were protective (OR = 0.5 (0.3 – 0.9); P = 0.03) for highest vs lowest quartile of chicken/turkey). Non-significant protective trend for increase in chicken/turkey consumption (OR = 0.6 (0.3 – 1.2); P = 0.10 for highest vs lowest quartile).

APPENDIX 3:

SUMMARY TABLES OF ARTICLES IDENTIFIED IN LITERATURE SEARCH (PUBMED, 1996–2007)

Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Colorectal cancer						
Le Marchand L, Wilkens LR, Hankin JH, Kolonel LN, Lyu LC. A case-control study of diet and colorectal cancer in a multiethnic population in Hawaii (United States): lipids and foods of animal origin. Cancer Causes Control. 1997 Jul;8(4):637-48.	Case-control study.	Ethnic groups at different risks of colorectal cancer in Hawaii. N = 698 male and 494 female Japanese, Caucasian, Filipino, Hawaiian, and Chinese patients diagnosed 1987-91 with pathologically confirmed adenocarcinoma of the colon or rectum. N = 1,192 population controls matched for age, gender and ethnicity.	Evaluation of role of dietary lipids and foods of animal origin on the risk of colorectal cancer.		FFQ, including 280 food items, for 3-year period before onset of symptoms (cases) or before interview (controls).	Chicken eaten without skin was associated inversely with risk in men (OR = 0.6 (0.4 – 0.9; P=0.07) and women (OR = 0.6; 95 % CI = 0.4 – 1.0; P = 0.03). The strongest association was found for eggs, for the highest vs lowest quartile in men (OR = 2.7; 95 % CI = 1.7-4.0) and women (OR = 2.3 (CI = 1.4-3.7); P < 0.001). Data suggests that eggs and, possibly, untrimmed red meat and processed meat increase, and chicken eaten without skin decreases, colorectal cancer risk.
Phinney SD. Metabolism of exogenous and endogenous arachidonic acid in cancer. *Adv Exp Med Biol* 1996;399:87-94.	Review					Epidemiologic studies in humans indicate a positive association between meat intake and colon cancer, but a negative association with chicken and fish.
Pancreatic cancer						
Li D, Day RS, Bondy ML, Sinha R, Nguyen NT, Evans DB, Abbruzzese JL, Hassan MM. Dietary mutagen exposure and risk of pancreatic cancer. *Cancer Epidemiol Biomarkers* Prev. 2007 Apr;16(4):655-61.	Hospital-based case control study.	June 2002 - May 2006. N = 626 cases N = 530 non-cancer controls, matched for race, sex and age.			Dietary exposure information collected via personal interview using a meat preparation questionnaire, using photographs of cooked meat.	A significantly greater portion of cases than controls showed a preference to well-done pork, bacon, grilled chicken, and pan-fried chicken, but not to hamburger and steak. Cases had a higher daily intake of food mutagens and mutagenicity activity (revertants per gram of daily meat intake) than controls did. A higher intake of dietary mutagens (those in the two top quintiles) was associated with a 2-fold increased risk of pancreatic cancer among those without a family history of cancer but not among those with a family history of cancer.

APPENDIX 3:
SUMMARY TABLES OF ARTICLES IDENTIFIED IN LITERATURE SEARCH (PUBMED, 1996–2007)

Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Breast cancer						
Cui X, Dai Q, Tseng M, Shu XO, Gao YT, Zheng W. Dietary patterns and breast cancer risk in the shanghai breast cancer study. *Cancer Epidemiol Biomarkers Prev* 2007 Jul;16(7):1443-8.	Case-control study.	Cases: breast cancer patients., 25-64yrs., n = 1446. Controls: age-matched, general population of urban Shanghai. n=1549.	Chicken intake, included in "meat-sweet" dietary pattern.	Principal component analyses identified two dietary patterns: a "vegetable-soy" pattern (tofu, cauliflower, beans, bean sprouts, green leafy vegetables) and a "meat-sweet" pattern (shrimp, chicken, beef, pork, candy, desserts).	Unconditional logistic regression analyses of exposure to dietary pattern vs risk of breast cancer (ie. case)	Risk was not associated with the vegetable-soy pattern. It was associated with the meat-sweet pattern (4th versus 1st quartile: OR = 1.3; 95% CI = 1.0-1.7; P=0.03), but only in postmenopausal women, specifically among those with estrogen receptor-positive tumors (4th versus 1st quartile: OR = 1.9; 95% CI = 1.1-3.3; P=0.03).
Delfino RJ, Sinha R, Smith C, West J, White E, Lin HJ, Liao SY, Gim JS, Ma HL, Butler J, Anton-Culver H. Breast cancer, heterocyclic aromatic amines from meat and N-acetyltrans-ferase 2 genotype. Carcinogenesis. 2000 Apr;21(4):607-15.	Case-control study	N = 114 cases with breast cancer and 280 controls with benign breast disease			HAA intake estimated from interview data on meat type, cooking method and doneness, combined with a quantitative HAA database.	White meat was significantly protective (>67 versus <26 g/day, OR = 0.46, 95% CI = 0.23-0.94, P = 0.02), as was chicken, including well done, pan fried and barbecued chicken.
Gertig DM, Hankinson SE, Hough H, Spiegelman D, Colditz GA, Willett WC, Kelsey KT, Hunter DJ. N-acetyl transferase 2 genotypes, meat intake and breast cancer risk. *Int J Cancer*. 1999 Jan 5;80(1):13-7.	Case-control study	Sub-cohort of 32,826 women in the Nurses' Health Study who gave a blood sample in 1989–1990. Women diagnosed with breast cancer (n = 466) after blood draw and prior to June 1, 1994, were matched to 466 controls.	Associations between meat intake and cooking method, acetylator genotype and breast cancer risk.	Chicken (servings per day) ≤ 0.14; 0.15–0.50; >0.50.	Self-administered food frequency questionnaires every 2 years	No associations between any meat intake or cooking method of meat and breast cancer risk. No risk associated with increased frequency of chicken intake OR = 0.9 (95 % CI = 0.6 – 1.2) for 0.15 – 0.50 servings/day and OR = 1.0 (0.6 – 1.6) for >0.50 servings/day vs ≤ 0.14 servings/day . Data suggests that HAAs may not be a major cause of breast cancer.

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Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Breast cancer						
Ambrosone CB, Freudenheim JL, Sinha R, Graham S, Marshall JR, Vena JE, LaughlinR, Nemoto T, Shields PG. Breast cancer risk, meat consumption and N-acetyltransferase (NAT2) genetic polymorphisms. *Int J Cancer*. 1998 Mar 16;75(6):825-30.	Case-control study.	N = 740 Caucasian women with incident breast cancer and N = 810 community controls; Subset (N = 793) provided a blood sample.	Meat intake.	Quartiles of poultry intake (chicken and turkey): Premenopausal women: <19; 15 – 26; 28 – 43; >43 Postmenopausal women: <12; 12 – 19; 19 – 30; >30 g/day	FFQ	In post-menopausal women, higher poultry consumption was inversely associated with risk (OR = 0.7 (0.5 – 1.0; for highest vs lowest quartile of intake) (P trend = 0.01), as was higher fish intake.; among pre-menopausal women, there was a ns trend for inverse associations between risk and poultry intake (OR = 0.6 (0.5 – 1.2; P = 0.20). Data suggests that consumption of meats and other concentrated sources of HAs is not associated with increased breast cancer risk.
Djuric Z, Depper JB, Uhley V, Smith D, Lababidi S, Martino S, Heilbrun LK. Oxidative DNA damage levels in blood from women at high risk for breast cancer are associated with dietary intakes of meats, vegetables, and fruits. *J Am Diet Assoc*. 1998 May;98(5):524-8.	Cross sectional survey	N = 21 healthy women with a first-degree relative with breast cancer.	Women assigned randomly to a low-fat (15% E fat) or non-intervention diet for 3 to 24 mths.	Intakes of specific foods: Meat type (pork, beef, fish, chicken) and cooking temperature; vegetables (raw and cooked) and fruit.	Levels of 5-hydroxymethyluracil, a type of oxidative DNA damage, were determined from blood samples. Diet data obtained from 3-day food records.	Poultry was negatively correlated with DNA damage (r = -0.456; P = 0.038). A regression model that included the intake of cooked vegetables, poultry and the sum of beef and pork intake. accounted for 79 % of the variation in DNA damage levels among women. Preliminary results are suggestive of a positive association of oxidative DNA damage with beef and pork intake, and a negative association with poultry and with cooked vegetable intake.
Potischman N, Weiss HA, Swanson CA, Coates RJ, Gammon MD, Malone KE, Brogan D, Stanford JL, Hoover RN, Brinton LA. Diet during adolescence and risk of breast cancer among young women. *J Natl Cancer Inst*. 1998 Feb 4;90(3):226-33.	Case-control study.	N = 1647 cases with newly diagnosed breast cancer; N = 1501 control subjects.			Interviewer-administered frequency of consumption and portion size of 29 key food items at ages 12-13 years. Mothers of a subset of respondents completed questionnaires, and food groups were recalculated after removal of foods with poor mother-daughter agreement.	NS trend for reduced risk associated with high vs low consumption of fruits and vegetables. Slight increases (borderline significance) in risk of breast cancer were found for intake of chicken or high-fat meat. These data do not provide evidence for a strong influence of dietary intakes during adolescence on risk of early-onset breast cancer.

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Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Bladder cancer						
Michaud DS, Holick CN, Giovannucci E, Stampfer MJ. Meat intake and bladder cancer risk in 2 prospective cohort studies. *Am J Clin Nutr.* 2006 Nov; 84(5): 1177-83.	2 large prospective, cohort studies (Nurses health Study, NHS and Health Professionals Follow Up study, HPFS)	Up to 22 y of follow-up and 808 incident bladder cancer cases. N = 47 422 men (HPFS cohort) and N = 88 471 women (NHS cohort) after excluding participants diagnosed with cancer before baseline (1986 for HPFS; 1980 for NHS) or those with implausibly high or low daily caloric intake.	Detailed data on meat obtained from multiple food-frequency questionnaires administered over time.	In 1980, women in the NHS completed a 61-item semiquantitative FFQ. Expanded versions (130 food items) of the FFQs were mailed to NHS participants in 1984, 1986, 1990, 1994, and 1998. For the HPFS cohort, the baseline (1986) and follow-up FFQs (1990, 1994, and 1998) included 131 food items. Reference period was past year.	Multivariate relative risks (RRs) and 95% CIs were estimated by using Cox proportional hazards models with control for potential confounders, including detailed smoking history. Self-reported diagnosis of bladder cancer confirmed by review of medical records.	Elevated risks of bladder cancer were observed among men and women who consumed chicken without skin $\geq$ 5 times/wk compared with those who did not consume chicken without skin. (RR for the top compared with the bottom category of chicken without skin intake was 1.52; 95% CI: 1.09, 2.11; P<0.05). No significant associations observed for chicken with skin in either cohort, nor other meats, including processed meats, hot dogs, and hamburgers. Chicken without skin contains more heterocyclic amines than chicken cooked without skin.
Hepatcellular cancer (liver)						
Kurozawa Y, Ogimoto I, Shibata A, Nose T, Yoshimura T, Suzuki H, Sakata R, Fujita Y, Ichikawa S, Iwai N, Fukuda K, Tamakoshi A. Dietary habits and risk of death due to hepatocellular carcinoma in a large scale cohort study in Japan. Univariate analysis of JACC study data. *Kurume Med J.* 2004;51(2):141-9.	Prospective cohort study; 1988-90, follow- up until 1999.	N = 46,465 male and 64,327 female Japanese, 40-79 y.	Dietary consumption patterns		The hazard ratio (HR) of Hepatocellular carcinoma (HCC) mortality for each food item by gender, age group (40-59; 60-79 y) and history of liver diseases.	Chicken, as well as boiled rice, ham and sausage, fish and pickles among men without history of liver diseases and miso-soup, fish, carrots and squash, and potatoes among women without history of liver diseases showed a significant inverse association with HCC mortality.

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Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Hepatcellular cancer (liver)						
Yu SZ, Huang XE, Koide T, Cheng G, Chen GC, Harada K, Ueno Y, Sueoka E, Oda H, Tashiro F, Mizokami M, Ohno T, Xiang J, Tokudome S. Hepatitis B and C viruses infection, lifestyle and genetic polymorphisms as risk factors for hepatocellular carcinoma in Haimen, China. *Jpn J Cancer Res*. 2002; 93(12):1287-92.	Case-control study	N = 248 patients with hepatocellular carcinoma (HCC) and 248 sex-, age- and residence-matched population-based controls			Could not obtain paper to describe measurements	Frequent intake of chicken reduced risk of HCC(OR=0.53; 95%CI=0.35-0.79).
Ovarian cancer						
Pan SY, Ugnat AM, Mao Y, Wen SW, Johnson KC. A case-control study of diet and the risk of ovarian cancer. *Cancer Epidemiol Biomarkers Prev* 2004; 13(9):1521-7.	Population-based case-control study	N = 442 incident cases of ovarian cancer diagnosed in 1994 to 1997 and N = 2,135 population controls		Chicken, 4 oz/wk - quartiles of distribution	Self-administered 69-item food frequency questionnaire (period of 2 years before interview) and general changes in the diet compared with 20 years ago.	Ovarian cancer risk positively associated with higher consumption of dietary cholesterol and eggs and inversely associated with higher intake of total vegetables and cruciferous vegetables and supplementation of vitamin E, beta-carotene, and B-complex vitamins. No association of risk with chicken intake.
Gastric cancer						
Huang XE, Tajima K, Hamajima N, Kodera Y, Yamamura Y, Xiang J, Tominaga S, Tokudome S. Effects of dietary, drinking, and smoking habits on the prognosis of gastric cancer. *Nutr Cancer* 2000;38(1):30-6.	Prospective prognostic study	N = 877 gastric cancer patients (578 men and 299 women) recruited Jan 1988 - Dec 1994.		Could not obtain paper to describe serving size	Survival status followed up until Dec 1998. Analysis controlled for age, gender, histological grade, and stage of disease.	Consumption of chicken meat (HR = 0.61, 95% CI = 0.39-0.95) more than three times per week significantly decreased mortality risk. Also protective were raw vegetables [HR = 0.74, 95% CI = 0.56-0.98] and tofu (HR = 0.65, 95% CI = 0.42-0.99),

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Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Gastric cancer						
Ward MH, Sinha R, Heineman EF, Rothman N, Markin R, Weisenburger DD, Correa P, Zahm SH. Risk of adenocarcinoma of the stomach and esophagus with meat cooking method and doneness preference. *Int J Cancer*. 1997 Mar 28;71(1):14-9.	Case-control study	66 counties of eastern Nebraska. N = 143 men and women diagnosed with adenocarcinoma of the stomach and oesophagus between July 1988 and June 1993; N = 502 controls.	The dietary assessment included several questions about usual cooking methods for meats and doneness preference for beef.		Telephone interviews for modified version of the Health Habits and History Questionnaire (HHHQ) (Block et al.,1990) that focused on nitrate, nitrite, sodium, vitamin C, carotenes and animal protein. Frequency of intake of beef, pork and chicken. Usual cooking method (fried/broiled, baked/roasted, boiled/poached, other)	High intake of red meat was associated with increased risks for both stomach and esophageal cancers. Broiling or frying of chicken or pork (data not shown) was not associated with the risk of these tumors. The numbers of individuals reporting barbecuing for these meats were too few to evaluate risk of BBQ/grilling chicken and pork.
Prostate cancer						
Norrish AE, Ferguson LR, Knize MG, Felton JS, Sharpe SJ, Jackson RT. Heterocyclic amine content of cooked meat and risk of prostate cancer. *J Natl Cancer Inst*. 1999 Dec 1;91(23):2038-44.	Population-based, case-control Study	N = 317 cases with prostate cancer aged 40–80 years and 480 age-matched controls in Auckland, New Zealand		Beefsteak: "rare," "medium," or "well-done" Other meat types" "cooked in liquid, microwaved or baked" or "fried, grilled, or barbecued" (if yes for chicken: "lightly browned or well-browned ?).	Levels of meat doneness and daily intake of heterocyclic amines (HAA) determined from self-reported dietary data and experimentally measured HAA levels in locally sourced meat samples cooked under controlled conditions to varying degrees of doneness.	Meat doneness was weakly and inconsistently associated with prostate cancer risk for individual types of meat, but increased risk was observed for well-done beefsteak (relative risk = 1.68; 95% CI = 1.02-2.77; P = 0.03). For chicken, compared to other cooking methods, RR for "fried/grilled/ barbequed" was non significant (RR = 0.78 (0.43–1.40) for medium/lightly browned and RR = 1.33 (0.91–1.94) for well-done/well-browned (P=0.21).

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Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
HCA, PhIP intake and chicken						
Bogen KT, Keating GA 2nd, Chan JM, Paine LJ, Simms EL, Nelson DO, Holly EA. Highly elevated PSA and dietary PhIP intake in a prospective clinic-based study among African Americans. *Prostate Cancer Prostatic Dis.* 2007;10(3):261-9.	Prospective clinic-based study	PC screening outcomes compared with survey-based estimates of dietary PhIP intake among 40-70-year-old African-American men with no prior PC.N = 392.	2-amino-1-methyl-6-phenylimidazo [4,5-b]pyridine (PhIP), a genotoxic rat-prostate carcinogen found primarily in well-cooked chicken and beef.		Food-frequency and meat-cooking/ consumption questionnaires; prostate-specific antigen (PSA) test and digital-rectal exam.	PhIP intake was attributable mostly to chicken (61%) and positively associated (R(2)=0.32, P<0.0001) with saturated fat intake. OR of 31 (95 % CI: 3.1-690) for highly elevated PSA > or =20 ng/ml was observed in the highest 15% vs lowest 50% of estimated daily PhIP intake (≥ 30 vs ≤ 10 ng/kg day) among men 50+ years old (P=0.0002 for trend) and remained significant after adjustment for self-reported family history of (brother or father) PC, saturated fat intake and total energy intake.
Wong KY, Su J, Knize MG, Koh WP, Seow A. Dietary exposure to heterocyclic amines in a Chinese population. *Nutr Cancer* 2005;52(2):147-55.	Cross-sectional, descriptive study	497 randomly sampled Chinese men and women aged 20-59 yr.	Heterocyclic aromatic amine (HAAs)content of cooked meat – contribution of chicken to total intake (from meat).	No intervention	Dietary meat consumption data (g/day), including type and cooking method, from food-frequency questionnaires. Twenty-five samples (each pooled from three sources) of meat and fish, cooked as commonly consumed, analyzed by HPLC for heterocyclic aromatic amines (HAAs) formed during high-temperature cooking (risk for colorectal and breast cancer)	Seven meat-cooking method combinations contributed 90.1% of this intake, namely, pan-fried fish, pork, and chicken (13.8 %), deep-fried chicken (19.6 %) as well as fish, roasted/ barbecued pork, and grilled minced beef.

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Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
HCA, PhIP intake and chicken						
Knize MG, Kulp KS, Salmon CP, Keating GA, Felton JS. Factors affecting human heterocyclic amine intake and the metabolism of PhIP. *Mutat Res.* 2002 Sep 30;506-507:153-62.	Quasi-experimental study	N = 6 male volunteers	Day 1: 150g well cooked skinless chicken breasts containing 9 – 13 µg PhIP (a heterocyclic amine). Next 3 days: one cup steamed broccoli. Day 4: 150g well cooked chicken containing 9 – 13 µg PhIP All other foods provided in 4 day period.	150g well cooked chicken	Urinary excretion of PhIP, pre- and post-broccoli consumption.	Five of the six individuals excreted more metabolites after broccoli consumption, implying induction of metabolizing enzymes which may have a cancer protective effect.
Thomson B. Heterocyclic amine levels in cooked meat and the implication for New Zealanders. *Eur J Cancer Prev.* 1999 Jul;8(3):201-6.	Review paper presented to an expert workshop on meat and colorectal cancer risk (Adelaide, 4th Dec 1998)	Review paper of human intake estimates of HCAs and animal cancer potency studies. Telephone survey of N = 902 New Zealand adults, (1994)	Review of studies of detected PhIP concentrations in cooked meats across cooking methods (chicken, beef, lamb, pork/bacon, fish, sausage)		Dietary consumption patterns of meat and cooking preferences determined using 24hr dietary recalls (telephone survey).	Approximately 1/3 of meat consumed on a daily basis in New Zealand is cooked by methods likely to result in the formation of HCAs. BBQ chicken provided highest concentration of PhIP of all meats, but no levels were detected in roasted chicken. When intake estimates are combined with animal cancer potency data, the greatest contributor to cancer risk is from the consumption of chicken.
Byrne C, Sinha R, Platz EA, Giovannucci E, Colditz GA, Hunter DJ, Speizer FE, Willett WC. Predictors of dietary heterocyclic amine intake in three prospective cohorts. *Cancer Epidemiol Biomarkers Prev.* 1998 Jun;7(6):523-9.	Cross-sectional survey	Random samples of 250 participants from each of three large prospective cohorts (mail survey)	Full paper not obtainable		Estimate of overall daily dietary HCA intake and inter-individual variation in intake by using data on HCA concentrations in various meats prepared by various cooking methods, in US in the 1990s. Questionnaire to assess frequency of consumption, cooking method, and typical outside appearance meats and gravy.	Dietary reports showed estimates of between 20 and 110-fold variation in HCA intake, depending on individual HCA, when the 10th and 90th percentiles of HCA intake were compared in the participants.

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Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Cardiovascular disease						
Pala V, Sieri S, Masala G, Palli D, Panico S, Vineis P, Sacerdote C, Mattiello A, Galasso R, Salvini S, Ceroti M, Berrino F, Fusconi E, Tumino R, Frasca G, Riboli E, Trichopoulou A, Baibas N, Krogh V. Associations between dietary pattern and lifestyle, anthropometry and other health indicators in the elderly participants of the EPIC-Italy cohort. *Nutr Metab Cardiovasc Dis.* 2006 Apr;16(3):186-201.	Prospective cohort study	N = 5611 Italians (1536 men and 4075 women), ≥ 60 years, participating in the European Prospective Investigation into Cancer and Nutrition (EPIC) (total sample in Italy N = 47,749).	Factor scores assigned, indicating the extent to which their diet conformed to each of 4 dietary patterns identified: Prudent (cooked vegetables, pulses, cabbage, seed oil and fish); Pasta & meat (pasta, tomato sauce, red meat, processed meat, bread and wine); Olive oil & salad (raw vegetables, olive oil, soup and chicken); Sweet & dairy (sugar, cakes, ice cream, coffee and dairy).		Semi-quantitative food questionnaires. Principal component factor analysis to identify dietary patterns and to examine the associations of these patterns with self-reported health-related variables (lipids, hypertension).	Hyperlipidaemic men and women and those who had dieted over the previous year consumed more of the prudent and olive oil & salad patterns and less of the sweet & dairy pattern than those with normal lipids/non-dieters. This suggests awareness of the health consequences of these patterns.
Sacks FM, Appel LJ, Moore TJ, Obarzanek E, Vollmer WM, Svetkey LP, Bray GA, Vogt TM, Cutler JA, Windhauser MM, Lin PH, Karanja N. A dietary approach to prevent hypertension: a review of the Dietary Approaches to Stop Hypertension (DASH) Study. Clin Cardiol. 1999 Jul;22(7 Suppl):III6-10.	Mulitcenter, randomized controlled parallel group feeding trial.	N = 459 adults with untreated systolic blood pressure < 160 mmHg and diastolic blood pressure 80-95 mmHg.	3 diet groups of 7-day menu cycle with 21 meals at 4 energy levels: Control American diet vs high fruits and vegetables diet vs DASH diet (high in fruits, vegetables, nuts, and low-fat dairy products, emphasizes fish and chicken rather than red meat, and is low in saturated fat, cholesterol, sugar, and refined carbohydrate).	Two or less servings of meats, poultry, and fish per day (DASH diet). Serving size unspecified.	Seven daily menus were developed for the DASH diet at 1600, 2100, 2600 and 3100 kcal/day.	The DASH diet lowered systolic BP significantly in the total group by 5.5/3.0 mmHg, in African Americans by 6.9/3.7 mmHg, in Caucasians by 3.3/2.4 mmHg, in hypertensives by 11.6/5.3 mmHg, and in non-hypertensives by 3.5/2.2 mmHg. The fruits and vegetables diet also reduced blood pressure in the same subgroups, but to a lesser extent

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Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Cardiovascular disease						
Sperber AD. Galil A. Sarov B. Stahl Z. Shany S. Authors Full Name Sperber, A D. Galil A, Sarov B, Stahl Z, Shany S. A combined community strategy to reduce cholesterol and other risk factors. Source. American Journal of Preventive Medicine 1996; 12(2):123-8.	2-year quasi-experimental study	N = 187 Israelis.	An integrated program to reduce coronary risk factors in the population of an Israeli kibbutz Intervention included food policy changes in the central kibbutz kitchen, health education programs aimed at all age groups, and health counseling for individuals at risk.		Evaluation was by questionnaire at baseline and at the end of two years, blood lipoproteins, and monitoring of all food purchased by the kibbutz.	Fifty-three percent of the adult population had borderline to high baseline total cholesterol levels. At one year, 27% of these were in the normal category. Consumption of fish, chicken meat, and vegetarian patties increased. An integrated health education program targeting individuals and the community together can be effective in reducing risk factors for coronary artery disease.
Contribution to dietary patterns						
Guenther PM, Jensen HH, Batres-Marquez SP, Chen CF. Sociodemographic, knowledge, and attitudinal factors related to meat consumption in the United States. *J Am Diet Assoc.* 2005 Aug;105(8):1266-74.	Cross-sectional study	N = 4,802 children and 9,460 adults from the Continuing Survey of Food Intakes by Individuals (1994 – 96; CSFII) and N = 5,649 adults from the Diet and Health Knowledge Survey (follow-up to CSFII), linked data.	Meat consumption: chicken, beef, pork, processed pork products.	None; > 0 and < 1oz (28g) cooked lean meat equivalent (Smaller); ≥ 1 oz cooked lean meat equivalent (Larger) over 2 days	Two non-consecutive 24-hour recalls. Diet and Health Knowledge Survey administered at least 1 week after the last 24-hour recall. calculated from Food Guide Pyramid meat groups, using recipe ingredients.	"Smaller" chicken consumers had lower discretionary fat intakes (50.8g/day), compared to non-consumers (56.7 g/day) or "Larger" consumers (56.4 g/day).

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Study	Design	Studies/participants	Diet	Dose	Measurement	Outcome
Other health conditions						
Okamoto K, Kobashi G, Washio M, Sasaki S, Yokoyama T, Miyake Y, Sakamoto N, Ohta K, Inaba Y, Tanaka H. Dietary habits and risk of ossification of the posterior longitudinal ligaments of the spine (OPLL); findings from a case-control study in Japan. *J Bone Miner Metab* 2004;22(6):612-7.	Case-control study (1998 – 2001)	Prevalent OPLL cases (n = 69) identified and matched by age and sex with community controls (n = 138) randomly selected from the general population in Hokkaido.	Not an intervention study	Chicken < 3 times/week Chicken ≥ 3 times/week	Self-administered food-frequency questionnaire to assess habitual dietary intake.	Frequent consumption of chicken (adjusted OR= 0.5; 95% CI = 0.3 - 0.98) and soy foods (adjusted OR = 0.4; 95% CI = 0.2 - 0.7) was significantly associated with a decreased risk of OPLL.
Immunity						
Brian K. McFarlin BK, Flynn MG, Mahon AK, Stewart LK, Timmerman KL, Lyle RM, Campbell WW. Energy Restriction with Different Protein Quantities and Source: Implications for Innate Immunity. *Obesity* 2006 Jul; 14(7): 1211-8.	Randomised controlled parallel group trial for 9 weeks (2-wk weight maintenance run-in).	54 postmenopausal women, 50 – 80 y, BMI <25 and > 34 kg/m^2.	Three energy restricted (ER) lacto-ovo vegetarian diets of 1000 kcal/d plus 250 kcal/d of either beef (BEEF; 25 % E Protein, n = 14), chicken (CHICK; 25 % E Protein, n = 15), or carbohydrate/fat foods (CARB (lacto-ovo), 17 % E Protein, n = 14), Control group (CON, n = 11) consumed their habitual diets.	5-day fixed rotation menu of 3 meals and 2 snacks daily. 250 kcal/day provided of either cooked beef tenderloin, (BEEF) chicken breast plus 2.5 tsp butter to match the saturated fatty acid content of the beef) (CHICK) or shortbread cookies and sugar coated chocolates (CARB,	Fasting blood collected before and after ER to determine leukocyte phenotype, neutrophil oxidative burst capacity, natural killer cell activity, stimulated interleukin-2 and interferon-_ production, and blood zinc and iron concentrations.	No significant effects of ER or protein quantity and source were found for the majority of indices of innate immunity. Small but significant ($p < 0.05$) declines in interleukin-2 production were found in the chicken and CHO groups only; however, the clinical significance of this finding is not known.

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