Meeting the nutrient reference values on a vegetarian diet

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Summary

- Surveys over the past 10 years have shown that Australians are increasingly consuming more plant-based vegetarian meals.
- Many studies demonstrate the health benefits of vegetarian diets. As with any type of eating plan, vegetarian diets must be well planned to ensure nutritional needs are being met.
- This clinical focus project shows that well planned vegetarian diets can meet almost all the nutritional needs of children and adults of all ages.
- Sample single-day lacto-ovo-vegetarian meal plans were developed to comply with the nutrient reference values — including the increased requirements for iron and zinc at 180% and 150%, respectively, for vegetarians — for both sexes and all age groups set by Australia's National Health and Medical Research Council and the New Zealand Ministry of Health.
- With the exception of vitamin D, long-chain omega-3 fatty acids and extended iron requirements in pregnancy for vegetarians, the meal plans meet key requirements with respect to energy; protein; carbohydrate; total fat; saturated, poly- and monounsaturated fats; α-linolenic acid; fibre; iron; zinc; calcium; folate; and vitamins A, C, E and B_{12}.

Although only 5%–6% of females and 1%–3% of males claim to be vegetarian,[1,2] a 2010 Newspoll Survey (commissioned by Sanitarium Health and Wellbeing) found that seven out of 10 Australians are eating more plant-based meals than previously, in the belief that eating less meat and more plant foods improves overall health. As with any dietary practice, vegetarian diets need to be well planned to ensure that meals are healthy, delicious and nutritionally adequate.[3]

Research has shown that a well planned vegetarian diet can meet nutritional needs for good health[4] and may reduce the risk of cancer,[4-8] cardiovascular disease,[5,8,9] metabolic syndrome, insulin resistance, type 2 diabetes,[10-14] hypertension[7,15,16] and obesity.[11,17-19] Choosing plant-based meals is also environmentally beneficial.[20-22] Vegetarian diets are generally lower in saturated fat and cholesterol and higher in dietary fibre, antioxidants and phytochemicals than non-vegetarian diets.[4] It is likely that the combination of these factors provide vegetarians with a significant health advantage.[7,23,24]

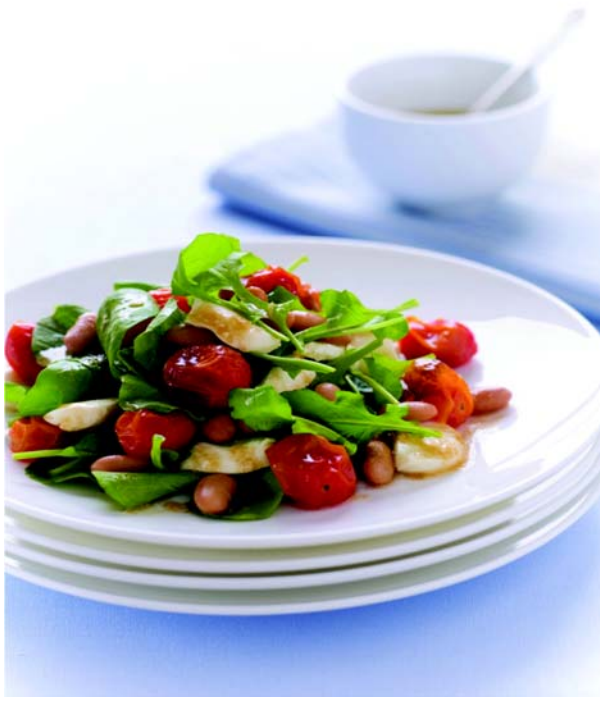
Our article showcases well designed lacto-ovo-vegetarian meal plans for all age groups and both sexes that meet the nutrient reference value (NRV) requirements (Box 1), as well as the higher requirements set for iron and zinc for vegetarians.

The challenge for vegetarians

Since the release, in 2006, of the revised *Nutrient reference values for Australia and New Zealand including recommended dietary intakes*,[25] which supersede the 1991 recommended dietary intakes (RDIs),[26] there has been some concern expressed about the ability to meet these recommendations. Compared with the 1991 RDIs, the 2006 NRVs recommend a small increase in iron for men, women and pregnant women and an increase in zinc for men (Box 2). For vegetarians, the further recommended increases in

Abbreviations

AI	adequate intake
ALA	α-linolenic acid
AMDR	acceptable macronutrient distribution range
DHA	docosahexaenoic acid
EER	estimated energy requirement
EPA	eicosapentaenoic acid
n-3 PUFA	omega-3 polyunsaturated fatty acid
NRV	nutrient reference value
PAL	physical activity level
RDI	recommended dietary intake
UL	upper level of intake



1 Definitions of nutrient reference values[25]

Nutrient reference value	Definition
Estimated average requirement (EAR)	A daily nutrient level estimated to meet the requirements of half the healthy individuals of a particular sex and life stage.
Recommended dietary intake (RDI)	The average daily dietary intake level that is sufficient to meet the nutrient requirements of nearly all healthy individuals (97%–98%) of a particular sex and life stage.
Adequate intake (AI)*	The average daily nutrient intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that is assumed to be adequate.
Upper level of intake (UL)	The highest average daily nutrient intake level likely to pose no adverse health effects to almost all individuals in the general population. As intake increases above the UL, the potential risk of adverse effects increases.

* Used when an RDI cannot be determined.

2 Comparison of 1991[26] and 2006[25] nutrient reference values (NRVs) for iron and zinc recommended by the National Health and Medical Research Council, including NRVs for vegetarians

	Men		Women		Pregnant women		Lactating women	
RDI	19–70+ years	Vegetarian*	19–70+ years	Vegetarian*	14–50 years	Vegetarian*	14–50 years	Vegetarian*
Iron								
1991	7 mg		16 mg†/7 mg‡		22 mg§/36 mg†		16 mg§/7 mg†	
2006	8 mg	14 mg	18 mg†/8 mg‡	32 mg†/14 mg‡	27 mg	49 mg	10 mg§/9 mg†	18 mg§/16 mg†
Zinc								
1991	12 mg		12 mg		16 mg		18 mg	
2006	14 mg	21 mg	8 mg	12 mg	10 mg§/11 mg†	15 mg§/16 mg†	11 mg§/12 mg†	17 mg§/18 mg†

RDI = recommended dietary intake. * 180% of non-vegetarian RDIs for iron and 150% of non-vegetarian RDIs for zinc. † 19–50 years. ‡ 51–70+ years. § 14–18 years.

iron requirement (80% higher than current RDIs for non-vegetarians) and zinc requirement (50% higher than current RDIs for non-vegetarians) present additional challenges. The higher iron requirement is based on the assumption that only 10% of iron is absorbed from a vegetarian diet, compared with 18% from a mixed diet that includes meat.[25,27] The higher zinc requirement is based on the fact that vegetarian diets have a higher phytate content[25,28-30] and evidence that the phytate-to-zinc ratio can affect zinc absorption.[25,27] Iron and zinc requirements are discussed in detail elsewhere in this supplement.[31,32]

Developing meal plans

The aim of our project was to develop single-day lacto-ovo-vegetarian meal plans that could be used as educational tools for vegetarian clients. Sample meal plans were developed for each sex and age category (Box 3), taking into account the appropriate physical activity level (PAL). The meal plans show the types and quantities of foods required to comply with the NRVs.

Foods were selected from a wide range of commonly available Australian foods. Each meal plan was devised to meet the recommended increased iron (180% of RDI) and zinc (150% of RDI) requirements within reasonable energy intakes while keeping macronutrient intakes within the acceptable macronutrient distribution range (AMDR).[25] Other nutrients, such as α-linolenic acid (ALA), fibre, vitamin B_{12}, vitamin C and calcium were included in amounts designed to meet the prescribed NRV value while not exceeding the upper level of intake (UL) for sodium or certain antioxidants such as vitamins A and E.[25] When the NRVs differed between sexes within an age group, the meals were planned to meet the higher requirements within an energy range applicable to both males and females. In many cases, meal plans were sex specific. Infants less than 1 year old were not considered because of

3 Nutrient reference value (NRV) categories by age and sex, showing appropriate physical activity level (PAL) as a rationale for developing sample meal plans

NRV age group	Physical activity level	Sample meal plan created
Children 1–3 years	1.6 (light activity)*	1-year-old, 2-year-old and 3-year-old child. Boys and girls have the same NRV requirements. Different ages within the 1–3-year-old category had different energy needs, which were reflected in the three sample meal plans for this age group. An energy range applicable to male and female was met.
Children 4–8 years	1.6 (light activity)	4-year-old.† Boys and girls have the same NRV requirements. An energy range applicable to male and female was met.
Children 9–13 years	1.8 (moderate activity)	9-year-old.† Boys have higher NRV requirements. An energy range applicable to male and female was met.
Children 14–18 years	1.8 (moderate activity)	14-year-old male and female.† Differing NRV and energy requirements.
Adults 19–30 years; adults 31–50 years	1.8 (moderate activity)	Males and females aged 19–30 years and 31–50 years have very similar NRV requirements within the same sex, although male and female requirements differ. Average adult heights were used to determine energy level.
Adults 51–70 years; adults 71+ years	1.6 (light activity)	Male and female. Meeting the older age group requirements (71+ years) automatically means the younger age group requirements (51–70 years) are met. Male and female requirements differ.
Pregnant women	1.6 (light activity)	Female with additional energy requirements (1.4 MJ/day).
Lactating women	1.6 (light activity)	Female with additional energy requirements (2.0 MJ/day).

* PAL is not assigned until the age of 3 years. For children under the age of 3 years, estimated energy requirements are prescribed values. † Youngest age chosen to meet nutritional requirements in minimal kilojoules applicable to the NRV age range. ◆

variable intake and reliance on breastmilk or infant formula as their main source of nutrition.

Energy requirements for each meal plan were determined according to the estimated energy requirements (EERs) outlined in the NRVs.[25] Within each NRV age group under 18 years, the youngest child in the group was chosen, on the grounds that if nutritional requirements are met at a lower energy level, requirements will also be met for older or more active children. Additional energy may be added as required. For adults, average height (165 cm for women and 175 cm for men), along with PAL, determined the estimated energy requirements. Although the 1995 National Nutrition Survey states that the mean height for adults over 19 years is 161.4 cm for women and 174.9 cm for men,[33] we adopted the average heights of 165 cm for women and 175 cm for men as used by the National Health and Medical Research Council in the recent revision of the *Australian guide to healthy eating*.[34]

A PAL of 1.8 (moderate activity) was chosen for teenagers and adults. A PAL equal to or above 1.75 is considered compatible with a healthy lifestyle for adults.[25] A light PAL (1.6) was chosen for young children, older adults, pregnant women and lactating women. In line with NRV recommendations, an additional 1.4 MJ/day and 2.0 MJ/day were applied for pregnant and lactating women, respectively.[25]

As no vegetarian consumption data are currently available, food selection for meal plans was based on foods that are commonly available in Australia and are considered good sources of the nutrients in focus. Meal plans were initially created and analysed using FoodWorks Professional, version 5, 2007 software (Xyris Software, Brisbane, Australia) using the AUSNUT 1999 (Australian food and nutrient database, 1999 version) food composition database.[35] As information on vitamins D, E and B_{12} content in foods was not available when meal plans were initially entered into FoodWorks, other sources were used to determine the content of these nutrients in our meal plans. The amounts of these nutrients in each meal plan were hand-calculated using the NUTTAB 2006 (nutrient tables for use in Australia, 2006 version) database.[36] The RMIT Lipid Research Group's fatty acid composition database[37] was used to calculate ALA content.[36] Food product nutrition information panels and nutrient information from company websites were used when needed.

Nutritional analyses were compared with the appropriate NRVs — RDI or adequate intake (AI).[25] The use of RDI when planning diets for individuals ensures that the needs of most people are covered by these recommendations.[25] When an RDI cannot be determined, an AI is used. The sodium content of each meal plan was compared with the daily recommended UL for sodium,[25] and the saturated fat target was chosen to be less than 10% of total energy.[25] For macronutrients, the goal was to achieve the AMDR. The AMDR is an estimate of the range of intake for each macronutrient for individuals (expressed as percentage contribution to energy) that would allow for an adequate intake of all other nutrients while maximising general health outcome.[25]

Key nutrients

In planning vegetarian diets to ensure adequate nutritional intake, it is wise to be aware of some key nutrients.[4] Iron, zinc, vitamin D and long-chain omega-3 polyunsaturated fatty acids (n-3 PUFAs) are considered nutrients of concern in vegetarian diets. It is important to note that vitamin D and long-chain n-3 PUFAs are also a concern for non-vegetarians who have limited sun exposure and consume minimal amounts of oily fish. Following, we highlight points of interest regarding these nutrients.

Iron

Cereal products are the main source of dietary iron for all Australians (a bigger contributor than meat, according to consumption data).[33] Consequently, cereal products were also a significant source of iron in these meal plans. Cereals, legumes, nuts, seeds and fortified foods were selected mostly in combination with vitamin C-rich foods, as vitamin C enhances iron absorption.[38] However, absorption concerns are less of an issue than previously thought.[39] Even though iron requirements have been set higher for vegetarians, those with lower stores of iron or higher physiological need will absorb more iron and excrete less iron — an important adaptive mechanism.[28,31,32]

Zinc

While red meat and seafood are good sources of zinc for non-vegetarians, other foods such as nuts, seeds, legumes and dairy foods are important sources of zinc for vegetarians and were included in the meal plans. Concerns

4 Four sample vegetarian meal plans*

NRV age group: children 4–8 y *4-year-old child, PAL 1.6* Reference weight 16.2 kg (boys), 15.8 kg (girls); reference height 102 cm (boys), 101 cm (girls)	**NRV age group: women 19–30 y and 31–50 y** *35-year-old woman, PAL 1.8* Reference weight 60.0 kg; reference height 165 cm (average height)	**NRV age group: adults 50–70+ y** *71-year-old man, PAL 1.6* Reference weight 67.5 kg; reference height 175 cm (average height)	**NRV age group: pregnant women** *25-year-old pregnant woman, PAL 1.6* Reference height 165 cm (average height) Energy requirements: additional 1.4 MJ/day for pregnancy
Breakfast: 2 fortified wholegrain wheat biscuits, 1/2 cup low-fat fortified soy milk, sprinkle (5 g) of chia seeds; 1 slice iron-fortified wholemeal toast with chopped banana	*Breakfast:* 2 fortified wholegrain wheat biscuits, 4 strawberries, 10 g chia seeds, 1/2 cup low-fat fortified soy milk; 1 slice multigrain toast with 1 poached egg	*Breakfast:* Rolled oats made with 1/2 cup dry oats, 1/2 cup low-fat fortified soy milk, 2 tbsp wheatgerm and 10 g chopped walnuts, 30 g pumpkin seeds and 1 banana	*Breakfast:* 2 fortified wholegrain wheat biscuits with 1/2 cup low-fat fortified soy milk with 1 banana and sprinkle (< 10 g) of chia seeds; 1 slice iron-fortified toast with Marmite and margarine; 1/2 cup freshly squeezed orange juice
Snack: 3/4 cup low-fat fortified soy milk and 2 strawberries	*Snack:* 30 g cashews and 6 dried apricot halves	*Snack:* 1 apple; hot chocolate made with 1 cup low-fat fortified soy milk, 2 tsp cocoa powder and 1 tsp sugar	*Snack:* 25 g cashews and 5 dried apricot halves
Lunch: Salad sandwich with tahini, tabouli and 2 slices wholemeal iron-fortified bread	*Lunch:* 1 wholemeal pita flatbread with chickpea falafel, hummus, 1/2 cup tabouli and salad	*Lunch:* Mixed-grain-bread sandwich with 40 g cheese, salad, 4 pieces sundried tomato and margarine; 1/2 cup orange juice	*Lunch:* 2 slices wholemeal iron-fortified toast with baked beans and 20 g low-fat melted cheese; hot chocolate made with 1 cup low-fat fortified soy milk and 2 tsp fortified malted chocolate powder
Snack: 2 rye and sesame crispbread biscuits, 1 spread with tahini and 1 with Marmite	*Snack:* Banana and wheatgerm smoothie made with 3/4 cup low-fat fortified soy milk, 2 tsp wheatgerm and 1 banana	*Snack:* 3 rye biscuits with tahini and honey	*Snack:* 35 g almonds and 1 kiwifruit
Dinner: Honey and soy brown fried rice, made with 40 g tofu, just under 1 cup cooked brown rice and vegetables	*Dinner:* Stir-fried greens with tofu, served with 1 cup cooked brown rice (100 g tofu, asparagus, bok choy and snow peas)	*Dinner:* Lentil curry with vegetables (pumpkin, peas, beans, canned tomatoes, 1/2 cup lentils) and cashews, served with 1 cup cooked brown rice and sprinkled with sesame seeds	*Dinner:* Tofu (100 g), chickpea (1/2 cup) and vegetable (spinach, broccoli and carrot) curry with 1 cup cooked brown rice
Snack: 100 g low-fat plain yoghurt	*Snack:* Hot chocolate, made with 1 cup low-fat fortified soy milk and 10 g fortified malted chocolate powder	*Snack:* Hot chocolate, made with 1 cup low-fat fortified soy milk, 2 tsp cocoa powder and 1 tsp sugar; 10 g walnuts	*Snack:* 200 g low-fat fruit yoghurt and 25 g pumpkin seeds

NRV = nutrient reference value. PAL = physical activity level. tbsp = tablespoon. tsp = teaspoon. y = years. * Add water as desired. ◆

about phytate as an inhibitor of zinc absorption are minimised by modern food processing methods.[40] When considering zinc requirements, it is important to remember that the body can adapt to different levels of zinc intake by adjusting the amount of zinc absorbed relative to the amount of endogenous zinc lost.[41,42]

Omega-3 polyunsaturated fatty acids

Given that vegetarian diets exclude fish as a source of n-3 PUFAs, it is important to include adequate amounts of short-chain n-3 PUFAs such as ALA (found predominantly in chia seeds, flaxseeds and walnuts). Small amounts of these seeds were included in the meal plans and provided significant amounts of ALA. ALA is endogenously converted to long-chain omega-3 fatty acids, but conversion depends on age, sex and dietary composition.[43] The meal plans used minimal amounts of omega-6 fatty acids (oils and margarines) to optimise conversion.[43]

Vitamin D

Vitamin D deficiency is not just a concern for vegetarians.[44] The average dietary intake of vitamin D for Australians is 2–3 μg/day, which is substantially below the AI of 5 μg/day (for children and younger adults).[25] Important dietary sources of vitamin D are margarine, eggs, vitamin D-fortified soy milk, and oily fish.[45] Minimal amounts of margarine and eggs were included in the meal plans, due

5 Nutrient analyses for the four sample vegetarian meal plans presented in Box 4

	NRV age group: children 4–8 y *4-year-old child, PAL 1.6* Reference weight 16.2 kg (boys), 15.8 kg (girls); reference height 102 cm (boys), 101 cm (girls)		**NRV age group: women 19–30 y and 31–50 y** *35-year-old woman, PAL 1.8* Reference weight 60 kg; reference height 165 cm (average height)		**NRV age group: adults 50–70+ y** *71-year-old man, PAL 1.6* Reference weight 67.5 kg; reference height 175 cm (average height)		**NRV age group: pregnant women** *25-year-old pregnant woman, PAL 1.6* Reference height 165 cm (average height) Energy requirements: additional 1.4 MJ/day for pregnancy	
Nutrient	**Meal plan provides**	**NRV/goal***	**Meal plan provides**	**NRV/goal***	**Meal plan provides**	**NRV/goal***	**Meal plan provides**	**NRV/goal***
Energy (kJ)	5800	5500–5900†	8600‡	10 050–10 350§	9700	9200–10 100§	10 600	10 300–10 600§
Protein (g)	55	20	90	46	101	81	120	60
% total energy	16%	15%–25%¶	18%	15%–25%¶	18%	15%–25%¶	19%	15%–25%¶
CHO (g)	186	—	262	—	277	—	284	—
% total energy	55%	45%–65%¶	52%	45%–65%¶	48%	45%–65%¶	46%	45%–65%¶
Fat (g)	38	—	64	—	80	—	91	—
% total energy	24%	20%–35%¶	27%	20%–35%¶	30%	20%–35%¶	32%	20%–35%¶
SFA (g)	8	—	12	—	14	—	17	—
% total energy	5%	< 10%¶	5%	< 10%¶	5%	< 10%¶	6%	< 10%¶
% total fat	21%	—	19%	—	18%	—	19%	—
PUFA (g)	17	—	22	—	34	—	26	—
% total fat	45%	—	34%	—	43%	—	29%	—
MUFA (g)	13	—	30	—	32	—	48	—
% total fat	34%	—	47%	—	40%	—	53%	—
ALA (g)	1.4	0.8	2.8	0.8	1.3	1.3	2.1	1.0
LC n-3 PUFA (mg)	—	55	—	90	—	160	—	115
Fibre (g)	31	18	46	25	48	30	53	28
Iron (mg)	18	18 (180% RDI)	32.6	32.4 (180% RDI)	24.8	14.4 (180% RDI)	36.6**	48.6 (180% RDI)
Zinc (mg)	7	6 (150% RDI)	13	12 (150% RDI)	21.4	21 (150% RDI)	16.5	16.5 (150% RDI)
Vitamin B_{12} (μg)	1.5	1.2	3.2	2.4	2.9	2.4	3.2	2.6
Calcium (mg)	824	700	1386	1000	1489	1300	2083	1000
Folate (μg)	463	200 (UL 400)	517	400 (UL 1000)	494	400 (UL 1000)	716	600 (UL 1000)
Vitamin A equivalents (μg)	429	400 (UL 900)	748	700 (UL 3000)	928	900 (UL 3000)	992	800 (UL 2800–3000)
Vitamin E (mg)	40	6 (UL 100)	10	7 (UL 300)	65	10 (UL 300)	25	7 (UL 300)
Vitamin D (μg)	< 1	5	< 1	5	< 2	15	< 2	5
Vitamin C (mg)	80	35 (no UL)	115	45 (no UL)	106	45 (no UL)	175	60 (no UL)
Sodium (mg)	1298	300–600 (UL 1400)	1738	460–920 (UL 2300)	1786	460–920 (UL 2300)	1908	460–920 (UL 2300)

ALA = α-linolenic acid. CHO = carbohydrate. LC n-3 PUFA = long-chain omega-3 polyunsaturated fatty acids. MUFA = monounsaturated fatty acids. NRV = nutrient reference value. PUFA = polyunsaturated fatty acids. RDI = recommended dietary intake. SFA = saturated fatty acids. UL = upper level of intake. y = years. * NRVs for Australia and New Zealand (RDI and adequate intake).[25] † Energy value range is applicable to both male and female for the youngest in this NRV age group (males being the higher and females being the lower value). If additional energy is required in an individual diet for an older child, add discretional kJ from foods including avocado, dried fruit, fresh juice, peanut butter and olive oil spread. Nutritional requirements are still met. ‡ The energy in this meal plan meets the requirements for a lower PAL of 1.6 (light activity), associated with an estimated energy requirement of 8900–9200 kJ. If additional energy is required in an individual diet, add discretionary kJ. Nutritional requirements are still met. § Energy range is provided to be applicable to the large age range in this NRV group. If additional energy is required, add discretionary kJ. Nutritional requirements are still met. ¶ Acceptable macronutrient distribution range.[25] ** This sample meal plan did not meet the extended RDI for iron (providing 180% of RDI for iron during pregnancy results in a level that is above the UL). ◆

to a focus on whole plant-food sources of fat, such as nuts, seeds and avocado. Vitamin D-fortified soy milk was not included in the meal plans, as its availability is currently limited in Australia. The AI for vitamin D assumes most Australians receive some vitamin D from the sun to adequately meet requirements.[25,45] Those with limited sun exposure, older adults (with higher requirements) or those with dark skin should supplement their diet with vitamin D.[4,45]

Analysis of sample lacto-ovo-vegetarian meal plans

The 13 sample meal plans are available online at http://www.sanitarium.com.au/~/media/sanitarium/sns-pdfs/meal-plan-summary-tables.ashx. The full nutritional analyses for all sample meal plans are available at http://www.sanitarium.com.au/~/media/sanitarium/sns-pdfs/meal-plans-and-analyses.ashx. Almost all meal plans met key NRVs (for energy; protein; carbohydrate; total fat; saturated, poly- and mono-unsaturated fats; ALA; fibre; iron; zinc; calcium; folate; and vitamins A, C, E and B_{12}), including the increased requirements for iron and zinc. An exception was for pregnant women, for whom increased iron requirements were not met. AI levels for vitamin D and long-chain n-3 PUFAs were not met across all meal plans. Below is a brief explanation of the analysis. Four examples of single-day vegetarian meal plans are presented in Box 4, and a nutrient analysis of each plan is provided in Box 5.

Energy

The NRV goals for energy were met based on the youngest child in each NRV category and on average heights for adults, with a PAL of 1.8 for adults and 1.6 for younger children, older adults, pregnant women and lactating women.

Macronutrients

Protein, carbohydrate and fat intakes were within the AMDR. The proportion of total energy contributed by saturated fat was consistently below the 10% target. Polyunsaturated and monounsaturated fats were the predominant sources of fat in each of the sample meal plans.

α-linolenic acid

As the ALA content of each meal plan was hand-calculated, the values are approximate. The AI for ALA was achieved in all meal plans, with the richest sources being chia seeds, walnuts and tofu.

Fibre

The AI was exceeded in all meal plans. There is no UL set for fibre, as a high intake of dietary fibre does not result in adverse effects when consumed as part of a healthy diet.[25]

Iron

The increased iron requirement for vegetarians (180% of RDI) was achieved for all meal plans with the exception of the meal plan for pregnant women. The best vegetarian sources of iron in our meal plans were firm tofu, iron-fortified breads and breakfast cereals, cashews, chickpeas, pumpkin seeds, sesame seeds, brown rice, fortified malted chocolate powder and tabouli.

Zinc

The increased zinc requirement for vegetarians (150% of RDI) was achieved for all meal plans, including adult males with the highest zinc requirements, without exceeding energy and fat needs. The best vegetarian sources of zinc in our meal plans included muesli, pumpkin seeds, sunflower seeds, wheatgerm, tofu, brown rice and sundried tomatoes.

Vitamin B_{12}

As the vitamin B_{12} content of each meal plan was hand-calculated, the values are approximate. All meal plans, including those for lactating women, meet the RDI for vitamin B_{12}. In our meal plans, the best sources of vitamin B_{12} were milk, fortified soy milk, yoghurt, cheese, egg and fortified yeast spread.

Calcium

Calcium requirements were easily met for all meal plans, including those for adolescents and older adults, who have the highest requirements. Care was taken not to exceed the UL for calcium (2500 mg) in high-energy meal plans. The best vegetarian sources of calcium in our meal plans were low-fat milk and cheese, tofu (calcium set), fortified soy milk, yoghurt, sesame seeds and sesame paste (tahini).

Vitamin E

As the vitamin E content of each meal plan was hand-calculated, the values are approximate. All meal plans met vitamin E requirements. The best sources of vitamin E in our meal plans were tahini, sesame seeds, wheatgerm, almonds, peanut butter, olive oil, margarine and eggs.

Vitamin D

As the vitamin D content of each meal plan was hand-calculated, the values are approximate. The meal plans did not meet the AI for vitamin D. The small amount of vitamin D accounted for in the analyses was attributed to margarine and cheese. Some brands of soy milk are fortified with vitamin D and provide a good source for vegetarians. Our analysis did not take into account vitamin D derived from safe sun exposure.

Long-chain omega-3 polyunsaturated fatty acids

Vegetarian diets cannot meet the requirements for n-3 PUFAs unless vegetarian docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) supplements (derived from microalgae) or fortified foods are consumed. As DHA/EPA-fortified foods are not widely available in Australia, long-chain n-3 PUFAs were not analysed in our meal plans. Although there is no separate official recommendation for n-3 PUFAs for vegetarians, it is suggested that they double the current AI of ALA if they do not consume a direct source of DHA and EPA, as ALA is converted to DHA and EPA.[43] People with increased need for n-3 PUFAs (eg, pregnant women, older people and people with diabetes) may benefit from adding a microalgae-derived DHA and EPA supplement.[46]

Other nutrients

Requirements for folate, vitamin C and vitamin A were met for all meal plans. Salt was not added to the meal plans, but the sodium content of the meal plans would be lower if the food composition database contained more food options without added sodium. Sodium levels did not exceed the UL.

Discussion

Our meal plans were designed to be nutrient-dense in order to meet nutritional requirements without supplying excess energy. For people who have higher energy needs, additional discretionary kilojoules may be added. A vegetarian dietary pattern that focuses on nutrient density rather than energy deficit will naturally assist with weight loss and maintain healthy weight status in the long term.[47-49]

The higher iron requirement (180% of RDI) recommended for pregnant vegetarian women translates to 49 mg per day. Of interest, the UL during pregnancy is 45 mg.[25] Our meal plan was only able to provide 36.6 mg within a reasonable energy intake. However, it is well recognised that the increased iron requirements during pregnancy can be difficult to meet, even for non-vegetarian women, and iron supplements are commonly recommended.[4] The iron content of most multivitamin supplements formulated for pregnant women would easily compensate for this shortfall.

In our dietary analysis, fibre intakes were well above the RDIs and suggested dietary targets. There is currently no UL set for dietary fibre and there are no significant adverse effects of a high fibre intake eaten as part of a healthy diet.[25]

Limitations

While we attempted to use mostly whole plant foods, in order to meet the NRVs (including the higher requirements for iron and zinc), some commonly available fortified foods were included (eg, soy beverages fortified with calcium and vitamin B_{12}; iron-fortified cereals and bread; fortified malted milk powder; and fortified yeast spread). The analyses were also limited to values available in the AUSNUT database used by FoodWorks in our analyses. There are also limitations in using the NRVs for estimating dietary adequacy. RDIs overestimate needs (as they are designed to meet the needs of the majority of the population) and don't take into account adaptive responses, as with iron[31] and zinc[32] or the protective phytonutrients from plant foods. These issues are particularly relevant to vegetarians.

Conclusion

Requirements for most key nutrients (except vitamin D, long-chain n-3 PUFAs and iron during pregnancy) can be met across the life cycle by well planned plant-based lacto-ovo-vegetarian diets. Furthermore, nutrient-dense vegetarian diets are more likely to provide additional health benefits, particularly with respect to prevention and treatment of many chronic diseases.

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1 Australian Bureau of Statistics. National Nutrition Survey: selected highlights Australia 1995. Canberra: ABS, 1997. (ABS Cat. No. 4802.0.) http://www.ausstats.abs.gov.au/ausstats/free.nsf/0/236465EA4E9B3D2BCA2572500049629/$File/48020_1995.pdf (accessed Apr 2012).

2 Vegetarian/Vegan Society of Queensland. A pound of flesh [survey report]. 2010. http://www.vegsoc.org.au (accessed Feb 2012).

3 Radd S, Marsh KA. Practical tips for preparing healthy and delicious plant-based meals. *MJA Open* 2012; 1 Suppl 2: 41-45.

4 Craig WJ, Mangels AR. Position of the American Dietetic Association: vegetarian diets. *J Am Diet Assoc* 2009; 109: 1266-1282.

5 Fraser GE. Associations between diet and cancer, ischemic heart disease, and all-cause mortality in non-Hispanic white California Seventh-day Adventists. *Am J Clin Nutr* 1999; 70 (3 Suppl): 532S-538S.

6 World Cancer Research Fund/American Institute for Cancer Research. Food, nutrition, physical activity, and the prevention of cancer: a global perspective. Washington, DC: AICR, 2007. http://www.dietandcancerreport.org/cancer_resource_center/second_expert_report.php (accessed Apr 2012).

7 Fraser GE. Vegetarian diets: what do we know of their effects on common chronic diseases? *Am J Clin Nutr* 2009; 89: 1607S-1612S.

8 Key TJ, Appleby PN, Spencer EA, et al. Mortality in British vegetarians: results from the European Prospective Investigation into Cancer and Nutrition (EPIC-Oxford). *Am J Clin Nutr* 2009; 89: 1613S-1619S.

9 Rajaram S. The effect of vegetarian diet, plant foods, and phytochemicals on hemostasis and thrombosis. *Am J Clin Nutr* 2003; 78 (3 Suppl): 552S-558S.

10 Villegas R, Gao YT, Yang G, et al. Legume and soy food intake and the incidence of type 2 diabetes in the Shanghai Women's Health Study. *Am J Clin Nutr* 2008; 87: 162-167.

11 Tonstad S, Butler T, Yan R, Fraser GE. Type of vegetarian diet, body weight, and prevalence of type 2 diabetes. *Diabetes Care* 2009; 32: 791-796.

12 Snowdon DA, Phillips RL. Does a vegetarian diet reduce the occurrence of diabetes? *Am J Public Health* 1985; 75: 507-512.

13 Jenkins DJ, Kendall CW, Marchie A, et al. Type 2 diabetes and the vegetarian diet. *Am J Clin Nutr* 2003; 78 (3 Suppl): 610S-616S.

14 Valachovicová M, Krajcovicová-Kudlácková M, Blazícek P, Babinská K. No evidence of insulin resistance in normal weight vegetarians. A case control study. *Eur J Nutr* 2006; 45: 52-54.

15 Berkow SE, Barnard ND. Blood pressure regulation and vegetarian diets. *Nutr Rev* 2005; 63: 1-8.

16 Appleby PN, Davey GK, Key TJ. Hypertension and blood pressure among meat eaters, fish eaters, vegetarians and vegans in EPIC-Oxford. *Public Health Nutr* 2002; 5: 645-654.

17 Berkow SE, Barnard N. Vegetarian diets and weight status. *Nutr Rev* 2006; 64: 175-188.

18 Rosell M, Appleby P, Spencer E, Key T. Weight gain over 5 years in 21,966 meat-eating, fish-eating, vegetarian, and vegan men and women in EPIC-Oxford. *Int J Obes (Lond)* 2006; 30: 1389-1396.

19 Newby PK, Tucker KL, Wolk A. Risk of overweight and obesity among semivegetarian, lactovegetarian, and vegan women. *Am J Clin Nutr* 2005; 81: 1267-1274.

20 Reijnders L, Soret S. Quantification of the environmental impact of different dietary protein choices. *Am J Clin Nutr* 2003; 78 (3 Suppl): 664S-668S.

21 Weber CL, Matthews HS. Food-miles and the relative climate impacts of food choices in the United States. *Environ Sci Technol* 2008; 42: 3508-3513.

22 Baroni L, Cenci L, Tettamanti M, Berati M. Evaluating the environmental impact of various dietary patterns combined with different food production systems. *Eur J Clin Nutr* 2007; 61: 279-286.

23 Sabaté J. The contribution of vegetarian diets to human health. *Forum Nutr* 2003; 56: 218-220.

24 Leitzmann C. Vegetarian diets: what are the advantages? *Forum Nutr* 2005; 57: 147-156.

25 National Health and Medical Research Council and New Zealand Ministry of Health. Nutrient reference values for Australia and New Zealand including recommended dietary intakes. Canberra: NHMRC, 2006. http://www.nhmrc.gov.au/guidelines/publications/n35-n36-n37 (accessed Apr 2012).

26 National Health and Medical Research Council. Recommended dietary intakes for use in Australia. Canberra: Australian Government Publishing Service, 1991.

27 Food and Nutrition Board and Institute of Medicine. Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Washington, DC: National Academy Press, 2001. http://www.nap.edu/openbook.php?record_id=10026&page=R1 (accessed Apr 2012).

28 Hunt JR. Bioavailability of iron, zinc, and other trace minerals from vegetarian diets. *Am J Clin Nutr* 2003; 78 (3 Suppl): 633S-639S.

29 Gibson RS. Zinc nutrition in developing countries. *Nutr Res Rev* 1994; 7: 151-173.

30 Chiplonkar SA, Agte VV. Predicting bioavailable zinc from lower phytate forms, folic acid and their interactions with zinc in vegetarian meals. *J Am Coll Nutr* 2006; 25: 26-33.

31 Saunders AV, Craig WJ, Baines SK, Posen JS. Iron and vegetarian diets. *MJA Open* 2012; 1 Suppl 2: 11-16.

32 Saunders AV, Craig WJ, Baines SK. Zinc and vegetarian diets. *MJA Open* 2012; 1 Suppl 2: 17-22.

33 Australian Bureau of Statistics. National Nutrition Survey: nutrient intakes and physical measurements Australia 1995. Canberra: ABS, 1998. (ABS Cat. No. 4805.0.) http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/CA25687100069892CA25688900268A6D/$File/48050_1995.pdf (accessed Apr 2012).

34 Byron A, Baghurst K, Cobiac L, et al. A modelling system to inform the revision of the Australian guide to healthy eating. Canberra: Commonwealth of Australia, 2011. http://www.eatforhealth.gov.au/sites/default/files/files/public_consultation/n55a_dietary_guidelines_food_modelling_111216.pdf (accessed Mar 2012).

35 Australia New Zealand Food Authority. Australian food and nutrient database 1999 (AUSNUT 1999). http://www.foodstandards.gov.au/scienceandeducation/scienceinfsanz/foodcompositionprogram/ausnut1999 (accessed May 2012).

36 Food Standards Australia New Zealand. NUTTAB 2006: Australian food composition tables. http://www.foodstandards.gov.au/_srcfiles/Final%20NUTTAB%202006%20Food%20Composition%20Tables%20-%20May%2020071.pdf (accessed May 2012).

37 RMIT Lipid Research Group. Fatty acid composition database, 2001 [computer program]. http://www.serve.com.au/sv2facid.html (accessed May 2010).

38 Davidsson L. Approaches to improve iron bioavailability from complementary foods. *J Nutr* 2003; 133 (5 Suppl 1): 1560S-1562S.

39 Reddy MB, Hurrell RF, Cook JD. Estimation of nonheme-iron bioavailability from meal composition. *Am J Clin Nutr* 2000; 71: 937-943.

40 Lönnerdal B. Dietary factors influencing zinc absorption. *J Nutr* 2000; 130 (5S Suppl): 1378S-1383S.

41 King JC. Zinc: an essential but elusive nutrient. *Am J Clin Nutr* 2011; 94: 679S-684S.

42 King JC. Does zinc absorption reflect zinc status? *Int J Vitam Nutr Res* 2010; 80: 300-306.

43 Davis BC, Kris-Etherton PM. Achieving optimal essential fatty acid status in vegetarians: current knowledge and practical implications. *Am J Clin Nutr* 2003; 78 (3 Suppl): 640S-646S.

44 Nowson CA, Diamond TH, Pasco JA, et al. Vitamin D in Australia. Issues and recommendations. *Aust Fam Physician* 2004; 33: 133-138.

45 Nowson CA, Margerison C. Vitamin D intake and vitamin D status of Australians. *Med J Aust* 2002; 177: 149-152.

46 Saunders AV, Davis BC, Garg ML. Omega-3 polyunsaturated fatty acids and vegetarian diets. *MJA Open* 2012; 1 Suppl 2: 22-26.

47 Thedford K, Raj S. A vegetarian diet for weight management. *J Am Diet Assoc* 2011; 111: 816-818.

48 Farmer B, Larson BT, Fulgoni VL 3rd, et al. A vegetarian dietary pattern as a nutrient-dense approach to weight management: an analysis of the national health and nutrition examination survey 1999–2004. *J Am Diet Assoc* 2011; 111: 819-827.

49 Craig WJ. Health effects of vegan diets. *Am J Clin Nutr* 2009; 89: 1627S-1633S. ❑