South African dietary total antioxidant capacity based on secondary intake data in relation to dietary recommendations

[a] **Louwrens H,** BTech (Consumer Science: Food and Nutrition) [b] **Rautenbach F,** MSc (Biochemistry) [a] **Venter I,** MNutrion
[a] Department of Agricultural and Food Sciences, Cape Peninsula University of Technology, South Africa
[b] Faculty of Applied Sciences, Cape Peninsula University of Technology, South Africa
Correspondence to: Mr Fanie Rautenbach, e-mail: rautenbachf@cput.ac.za
Keywords: dietary TAC; ORAC; 5-A-day; food groups; plant foods; beverages

Abstract

Objective: In this exploratory study, the average adult South African dietary total antioxidant capacity (TAC) was estimated using secondary data and was evaluated against that determined for dietary intake recommendations.

Design: The average adult South African dietary TAC was estimated using a report published by the Department of Health that summarises food consumption studies conducted in South Africa between 1983 and 2000. This estimated adult South African dietary TAC was evaluated against that determined for dietary intake recommendations incorporating the five-a-day concept and the basic food groups and beverages (tea and coffee).

Results: The average adult South African dietary TAC was estimated as 11 433 micromoles (µmoles) Trolox equivalents (TE)/person/day, with beverages (tea) being the main contributor (38.5%). The dietary TAC based on the recommended five-a-day concept and other dietary intake recommendations was 20 513 µmoles TE/person/day, with beverages again being the main contributor (47.8%).

Conclusions: Compared to the TAC of the five-a-day concept and other dietary intake recommendations, the South African population consumes about half of this estimated TAC per day. It is especially in the vegetable group and beverages where actual consumption is well below the coupled TAC. Grains are the only food group where consumption is above the coupled TAC. The five-a-day concept is only the aim for minimum intake and not the ultimate goal. An increase in these foods, along with beverages (tea) and whole grains to the recommended servings, can uphold the dietary TAC and health benefits.

S Afr J Clin Nutr 2009;22(4):195-202

Introduction

Foods of plant origin, such as fruits, vegetables, grains and several beverages, provide a variety of antioxidants in the diet.[1,2] The consumption of these food items, with their antioxidant contribution to the diet, has been associated with a decrease in cardiovascular disease, cancer[3] and other chronic diseases, such as diabetes mellitus and renal failure.[2] Besides the antioxidant vitamins C and E, fruit and vegetables also contain phytochemical antioxidants such as carotenoids and flavonoids.[2] Phytochemicals are non-nutritive substances in plants that possess health-protective benefits,[4] most of which are attributed to them being antioxidants.[2]

Antioxidants can be defined as substances that can quench or stabilise free radicals.[1] Excess free radicals in the body contribute to the development of oxidative stress, which plays a role in the development of chronic diseases[2] such as those mentioned above. Stroke, ischaemic heart disease, tuberculosis, diarrhoea and lower respiratory infections, of which the development is linked to oxidative stress,[4] are some of the key chronic diseases that are major contributors to human death in all nine provinces of South Africa (SA).[5] Antioxidants have the capacity to prevent cellular damage from free radicals through a number of mechanisms.[4]

A daily per capita consumption of up to nine servings of fruit and vegetables is recommended.[3] Studies have indicated that a large number of South Africans do not consume the recommended daily intake of at least five servings (400 g) of fruit and vegetables.[6,7,8] However, South African fruit and vegetable intake has increased by 84% from 1962 to 2000. This increase can be attributed to fruit and vegetables becoming more accessible.[9] South Africans are not the only nation with insufficient fruit and vegetable intake. A study by Guenther et al[10] showed that only 40% of Americans consume the recommended five servings of fruit and vegetables daily. Besides being encouraged to eat plenty of fruit and vegetables every day through the food-based dietary guidelines (FBDGs),[6] South Africans are also urged to eat other foods of plant origin, such as dry beans, peas, lentils and soya. A daily consumption of 100 to 200 g cooked pulses is recommended.[11]

A further recommendation related to the South African FBDGs is that South Africans should eat more cereals and grains in the unprocessed or minimally processed form,[7,12] as these are particularly rich in antioxidants.[12] The data indicate that South Africans consume refined grains more often than whole grains.[7] The health benefits of whole grains are often underestimated. Whole grains provide equal or even larger amounts of phytochemicals than fruit and vegetables and should therefore be consumed daily in sufficient amounts (three servings),[12] which are not met in the diet of the South African population.[8]

A daily fluid intake of two litres is recommended. This can be taken in the form of tap water, coffee, tea or any other water-based beverage.[13] Studies have indicated that South Africans consume between 1.40 and 2.19 litres of fluid per person per day.[13] A study done using three different assays to estimate the TAC of several beverages found that coffee had the highest TAC. Tea (black and green) and citrus juice also have a high TAC, but not as high as coffee. The consumption of these beverages can also be recommended for protection against oxidative stress-induced diseases because of their antioxidant content.[1] An intake of one to two cups of coffee and four to six cups of tea has been recommended.[14] If the above dietary recommendations regarding fruit, vegetable,[6] legume,[11] unprocessed cereal/grain[7,12] and beverage[1,13,14] intake are followed, overall public health can be improved.

The TAC is the cumulative capacity of food components to scavenge free radicals. It can be used as an important measure to determine the relationship between oxidative stress-induced diseases and dietary antioxidants from plant foods.[1] Whole diets ought to be considered when addressing the role of dietary antioxidants in health.[15] The objective of this study was to estimate a daily average dietary TAC for the South African adult population and to compare it to the TAC of a diet incorporating the recommended daily intake from food groups and beverages. In this exploratory study, the TAC (using the oxygen radical absorbance capacity [ORAC] method) of the South African adult daily average dietary intake of whole basic foods was calculated using secondary data and evaluated against the calculated TAC based on the recommended five-a-day concept, as well as recommendations regarding the daily intake of other plant foods included in the basic food groups and beverages, such as tea and coffee. The whole foods commonly consumed by South African adults per day[16] were used for the calculations of the dietary TAC in this study.

Ronald Prior, one of the leading scientists in antioxidant capacity testing, suggested that "the ORAC measure may help define the dietary conditions needed to prevent tissue damage".[17] In 1999, Prior estimated that a daily intake of between 3 000 and 5 000 ORAC units (micromole (µmole) Trolox equivalents (TE)) would be required to have a significant influence on human plasma.[17] However, in 2001 the ORAC assay was changed when phycoerythrin was replaced by fluorescein (FL) as the fluorescent probe.[18] As the $ORAC_{FL}$ method produces significantly higher ORAC values compared to the original method, the 3 000 to 5 000 ORAC unit estimation is now obsolete. Wu et al[19] calculated the actual daily fruit and vegetable $ORAC_{FL}$ intake of persons in the USA to be 5 724 µmole TE (approximately 2.5 servings per person) and that, for nine fruit and vegetable servings, the $ORAC_{FL}$ intake per day could be as high as 20 000 µmole TE.

Methodology

ORAC method

The ORAC method has gained a lot of attention among researchers as a method to determine the TAC of samples under investigation.[20] The $ORAC_{FL}$ method has the advantage over other methods that it can directly measure the hydrophilic chain-breaking antioxidant capacity against the peroxyl radical.[18] Another advantage is that similar assay conditions and standards are used for both the hydrophilic (H) and lipophilic (L) $ORAC_{FL}$ method, such that the two values can be added together to record a TAC for the sample.[20] Three unique aspects of the ORAC method are that the assay is done at a pH of 7.4, a temperature of 37°C and in the presence of peroxyl radical (AAPH), which is similar to the conditions inside the human body.[21] Data from the ORAC method is expressed as µmoles of TE per gram or per litre.[19]

Estimated adult South African dietary TAC

The report compiled by Nel and Steyn[16] for the Department of Health summarises the food consumption studies conducted in SA between 1983 and 2000. This report was used as the source for obtaining the daily average whole food intake of the adult South African. The report represents the daily per capita intake of food and beverages based on those foods and beverages consumed by more than 3% of South African adults of all ages and ethnic groups. Estimation of the TAC was performed on these dietary intakes obtained from the food consumption studies included in the report and on a summarised intake of all the studies also included in the report (Method 1 and Method 2). The individual studies (n = 7) and the summarised intake of the South African intake, Method 1 and Method 2 (n = 2), all include the per capita intake of persons older than the age of 10 and from areas within the South African borders. Method 1 did not take ethnic proportions into consideration for each province of SA when the food consumption was estimated, whereas Method 2 did consider this factor.[16] Details of the food consumption studies used are summarised briefly in Table I.

Table I: Studies used to estimate the adult South African dietary TAC

Study	Description of study population[a]	
	Participants	Area
Lebowa	Black adolescents	Rural villages in Northern Province
Dikgale	Black adults	Rural villages in Northern Province
BRISK[b]	Black adults	Urban areas in Cape Peninsula
THUSA[c]	Black adults	Urban and rural areas in North West Province
FYFS[d]	Black first-year students	Rural and urban areas in Gauteng
WRFS[e]	Black, white, coloured, Asian adults	All provinces of South Africa, rural and urban
CORIS[f]	White adults	Three towns in the south-western Cape, semi-rural
Method 1[g]	All	South Africa (rural and urban)
Method 2[h]	All	South Africa (rural and urban)

[a] Nel & Steyn, 2002[16]
[b] Black Risk Factor Study
[c] Transition, Health and Urbanisation Study
[d] First-year Female Student Project
[e] Weight and Risk Factor Study
[f] Coronary Risk Factor Study
[g] Summary of the individual studies (rural and urban)
[h] Summary of the individual studies (rural and urban) considering ethnic proportions

The food items consumed and obtained from the report for the summarised intakes (Method 1 and Method 2) and the individual studies (n = 7)[16] were grouped into those basic food groups incorporating plant foods (n = 5) and beverages (Table II) and the dietary per capita intake per day for each study considered. A National Nutrient Database (NDB) code from the United States Department of Agriculture (USDA) of which the food description corresponded most

Table II: Basic whole food items consumed in the summative and individual food consumption studies and their coupled TAC database food item used for the dietary TAC analysis

Food group	Food items consumed[a]	Coupled TAC database food item[b]	NDB code[c]
FRUIT	Apple, average, raw	Apples, raw, with skin	09003
	Apricot, canned	Apricot, raw[d]	09021
	Apricot, raw	Apricot, raw	09021
	Avocado, raw (peeled)	Avocados, Hass, raw	97080
	Banana, raw (peeled)	Bananas, raw	09040
	Grape, raw, fresh	Grapes, red, raw (33% of 'grapes')	99074
		Grapes, white or green, raw (67% of 'grapes')	99047
	Loquat, litchi, guava wild fruit, canned	Guava, red-fleshed[d]	99428
	Loquat, litchi, guava, wild fruit, raw	Guava, red-fleshed	99428
	Mango, raw (peeled)	Mangos, raw	09176
	Naartjie, raw (peeled)	Tangerines (mandarin oranges), raw	09218
	Orange/mineola fresh (peeled)	Oranges, raw, navels	09202
	Paw paw, raw (peeled)	Not available[e]	
	Peach, canned	Peaches, canned, heavy syrup, drained	09370
	Peach, raw	Peaches, raw	09236
	Peach, dried	Peaches, raw[d]	09236
	Pear, raw	Pears, raw	09252
	Pineapple, canned	Pineapple, raw, all varieties[d]	09266
	Pineapple, raw (peeled)	Pineapple, raw, all varieties	09266
	Raisins, currants, dried	Raisins, seedless	09298
	Strawberry, raw	Strawberries, raw	09316
	Watermelon raw, peeled	Watermelon, raw	09326
VEGETABLES	Broccoli, boiled	Broccoli, cooked, boiled, drained, without salt	11091
	Cabbage, cooked	Cabbage, cooked, boiled, drained, without salt	11110
	Carrot, raw (flesh and skin)	Carrots, raw	11124
	Carrot, flesh and skin, cooked	Carrots, cooked, boiled, drained, without salt	11125
	Cauliflower, boiled	Cauliflower, cooked, boiled, drained, without salt	11135
	Cucumber, raw	Cucumber, with peel, raw	11205
	Green beans, cooked	Beans, snap, green, raw[f]	11052
	Lettuce, raw	Lettuce, iceberg (includes crisphead types), raw	11252
	Marrow, gem (summer), etc., cooked	Squash, summer, zucchini includes skin, raw[f]	11477
	Mealies/sweetcorn, cooked, fresh	Corn, sweet, yellow, raw[f]	11167
	Onion, cooked	Onions, yellow, sautéed	11286
	Onion, raw	Onions, raw	11282
	Peas, cooked	Peas, green, frozen, unprepared[f]	11312
	Potato, cooked	Potatoes, white, flesh and skin, raw[f]	11354
	Pumpkin/butternut, hubbard squash, cooked	Pumpkin, raw[f]	11422
	Salad: beetroot	Beets, raw[f]	11080
	Spinach, cooked	Spinach, raw[f]	11457
	Sweet potato, cooked without skin	Sweet potato, cooked, boiled, without skin	11510
	Tomato, cooked, fresh	Tomatoes, red, ripe, cooked	11530
	Tomato, raw fresh	Tomatoes, red, ripe, raw, year round average	11529
	Wild leaves (marog, amarant, beetroot, pumpkin), raw	Beet, greens, raw	11086
BREAD, CEREALS, RICE & PASTA	Brown bread/rolls	Not available[g]	
	Corn flakes	Not available[g]	
	Maltabella	Not available[g]	
	Maize porridge	Not available[g]	
	Maize samp	Not available[g]	
	Matzos, crackers, Provita	Not available[h]	
	Oats	Not available[g]	
	Pasta	Not available[g]	
	Rice, white cooked	Not available[g]	
	Weetbix	Not available[g]	
	White bread/rolls	Not available[g]	
LEGUMES &	Beans, sugar, kidney, haricot dried, cooked	Beans, kidney, red, mature seeds, raw[f]	
NUTS	Beans canned in tomato sauce	Broadbeans, canned beans (68%)[f]	11033
		Tomato products, canned, sauce (32%)[f]	11549
	Dried soybeans, cooked	Soybeans, mature seeds, raw[f]	16108
	Split peas, cooked	Peas, split, mature seeds, raw[f]	16085
	Almonds	Nuts, almonds	12061
	Peanuts	Peanuts, all types, raw	16087
	Peanut butter, smooth style	Peanut butter, smooth style, with salt	16098
OILS	Salad dressing/ mayonnaise	Not available[h]	
	Sunflower oil	Not available[g]	
BEVERAGES	Coffee[i]	Not available[g]	
	Orange juice, fresh	Orange juice, raw	09206
	Orange, peach, loquat, litchi guava, wild fruit juice	Apple juice canned or bottled, unsweetened without added ascorbic acid (80% of 'juice')	09016
		Orange juice (20% of 'juice')	09206
	Rooibos[i]	Not available[g]	
	Tea	Tea, brewed, prepared with tap water	14355

[a] Nel & Steyn, 2002[16]

[b] USDA, 2007[22]

[c] National Database (NDB) code; USDA National Database for Standard Reference, Agricultural Research Service. Release 18.2005. http://www.nal.usda.gov/fnic/foodcomp.

[d] For canned and dried foods the TAC of the fresh foods was converted on the basis of the moisture content.

[e] Obtained from Patthamakanokporn et al.[23]

[f] For cooked foods the TAC of the raw foods was converted on the basis of the food yields; USDA. Food Yields: Summarised by different stages of preparation. 1975. Agricultural Research Service.

[g] TAC analysis (H-ORAC) done by the Analytical Laboratory Services, Cape Peninsula University of Technology.

[h] Matzos, crackers, Provita: limited per capita intake of 0.6 g and 1.7 g per day in two studies; Salad dressing/mayonnaise: limited per capita intake range of 0.9 g to 4.2 g per day across four studies.

[i] Coffee (instant) as 1% solution and rooibos as ±2.5 g per 180 ml boiled water steeped for 3 minutes.

to that consumed was assigned to each food item. If no TAC was available for a specific food or beverage item, the TAC for a similar food or beverage was used as proxy. For canned and dried foods the TAC of the fresh foods was converted on the basis of the moisture content. For foods consumed cooked for which only the TAC of the raw foods was available, the TAC was converted on the basis of the food yields. Where problems were encountered with allocating NDB codes to foods consumed, a combination of codes was entered to assign a combined calculated TAC for that particular food item (such as with beans canned in tomato sauce) (Table II). The food items consumed[16] that were not listed in the USDA ORAC Report of Selected Foods[22] (Table II) were analysed by the Analytical Laboratory Services at the Cape Peninsula University of Technology (CPUT). The extraction method according to Prior et al[20] was used and the ORAC analysis according to Wu et al.[19] Only the H-ORAC was measured, and these values were used as a representation of the TAC because the L-ORAC of most food products contributes minimally to the TAC. The percentage L-ORAC contribution to the TAC of breads, cereals and sorghums calculated on the basis of the USDA ORAC report[22] was found to be only 5.67%.

The food items not listed in the USDA ORAC Report of Selected Foods[22] that had to be analysed due to reasonable intakes reported across the studies were: maize porridge, brown bread, white bread, white rice, samp, Weetbix, pasta, oats, Maltabella, Rice Crispies, corn flakes, sunflower oil, coffee and rooibos (Table II). Sales figures were obtained from two retail food store head offices and used to sample the top-selling brands of these foods from three different retail food stores, each located in a different sub-council of the City of Cape Town, during three different months of the year to include for variation caused by seasonal factors. A minimum of nine items were analysed in triplicate for each food/beverage.

Each food item, with its respective TAC, obtained either from the USDA ORAC Report of Selected Foods,[22] or adapted (Table II footnotes) or analysed, was entered in a Microsoft Excel spreadsheet. The adult South African dietary TAC could then be calculated from the entered information as well as the contribution of each food group/item to the adult South African dietary TAC. Values were expressed as μmoles TE per person per day. Only basic food items were considered, as these are the foods assigned to the food groups in food group plans.[24] Non-basic food items consumed (rusks, potato crisps, maize-based snacks, custard powder, carbonated cold drinks, squash-type cold drinks, marmalade, chocolate sweets, honey, jams, tomato sauce, etc.)[16] were not included in the calculation of the dietary TAC, as these foods should be consumed only in moderation and only after basic nutrient needs have been met by the basic foods.[24] Alcoholic beverages were not included in the calculation of the dietary TAC due to the wine and spirit types and the respective intakes not being specified in the Nel and Steyn report.[16]

TAC determination of the South African diet incorporating dietary intake recommendations

In order to determine the daily TAC through a diet that subscribes to the dietary intake recommendations, the five-a-day concept was used as the foundation, together with the recommended daily intake of plant foods that occur in the basic food groups as well as of tea and coffee. The five-a-day concept implies that a person should consume 400 g of fruits and vegetables per day; five portions of 80 g each.[25] The fruit and vegetable serving sizes used to determine the daily dietary TAC of this food group were based on a small/medium-sized portion consumed and not on an average of 80 g each. Portions were closely related to 80 g, but, as in other studies, a portion size was either bigger or smaller than 80 g. The 80 g portion size is only a calculated average of the 400 g of fruits and vegetables per day and is actually an underestimation of fruit and vegetable sizes.[25] Serving sizes for the rest of the food items were based on medium-sized portions. The Food Quantities Manual of the South African Medical Research Council (MRC)[26] was used to obtain these portion sizes.

Food items used to formulate the suggested dietary intake were those that occurred in at least two-thirds of the selected studies indicated in Table I. These food items were then included as part of the consumption combinations to be formed for the daily intakes. Each food item's NDB code(s) was entered in a Microsoft Excel spreadsheet along with its TAC. With this information, all possible food item combinations were compiled on the spreadsheet to be representative of the fruit, vegetable and bread, cereal, rice and pasta food group servings, as well as legume (kidney bean) and beverage (tea and coffee) servings.

For the fruit group, banana, apple and orange juice were combined in pairs of two to form the two minimum recommended servings for this group.[24] A serving of 125 g of fruit juice was included as part of the fruit group.[27] However, fruit juice can only count once towards the five-a-day recommendation,[28] as fresh fruit is preferred over fruit juice because of its nutrient and fibre content.[27] All possible combinations from the five food items from the vegetable group were formulated to obtain the TAC of the recommended minimum three servings.[24] The vegetables representing this group were cabbage (cooked), pumpkin (cooked), tomato (raw), carrot (cooked) and sweet potato (cooked). Potatoes do not always form part of the vegetable group in the five-a-day recommendation because of their starch content.[25-27] Potatoes therefore also did not form part of the combinations for the suggested vegetable intake for this study. However, they were listed as part of the vegetable group in the Nel and Steyn[16] report (which formed the basis of this study) and were therefore included in the vegetable group intake of the South African average per capita dietary TAC estimation.

For the bread, cereal, rice and pasta group, only five food items were included, with one item occurring twice in each combination to obtain the six minimum recommended servings.[24] These food items were maize porridge, brown bread/rolls, white bread/rolls, white rice and samp. Because of the high intake of kidney beans,[16] this food item was included to represent the food group meat, poultry, fish, dry beans, eggs and nuts. Constant daily amounts of the recommended serving of 100 g kidney beans,[11] four cups of tea (180 g each) and one cup of coffee (180 g)[14] were automatically included in each combination for the calculation of the daily per capita dietary TAC.

Moderate alcohol consumption was not included in the suggested TAC determination, despite its potentially protective effect in the reduction of risk for cardiovascular disease,[30,31] based on the following: alcohol use by many South Africans is often excessive, particularly over weekends;[32] excess consumption carries adverse health and social consequences;[30,31] the benefits are likely only applicable to older South Africans and not to the majority of South

Africans, who are younger;[32] and people who do not drink are not advised to start drinking to gain the potential health benefits.[32] For older South Africans, a moderate alcohol consumption of none to one alcoholic drink per day for women (non-pregnant) and none to two alcoholic drinks per day for men[27] would increase the suggested dietary TAC in the range of 580 to 5 732 µmoles TE for women and 1 160 to 11 464 µmoles TE for men, if white table wine (NDB code: 14106)[22] and red table wine (NDB code: 14096)[22] are considered respectively (one drink = 5 fl oz wine or 148 mL).[27] The suggested amount of oil to consume per capita per day (6 teaspoons) per 2 000 to 2 200 calorie level[33] was also not included, as this made a negligible contribution (7.5 µmoles TE) to the daily adult dietary TAC.

To simply suggest that a person should consume five portions of fruit and vegetables per day is only a guide for how much to consume and not really what to consume from the fruit and vegetable groups. In the USDA's food guide, MyPyramid,[34] the vegetable group is divided into subgroups from which a person should choose the servings. From the vegetable group one should consume at least one dark green vegetable (e.g. broccoli or spinach), an orange vegetable (e.g. carrots or butternut) and another from the 'other vegetables' (e.g. tomato, onions or cabbage).[33] Servings from the fruit group should consist of at least one citrus fruit (e.g. oranges)[35] and one 'other fruit', such as apple or banana.[34] The minimum recommendation for whole grains is half of the grain intake,[33] which is three portions.[12] Although the subgroup food items have not yet been incorporated in a quantified manner for consumer guidance,[33] they were used in this study as part of the TAC determination of the South African diet incorporating dietary intake recommendations.

Specific food items from the above subgroups were selected if they were listed in the summarised intake of all the South African food consumption studies and consumed by a larger percentage of the population[16] to determine the dietary TAC if South Africans did consume these specified vegetable and fruit food items. The food items that were selected for the determination of the dietary TAC from specific foods are spinach (cooked), pumpkin (cooked), and tomato (raw) for the three servings from the vegetable group. Orange and apple/banana were selected for the two servings from the fruit group. Oats, brown bread and Weetbix formed the three whole grain servings, and maize porridge, white rice and white bread the three refined grain servings. The serving of kidney beans and the servings of coffee and tea were again included as constant daily intakes.

Results

Estimated adult South African dietary TAC

The average per capita adult South African TAC for the dietary intake of the South African adult population was estimated at 11 433 µmoles TE/person/day (Table III). The estimated dietary TAC comprised of contributions from the food groups fruits, vegetables, grains (which include bread, cereal, rice and pasta), legumes and nuts, along with beverages (tea and coffee). The beverage group made the largest contribution, of 38.5% (4 397 µmoles TE/person/day), to the estimated dietary TAC. Grains made the second largest contribution, of 25.6% (2 926 µmoles TE/person/day). Vegetables and fruits contributed 11.0% and 19.5% respectively. The intake of legumes and nuts made a contribution of only 5.5% (623 µmoles TE/person/day).

The estimated daily dietary TAC (µmoles TE) of the selected South African food consumption studies is indicated in Table III. Studies that obtained the highest dietary TAC per adult per day were the Coronary Risk Factor Study (CORIS), with 15 934 µmoles TE/person/day, and the Weight and Risk Factor Study (WRFS), with 14 746 µmoles TE/person/day. The Lebowa study obtained the lowest dietary TAC, with only 7 635 µmoles TE/person/day.

In the fruit group, the dietary TAC from the First-year Female Student Project (FYFS) and the WRFS (6 577 and 5 972 µmoles TE/person/day respectively) were the highest, as the dietary intakes consisted of a variety of fruits.[16] In the FYFS, mangos were the main contributor to the fruit TAC (24%), and in the WRFS it was apples (40%). The lowest fruit consumption occurred in the Lebowa study,[16] where the average fruit intake of the participants contributed only 209 µmoles TE/person/day.

The TAC of the vegetable group was the highest in the WRFS (2 200 µmoles TE/person/day) because of the intake of a larger variety of vegetables.[16] The consumption of potatoes was the highest in the CORIS.[16] More than half (53%) of the TAC from the vegetable group in this study was contributed by the consumption of potatoes (1 042 µmoles TE/person/day).

The TAC of the bread, cereal, rice and pasta group was similar for most of the studies, except for the WRFS and the CORIS, which had slightly lower TACs. The Transition, Health and Urbanisation Study (THUSA) was the only study in which the participants indicated having consumed Maltabella porridge, which is a rich source of antioxidants[36] as it consists mainly of red sorghum (personal communication Goliath, 2008).

Table III: Calculated average dietary TAC (µmoles TE/person/day) of the various studies and the food groups considered

Food group	Average per capita daily dietary TAC (µmoles TE) of South African food consumption studies[a]											
	M1R[b]	M2R[c]	M1U[d]	M2U[e]	Lebowa	Dikgale	BRISK[f]	THUSA[g]	FYFS[h]	WRFS[i]	CORIS[j]	Average
Fruits	278	363	898	2 195	209	445	1 424	2 646	6 577	5 972	3 553	2 233
Vegetables	971	1 057	1 129	1 375	742	1 425	1 013	1 041	856	2 200	1 983	1 254
Grains	3 704	3 593	3 120	2 325	3 820	3 636	2 874	3 175	2 845	1 569	1 528	2 926
Legumes & nuts	707	683	606	494	150	1 276	547	834	617	581	350	623
Beverages	4 159	4 344	4 163	4 902	2 714	5 475	2 821	4 435	2 420	4 424	8 511	4 397
TAC	**9 818**	**10 040**	**9 916**	**11 291**	**7 635**	**12 256**	**8 678**	**12 131**	**13 315**	**14 746**	**15 934**	**11 433**

[a] Nel & Steyn, 2002[16] [b] M1R: Method 1 – Rural [c] M2R: Method 2 – Rural [d] M1U: Method 1 – Urban [e] M2U: Method 2 – Urban [f] Black Risk Factor Study [g] Transition, Health and Urbanisation Study [h] First-year Female Student Project [i] Weight and Risk Factor Study [j] Coronary Risk Factor Study

For legumes and nuts, which represent the meat, poultry, fish, dry beans, eggs and nuts group, the dietary TAC in all the studies was contributed mainly by the consumption of kidney beans (74%). Kidney beans featured in all the studies, with the highest consumption in the Dikgale study[16] (1 244 µmoles TE/person/day). Peanuts and peanut butter contributed 15% to the dietary TAC in the legumes and nuts group, mainly in the WRFS, the FYFS and the THUSA.

The consumption of beverages made a reasonable contribution to the dietary TAC. The highest dietary TAC through the consumption of beverages was in the CORIS, with black tea and coffee being the major sources. The dietary TAC per person per day from the consumption of black tea was the highest in the Dikgale study (5 475 µmoles TE/person/day). The WRFS is the only study in which a per capita rooibos intake featured.[16] The intake of black tea made the largest contribution (68%) to the dietary TAC of the beverage group, with coffee (29%) and rooibos (3%) contributing less.

Beverages (tea and coffee) were the main contributors to the dietary TAC, except in the Lebowa study, the WRFS and the FYFS. In the Lebowa study, the bread, rice and cereal group (maize porridge and brown bread/rolls) made the largest contribution, and fruit was the main contributor to the dietary TAC in the WRFS and the FYFS.

TAC determination of the South African diet incorporating dietary intake recommendations

Five-a-day concept and other recommended intakes from the basic food groups as well as tea and coffee

From all the possible combinations of the five-a-day fruit and vegetable concept and the other dietary recommendations, the average suggested dietary TAC per day was calculated to be 20 513 µmoles TE/person/day (Table IV). Beverages (tea and coffee) made the largest contribution toward the average, with 48% (9 810 µmoles TE/person/day), and vegetables the smallest, with only 10% (1 963 µmoles TE/person/day). Fruits and grains made similar contributions of 13% (2 688 µmoles TE/person/day and 2 627 µmoles TE/person/day respectively). Legumes made a 17% (3 425 µmoles TE/person/day) contribution to the suggested average dietary TAC.

Evaluated against the recommended intakes from the five-a-day and other dietary recommendations, the estimated TAC of the adult South African diet is far below the suggested TAC, except for the TAC from the bread, cereal, rice and pasta group (Table V). The TAC from this food group is 11% (299 µmoles TE) higher than the coupled TAC. This is mainly due to the intake of maize porridge and brown bread, which contribute 43% and 26% respectively to the intake of this group. The food groups of which the intakes are far below the coupled TAC are the beverage group (45%), as well as legumes and nuts (15%). The TAC of the fruit and vegetable groups in the adult South African diet is 83% (2 233 µmoles TE/person/day) and 64% (1 254 µmoles TE/person/day) respectively of the coupled intakes (2 688 µmoles TE/person/day and 1 963 µmoles TE/person/day respectively). The average estimated adult South African dietary TAC is only 55.7% (11 433 µmoles TE/person/day) of the calculated suggested dietary TAC (20 513 µmoles TE/person/day).

Table IV: Suggested TAC (µmole TE/person/day) from dietary recommendations

Food group	5-a-day and other recommendations[a,b,c]	5-a-day (MyPyramid) and other recommendations[a,b,c]
Vegetables	1 963 (± 440)	1 983
Fruit	2 688 (± 802)	3 745
Grains	2 627 (± 324)	2 607
Legumes	3 425 (± 0)	3 425
Beverages	9 810 (± 0)	9 810
TAC	**20 513 (± 971)**	**21 570**

[a] Values indicated as averages (standard deviation)
[b] Basic food groups and beverages
[c] The suggested amount of oil to consume per capita per day (6 teaspoons) per 2 000 to 2 200 calorie level[33] was not included, as this makes a negligible contribution (7.5 µmoles TE) to the daily adult dietary TAC.

Table V: Comparison between the estimated TAC (µmoles TE/person/day) of the adult South African dietary intake and the TAC of the suggested dietary intakes

Food group	Estimated South African dietary TAC[a]	Suggested South African dietary TAC (based on dietary recommendations)[a,b,c]	% intake of suggestion
Vegetables	1 254	1 963 (± 440)	63.9
Fruit	2 233	2 688 (± 802)	83.1
Grains	2 926	2 627 (± 324)	111.4
Legumes & Nuts/Legumes	623	3 425 (± 0)	16.4
Beverages	4 397	9 810 (± 0)	44.8
Total	11 433	20 513 (± 971)	55.7

[a] Values indicated as averages (standard deviation)
[b] Five-a-day concept and other recommended intakes from the basic food groups, as well as tea and coffee
[c] The suggested amount of oil to consume per capita per day (6 teaspoons) per 2 000 to 2 200 calorie level[33] was not included, as this makes a negligible contribution (7.5 µmoles TE) to the daily adult dietary TAC.

MyPyramid sub-groupings and other recommended intakes from the basic food groups as well as tea and coffee

When the above calculations are repeated using the MyPyramid sub-grouping of fruits (e.g. citrus and other fruit),[34,35] vegetables (e.g. green leafy, orange and other vegetables) and grains (e.g. refined and whole grain),[33] the dietary TAC from the specific food groups was determined to be 21 570 µmoles TE/person/day (Table IV). From the specific food intakes suggested, the beverage servings (9 810 µmoles TE/person/day) made the largest contribution (45%) to the dietary TAC. Refined grains made the smallest contribution to the dietary TAC, with only 4% (804 µmoles TE/person/day). Vegetables and the whole grain servings made similar contributions of 9% (1 983 µmoles TE/person/day) and 8% respectively (1 803 µmoles TE/person/day). Fruit made a contribution of 17% (3 745 µmoles TE/person/day), with legumes contributing less at 16% (3 425 µmoles TE/person/day). The difference between the suggested intake of the MyPyramid sub-grouping (21 570 µmoles TE/person/day) and that of five-a-day (20 513 µmoles TE/person/day) is largely due to the replacement of orange juice with oranges in the fruit group of the former. The TAC of oranges (1 819 µmoles TE/100g) is 2.5 times higher than that of orange juice (726 µmoles TE/100g).[22]

Discussion

Beverages (which include tea and coffee) made the largest contribution to the estimated adult South African dietary TAC, followed by grains (which include bread, cereal, rice and pasta), fruits and vegetables, with legumes and nuts making the smallest contribution. The CORIS and the WRFS obtained the highest dietary TAC per adult per day, and the Lebowa study the lowest (Table III). The CORIS sample were Caucasian adults from a semi-rural area of the Western Cape, while the WRFS included all race groups from all the provinces of SA, which on average consumed a larger number of food items.[16] Possible reasons for the higher intake of food in the Western Cape are the lower unemployment rate compared to the other provinces, and the household food expenditure being higher than the national average.[37] Beverages made the major contribution to the CORIS estimated dietary TAC, and fruits, along with beverages and vegetables, made the major contributions to the WRFS estimated adult dietary TAC. Grains, along with beverages, made the major contributions to the estimated adult dietary TAC of the Lebowa study, in contrast to fruits and vegetables, which made smaller contributions (Table III). The participants in this study lived in rural villages in the Northern Province, where under-nutrition is prevalent.[38] Factors such as affordability and availability are possible reasons for the insufficient dietary intake in rural villages,[6] such as those represented in the Lebowa study.

In the TAC determinations of the South African diet incorporating the five-a-day concept or the MyPyramid sub-groupings, along with other recommended intakes from the basic food groups as well as tea and coffee, the largest contribution to the TAC determinations was also made by the beverages and the smallest contributions by the grains and vegetables. The average estimated adult South African dietary TAC is, however, only about half of the calculated suggested dietary TAC, which is attributed largely to the inadequate intakes of all the food groups, besides the grains, and beverages (Table IV). Most South Africans consume starchy foods, such as maize, bread and rice, and, as they are the most economic sources of dietary energy, they form the staple foods of the South African diet.[7] The estimated adult South African dietary TAC from the fruit and vegetable groups, for example, is only 61% of the average fruit and vegetable TAC consumption by the US population as determined by Wu et al.[19] Studies done in SA have indicated that most South Africans consume inadequate amounts of fruit and vegetables,[6] especially vegetables.[39] South Africans are furthermore not only urged through the FBDGs to increase their fruit and vegetable intake,[6] but also to include more legumes in their meal plans[11] and to consume an adequate daily intake of water, which can be in the form of beverages such as tea.[13]

Conclusions

Expressed in ORAC units, the recommended dietary TAC per person per day is calculated to be 20 513 µmole TE/person/day, ranging between 19 500 µmole TE and 21 500 µmole TE. Beverages, especially black tea, contribute about half of the suggested TAC. In combination, fruits and vegetables contribute just over 22.5% of the suggested TAC. Often overlooked as a source of antioxidants, grains contribute just fewer than 13% of the suggested TAC. Results from the estimated average dietary TAC in this study indicate that, compared to the five-a-day concept and other dietary recommendations, the South African population consumes about half of the suggested TAC. It is particularly in the vegetable and beverage (tea) groups where the estimated consumption is well below the suggested TAC, and this effect is amplified in some of the studies done in rural areas (e.g. the Lebowa study and the Dikgale study). Of the studies included, the highest dietary TAC was among the participants in the CORIS, who consumed about 77% of the suggested TAC. The only food group where consumption is above the coupled TAC is grains. This can possibly be attributed to the higher consumption of grain products in rural areas because of their lower cost and greater availability. However, the suggested TAC can vary depending on the type of fruit or vegetable included and the serving size, as found in the MyPyramid results.

A limitation of the study methodology could be the reference table of the South African food intakes that was used as basis for this study, as it consists only of South African studies that were conducted between 1983 and 2000[16] and may not represent current food and beverage intakes.[9] Further limitations are the restricted descriptions provided for some of the food and beverages items in the Department of Health report[16] that had to be coupled with the descriptions in the USDA ORAC Report for Selected Foods,[22] and the fact that this database and not a South African database was used for the TAC calculations. The exclusion of commonly consumed non-basic and composite foods that are plant-based or contain plant-based ingredients is a further limitation. It therefore is emphasised that the South African adult per capita dietary TAC is only an estimated intake and not an absolute intake, and that it may underestimate intake. It would take some time to compile a comprehensive TAC database to make specific food selections, and even then it would not be possible to control for diverse factors such as conditions of growth, harvesting, handling, storage, preparation and processing, which influence the antioxidant capacity of food products.[40,41] Even the current USDA ORAC Report of Selected Foods[22] does not provide L-ORAC values for all foods included.

Recommendations

Because the estimated average per capita dietary TAC of South Africans is less than the suggested, health professionals should initialise an active campaign to help consumers better understand the important health benefits of antioxidants and aim to increase the intake of antioxidant-rich whole food sources. Since the consumption of fruit and vegetables by South Africans is still below the recommended amounts,[6] the consumption of fruit and vegetables should be encouraged most in such a campaign, as these food items contribute to the dietary TAC[1,2] and play a protective role against the development of chronic diseases.[42] It should also be emphasised that five fruits and vegetables a day is only the aim for minimum intake, and not the ultimate goal.[29] Previous research has identified specific fruits and vegetables that have the most health-protective properties. These specific food items from the vegetable group are onions, carrots, spinach, cabbage, broccoli, Brussels sprouts, cauliflower and tomatoes, and from the fruit group citrus fruit and any other fresh fruit.[33,35] With regard to fruit and vegetables, however, the best advice remains to include a variety of these foods in the daily diet.[6] Food-guide pyramids[34] need to be used in conjunction with the proposed beverage consumption guidance system.[27]

The answer lies in a food guide/beverage guide pyramid that delivers the most nutraceuticals.[43]

The South African FBDGs were developed to encourage undernourished persons to choose a more adequate diet and over-nourished persons a more prudent diet.[44] The dietary guidelines of "eating plenty of fruit and vegetables",[6] "eating dry beans, peas, lentils and soya often",[11] "making starchy foods the basis of most meals", while eating more of the cereals and grains in an unprocessed or minimally processed form[7] and "drinking lots of clean, safe water" (that may be taken in the form of beverages such as tea)[13] can support achieving the suggested daily dietary TAC. Due to widespread household food insecurity in SA,[42] nutrition messages should incorporate the recommendation of whole grains as three servings[12] and to wait at least one hour after eating before drinking tea, or drinking tea between meals.[45] Whole grains may reduce the availability of minerals, but if consumed in the recommended amounts they will not have any negative effects of the mineral content.[46] Tea consumption does not influence iron status in healthy people, but groups at risk of iron deficiency should apply the intake advice.[45] In addition to fruit and vegetables, the consumption of the recommended servings of beverages (tea), whole grains and legumes by the South African adult population should also be encouraged.[42]

When considering fruit and vegetable intakes, it is important to consider composite foods, such as stewed tomatoes and onions and meat dishes incorporating vegetables that are commonly consumed by adult South Africans.[16] These were not included in the estimated daily dietary TAC of this study, as they are not whole foods. The exclusion of vegetables and fruit from composite foods for the estimate of intakes results in an underestimation of the contribution that vegetables and fruit make to total nutrient intakes.[25] Dieticians/nutritionists should therefore pay more attention to describing the consumed food items in dietary intake reports (composite dish ingredients, fruits with or without peel, type of wine, etc), as this can assist the database selection of dietary items, in particular to provide for a more precise phytonutrient intake quantification. To obtain more precise dietary TAC and phytonutrient intakes, the use and consumption of herbs and spices should also be considered as contributory sources, although possibly in minimal amounts.[22] Caution should be exercised in such interpretations, however, as no specific dietary guidance for herb and spice use is advocated. A frequent intake of herbs and spices, as well as alcoholic beverages and possibly some non-basic foods (i.e. cocoa-rich products), may contribute disproportionately to the dietary TAC and phytonutrient intakes relative to the recommended food guide/beverage guide pyramid contributions. This may impact on the overall nutritional adequacy of the diet.

Assigning an ORAC value to food servings, combined with consumer education and the suggested TAC per day that needs to be achieved, can be an important guidance tool for the healthy lifestyle of consumers. However, it should be borne in mind that it is not only nutritional factors, but also lifestyle and environmental factors, which can have an influence on the antioxidant capacity of an individual. Factors such as smoking, psychological stress, alcohol, low fish intake and also exposure to natural ultraviolet light have a negative influence on antioxidant capacity and a healthy lifestyle.[47]

References

1. Pellegrini N, Serafini M, Colombi B, et al. Total antioxidant capacity of plant foods, beverages and oils consumed in Italy assessed by three different in vitro assays. J Nutr 2003;133:2812–19.
2. Tsao R, Akhtar MH. Nutraceuticals and functional foods: Current trend in phytochemical antioxidant research. J Food Agric Environ 2005;3(1):10–7.
3. Lotito B, Frei B. Consumption of flavonoid-rich foods and increased plasma antioxidant capacity in humans: Cause, consequence, or epiphenomenon. Free Radic Biol Med 2006;41:1727–46.
4. Ferrari CKB, Torres EAFS. Biochemical pharmacology of functional foods and prevention of chronic diseases of aging. Biomed & Pharmacother 2003;57:251–60.
5. Bradshaw D, Nannan N, Laubscher R, et al. South African national burden of disease study. Estimates of provincial mortality. Medical Research Council, Burden of Disease Research Unit, South Africa; 2000.
6. Love P, Sayed N. Eat plenty of vegetables and fruits everyday. SAJCN 2001;14(3):S24–32.
7. Vorster HH, Nel TA. Make starchy foods the basis of most meals. SAJCN 2001;14(3):S17–24.
8. Steyn NP, Maunder EMW, Labadarios D, Nel JH. Foods and beverages that make significant contributions to macro- and micronutrient intakes of children in South Africa – do they meet the food-based dietary guidelines? SAJCN 2006;19(2):66–76.
9. Schneider M, Norman R, Steyn N, Bradshaw D. The South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to low fruit and vegetable intake in South Africa in 2000. S Afr Med J 2007;97(8):717–23.
10. Guenther PM, Dodd KW, Reedy J, Krebs-Smith SM. Most Americans eat much less than recommended amounts of fruits and vegetables. J Am Diet Assoc 2006;106:1371–9.
11. Venter CS, Van Eyssen E. More legumes for better overall health. SAJCN 2001;14(3):S32–8.
12. Jones JM, Reicks M, Adams J, Fulcher G, Marquart L. Becoming pro-active with the whole-grain message. Nutr Today 2004;39(1):10–7.
13. Bourne LT, Seager JR. Water – the neglected nutrient. SAJCN 2001;14 (3):S64–9.
14. Elhatton M. The buzz on caffeine and heart problems. Perspectives in Cardiology, 2002; November/December:21–4.
15. Saura-Calixto F, Goñi I. Antioxidant capacity of the Spanish Mediterranean diet. Food Chem 2006;94:442–7.
16. Nel JH, Steyn NP. Report on South African food consumption studies undertaken amongst different population groups (1983–2000): Average intakes of foods most commonly consumed. Pretoria: Department of Health; 2002.
17. Weller K. Can foods forestall aging? Agric Res Mag 1999;47(2):14–7.
18. Ou B, Hampsch-Woodill M, Prior RL. Development and validation of an improved oxygen radical absorbance capacity assay using fluorescein as the fluorescent probe. J Agric Food Chem 2001;49:4619–26.
19. Wu X, Gu L, Holden J, et al. Development of a database for total antioxidant capacity in foods: A preliminary study. J Food Compos Anal 2004;17:407–22.
20. Prior RL, Hoang H, Gu L, et al. Assays for hydrophilic and lipophilic antioxidant capacity (oxygen radical absorbance capacity (ORACFL) of plasma and other biological and food samples. J Agric Food Chem 2003;51:3273–9.
21. Bisby RH, Brooke R, Navaratnam S. Effect of antioxidant oxidation potential in the oxygen radical absorption capacity (ORAC) assay. Food Chem 2008;108:1002–7.
22. United States Department of Agriculture. Oxygen radical absorbance capacity (ORAC) of selected foods. Beltsville: Nutrient Data Laboratory; 2007.
23. Patthamakanokporn O, Puwastien P, Nitithamyong A, et al. Changes of antioxidant activity and total polyphenol compounds during storage of selected fruits. J Food Compos Anal 2008;21:241–8.
24. Whitney E, Rolfes SR. Understanding nutrition. 10th edition. Belmont: Thomson Wadsworth; 2005:42, 48.
25. O'Brien MM, Kiely M, Galvin M, Flynn A. The importance of composite foods for estimates of vegetables and fruit intakes. Public Health Nutr 2003;6(7):711–26.
26. Langenhoven ML, Conradie PJ, Wolmarans P, Faber M. Food quantities manual. 2nd edition. Parow, South Africa: Medical Research Council, National Research Programme for Nutritional Intervention; 1991.
27. Popkin BM, Armstrong LE, Bray GM, Caballero B, Frei B, Willet WC. A new proposed guidance system for beverage consumption in the United States. Am J Clin Nutr 2006;83:529–42.
28. Williams C. Healthy eating: Clarifying advice about fruit and vegetables. Brit Med J 1995;310:1453–5.
29. Walter C, Willet MD. The power of fruits and vegetables. Mother Earth News, October/November. 2005;68–70.
30. Lichtenstein AH, Appel LJ, Brands M, et al. Diet and lifestyle recommendations revision 2006: A scientific statement from the American Heart Association Nutrition Committee. Circulation 2006;114:82–96.
31. Yusuf S, Hawken S, Ôunpuu S, et al. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): Case control study. Lancet 2004;364:937–52.
32. Van Heerden IV, Parry CDH. If you drink alcohol, drink sensibly. SAJCN 2001; 14(3):S71–7.
33. Britten P, Marcoe K, Yamini S, Davis C. Development of food intake patterns for the MyPyramid food guidance system. J Nutr Educ Behav 2006;38:S78–92.
34. United States Department of Agriculture. Inside the pyramid. Available from http://www.mypyramid.html (Accessed 21/07/2008).
35. Van Duyn MA, Pivonka E. Overview of the health benefits of fruit and vegetable consumption for the dietetics professional: Selected literature. J Am Diet Assoc 2000;100:1511–21.
36. Awika JM, Rooney LW. Sorghum phytochemicals and their potential impact on human health. Phytochemistry 2004;65:1199–221.
37. Bonti-Ankomah S. Addressing food insecurity in South Africa. Paper presented at the SARPN conference on land reform and poverty alleviation in Southern Africa. Pretoria, 4–5 June 2001.
38. Labadarios D, Steyn NP, Maunder U, et al. The National Food Consumption Survey (NFCS): South Africa, 1999. Public Health Nutr 2005;8(5):533–43.
39. Vorster HH, Oosthuizen W, Jerling JC. The nutritional status of South Africans – a review of the literature. Durban: Health Systems Trust; 1997.
40. Bacchiocca M, Biagiotti E, Ninfali P. Nutritional and technological reasons for evaluating the antioxidant capacity of vegetable products. Ital J Food Sci 2006;18:209–17.
41. Kalt W. Effects of production and processing factors on major fruit and vegetable antioxidants. J Food Sci 2005;70:R11–9.
42. Maunder EMW, Matji J, Hlatshwayo-Molea T. Enjoy a variety of foods – difficult but necessary in developing countries. SAJCN 2001;14(3):S7–11.
43. Lachance PA, Nakat Z, Jeong W. Antioxidants: An integrative approach. Nutrition 2001;17:835–8.
44. Vorster HH, Love P, Browne, C. Development of food-based dietary guidelines for South Africa – the process. SAJCN 2001;13(3):S3–6.
45. Nelson M, Poulter J. Impact of tea drinking on iron status in the UK: A review. J Hum Nutr Dietet 2004;17:43–54.
46. Slavin JL, Martini MC, Jacobs Jr DR, et al. Plausible mechanisms for the protectiveness of whole grains. Am J Clin Nutr 1999;70(Suppl):459S–63S.
47. Lesgards J, Durand P, Lassarre M, et al. Assessment of lifestyle effects on the overall antioxidant capacity of healthy subjects. Environ Health Persp 2002;10(5):479–86.