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Coffee and Tea Group Contribute the Most to the Dietary Total Antioxidant Capacity of Older Adults: A Population Study in a Medium-Sized Brazilian City

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ABSTRACT

Objective: The dietary total antioxidant capacity (TAC) has been proposed as a suitable tool to estimate the dietary antioxidant intake. However, the main foods/groups that contribute to the dietary TAC of older adults are poorly studied. We aimed to estimate the dietary TAC and to identify the main foods/groups that contribute to the dietary TAC of older adults in a medium-sized Brazilian city.
Methods: A cross-sectional population-based survey with older adults ($\geq$60 years old) was conducted in Viçosa, Brazil. The assessment tool for food consumption was the recall of habitual consumption. A database with ferric reducing antioxidant power (FRAP) values for foods to evaluate the dietary TAC was used.
Results: We evaluated 620 older adults in which the majority were women. The dietary TAC mean was 11.9 (7.1) mmol/d (food only) adjusted by energy. Besides, when supplements were considered the dietary TAC increased to 35.2 (215.9) mmol/d. The food groups that contributed the most to the dietary TAC were coffee and tea, vegetables, and fruits and juices. The coffee and tea group explained most of the variability of dietary TAC (58.3%).
Conclusions: We concluded that the older adults studied had a relatively low dietary TAC consumption. The coffee and tea were the food group that contribute the most to the dietary TAC. Our data show the need to implement national strategies aimed at improving the quality of the diet of older adults. We highlight the need to increase the consumption of different food groups and, consequently, the intake of different compounds with antioxidant capacity, which will contribute to a better dietary TAC with possible positive health effects.

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Introduction

Aging is a physiologic process that results from the impact of the accumulation of a wide variety of molecular and cellular damage over time (1, 2). In the world, the proportion of people aged 60 years or older will nearly double from 12% in 2015 to 22% in 2050 (2). Aging is one of the main risk factors for non-communicable chronic diseases (NCD), like cardiovascular diseases, type 2 diabetes mellitus, cancers, chronic respiratory diseases, and others, which affect the quality of life, health systems and all of society (2).

Although aging is a natural process, studies have observed that lifestyle like food consumption can influence various pathways related to the aging process (3,4). An increase in oxidative stress, telomeres shortening, and other processes involved in deoxyribonucleic acid damage are associated with aging (4). Some studies have shown that food consumption can modulate these processes (5,6).

In this context, regular intake of fruits and vegetables, which are good sources of antioxidants in the diet is associated with lower incidence and mortality for several NCD (7,8). One hypothesis for this protective effect is that antioxidant compounds protect cells from oxidative damage induced by free radicals (9,10). Besides, the diet can play a key role in regulating the plasmatic redox state as the main external contributor of defense against reactive oxygen and nitrogen species (9).

A common parameter to evaluate the antioxidant potential of a diet is the dietary total antioxidant capacity (TAC), which considers the antioxidants, as well as synergistic effects between them (11,12). This antioxidant intake measurement tool has been suggested as a potential marker of diet quality in healthy individuals (13,14). An inverse association of TAC with the risk of chronic diseases has been shown, indicating that this method has great potential for clinical applications and in public health (15). Studies on dietary TAC have been conducted in different populations, mainly international studies that include the older adult population (15). However, little is known about the application of dietary TAC in Brazilian older adults.

In Brazil, several studies have reported a low diet quality among older adults, highlighting the low consumption of fruits and vegetables (16,17). Besides, data from the

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Household Budget Survey 2008/2009, conducted by Instituto Brasileiro de Geografia e Estatística, reveal the inadequate intake of nutrients such as A, C, D and E vitamins, pyridoxine, thiamin, and the minerals calcium and magnesium among older adults. Furthermore, high consumption of saturated fat, sodium and added sugars can be observed in the older adults' diet (18). This diet profile can compromise the dietary TAC and contribute to the emergence of NCD, as well as to impact the progression of these diseases.

Given that dietary habits vary by country, the food source of dietary TAC at the intake level may also differ. In this context, we aimed to estimate the dietary TAC of older adults in a medium-sized Brazilian city and to identify the main foods/groups that contributed to the dietary TAC, providing an overview of TAC in the older adult population.

Material and methods

Subjects

This is a cross-sectional, population-based study, conducted in a medium-sized Brazilian city (Viçosa, Minas Gerais) between March and December 2009. Older adults aged 60 or older, non-institutionalized, living in the municipality (rural and urban) were the targets of the research. This study integrates the research project "Health conditions, nutrition, and drug use by older adults in the municipality of Viçosa." To obtain the source population and subsequent sampling, the older adults were identified by the census during the National Vaccination Campaign for the Older adults (19). To complement the identification, the following databases were used: workers of the Universidade Federal de Viçosa (active and retired); Family Health Strategy; the municipal Physiotherapy Service; Health Center for Women; Psychosocial Services; System of registration and monitoring for hypertensive and diabetics, and Polyclinic. After this process, the source population amounted to 7980 older adults, which were used to calculate the sample size.

To calculate the sample size the following criteria were considered: a confidence level of 95%, an estimated prevalence of 50% for different outcomes of interest in the larger project, a tolerated error of 4%, and 20% to cover losses. From this, a sample size of 670 subjects was required. The older adults were selected by simple random sampling, by drawing from the database. However, there were losses due to: refusal (3.6%), randomly selected individuals that already died (1.3%), addresses not found (1.2%), or move from the municipality (1.2%). Thus, the final sample consisted of 621 older adults. For this study in specific, there was no information on food consumption for one of the older adults selected and, therefore, the final sample consisted of 620 older adults (Figure 1). Subjects were informed of the objective of the study and if they agreed to participate, an informed consent form was signed. Besides, a personal appointment was made to collect socio-demographic, anthropometric, and other variables. The study was approved by the Committee on Ethical Research of the Universidade Federal de Viçosa (Official Letter No. 27/2008/CEP/UFV).

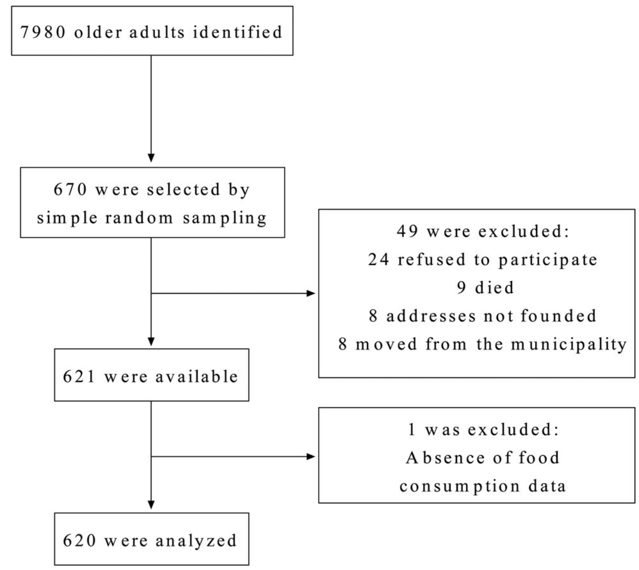

Figure 1. Flowchart of study participants.

Dietary assessment and use of supplements

To obtain information about food consumption, one standard recall of habitual consumption (RHC) was applied, using the multiple-pass method (20)· In summary, the multiple-pass method consists of five steps to better standardize the food consumption data collection and to try to obtain a maximum of information about foods consumed. The recall was conducted in person, in a random weekday according to the availability of the subject. The older adult subjects were asked about their food consumption throughout the day with the following sentence: "From this point on, I would like to know some information about your habitual food consumption." They listed the foods consumed with their respective portions in household measures, time, and type of meal. An instruction manual that included photographs to facilitate the estimation of portion sizes was used which were later converted to grams (g) or milliliters (mL). At the end, a detailed review was carried out with the elderly to prevent that any food was forgotten.

Nutrients intake were calculate based on Brazilian and American food composition tables (21,22) using the software Diet Pro® version 5.7. Then, energy intake was estimated. The data on the use of antioxidant supplements were carefully questioned from the following question: "In the last 15 days, did you use any medication or supplement?" As proof of use, during the interview, they were asked to present leaflets, packaging, and/or medical prescriptions. Medicines and supplements were classified according to the Anatomical Therapeutic Chemical (ATC) Classification System (23). The 15-day recall period was defined in line with the literature to minimize memory bias (24).

Dietary TAC estimate

Dietary TAC was estimated based on the ferric reducing antioxidant power (FRAP) assay, which measures iron reduction in the presence of antioxidants and was expressed as mmol per 100 grams of food (mmol/100g). A FRAP value was assigned to each food item and supplements used according to data published by Carlsen et al. (25) and Koehnlein et al. (26). When it was possible to obtain the analytical FRAP value for a specific food, the following criteria were used:

- If there were more than one value for the same food, the average value of FRAP was calculated (n = 114);
- For processed foods, the FRAP values of the main ingredients were used, taking into account their proportion in the preparation (n = 22);
- When an analytical FRAP value for a particular food could not be obtained, the average value of similar foods, for example, foods of the same botanical group or a different way of preparing the same food, was assigned (e.g. the mean FRAP value of endive, leeks, celery, and spinach was used for chard) (n = 68);
- For some foods, *e.g.* bean sprouts, the heart of palm, quinoa, gelatin, and mocotó jelly, no FRAP value could be assigned by using any of the above criteria (n = 15). Besides, the consumption of these foods was low and, therefore, their contribution to dietary TAC intake was considered not significant;
- Out of the 219 food items present in the RHC, 204 foods were assigned FRAP values (coverage rate for foods was 93.1%);

The individual dietary TAC resulted from multiplying the amounted of foods/beverages in the RHC by the corresponding FRAP values. Dietary TAC was calculated based only on the contribution from foods/beverages and dietary TAC from foods and supplements was calculated based on the contribution from foods/beverages and supplements for all individuals.

Studies show a high antioxidant capacity of coffee (27,28). Chlorogenic acids are the leading phenolic compounds in coffee seeds (29). Despite the controversial results about the bioavailability of some phenolic compounds (30,31), seems that about one-third of the ingested amount of chlorogenic acids through a coffee can be absorbed and metabolized in the human gastrointestinal tract (29). In addition, this bioavailability has a large inter-individual variation (32). Therefore, dietary TAC was estimated in two ways: with and without the inclusion of coffee antioxidant capacity values. We processed our analysis this way because the coffee and tea groups contributed the most to TAC. Dietary TAC was also estimated for different food groups (coffee and tea; vegetable; fruits and juices; cereals and cereal products; seed, nuts, and pulses; meat and meat products; milk and dairy products; oils and fats; alcoholic beverages; sweet and miscellaneous food; cocoa products and nonalcoholic beverages). The contribution to the total antioxidant capacity of these groups to the dietary TAC (with the contribution of coffee) was calculated as follows:

$$\text{Group TAC contribution } \% = \text{Group TAC} \times 100 / \sum \text{TAC from all groups}$$

Since dietary TAC is correlated with total energy intake, energy adjusted FRAP scores were calculated using the residual method. This adjustment is necessary to analyze the net effect of the nutrient without energy influence (33). TAC scores were calculated using Microsoft Excel 2010 (Microsoft Corp, Redmond, WA, USA).

Statistical analyses

The Kolmogorov–Smirnov test and Levene's test were used to evaluating the normality and de variance homoscedasticity of the variables among the comparing groups. Descriptive analysis included estimates of central tendency and dispersion for quantitative variables and frequency distribution for qualitative variables. To assess the relation between TAC tertiles and categorical variables the linear trend Chi-square test was used. On the other hand, Kruskal-Wallis test followed by Mann-Whitney U test with Bonferroni correction was used to evaluate quantitative variables across TAC tertiles. Although our data do not meet the assumptions of the normal distribution, in some cases we chose the mean and standard deviation to represent the results. In some cases, the median value was zero in all tertiles of dietary TAC and due to this, we opted to use mean and standard deviation values.

To explore the relative contribution of food groups in the dietary TAC, the quantile regression analysis was performed, and the coefficients of determination were evaluated. This model was adopted because dietary TAC does not follow a normal distribution. Dietary TAC was considered the dependent variable and the independent variables were the intake of (1) others, sweets and chocolate, (2) nonalcoholic beverages, (3) alcoholic beverages, (4) fruits and juices, (5) milk, dairy products, and meat, (6) oils, fats, pulses, nuts, seeds, and vegetables, (7) cereals, (8) coffee and tea, in grams/d. The stepwise forward procedure was adopted, considering a statistical significance level of 0.05. The criterion used for variable entry order (food groups) in the model was the value of the Spearman correlation coefficient, starting from the largest. All analyses were performed using Stata® software version 13.1.

Results

We evaluated 620 older adults, with a mean age of 70 (sd = 8.1) years. Additionally, 53.2% were female, 20.8% presented >4 years of education level, had a mean personal income of U$688.00, 55.7% never smoked, 70.0% were sedentary, 36.1% used polypharmacy, and 12.9% used supplements in the 15 days prior to the interview. We verified that the mean of dietary TAC intake adjusted for energy was 11.9 (sd = 7.1) mmol/d from foods, 35.2 (sd = 215.9) mmol/d from foods and supplements, and 3.1 ± 1.8 mmol/d without the contribution of coffee. The coffee and tea group was the highest contributor to dietary TAC (Figure 2). Supplements that most contributed to TAC were vitamin C (74.3%), vitamin E (20.8%), and *Ginko Biloba* (4.5%). Among the 23 supplements used seven could have FRAP values assigned (coverage rate for supplements was 30.4%).

We evaluated the characteristics of the older adults according to TAC tertiles. We verified a lower personal

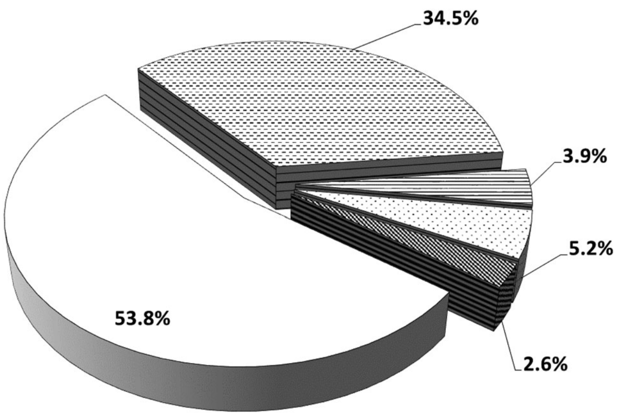

Figure 2. Proportion of variation in dietary TAC (R^2) explained by the contribution of intake of food groups assessed by quantile regression. Coffee and tea(53.8%); milk, dairy products, and meat(3.9%); cereals(5.2%); others(2.6%), not explainable by food amounts(34.5%). TAC, total antioxidant capacity.

income in the second and third tertiles compared to the first tertile. Considering dietary TAC only from foods, we observed a trend of higher schooling as the tertile increases. On the other hand, considering dietary TAC from foods and supplements, we noted a tendency of a high frequency of women, higher schooling, older adults that never smoked, and the use of supplements in the higher tertiles (Table 1).

Coffee stood out among the foods that most contributed to the dietary TAC, however, after excluding the coffee and tea group, the contribution of the vegetables, fruits and juices and cereals food groups were the most significant (Table 2). Finally, we evaluated the food group consumption across TAC tertiles. We noted an increase in the consumption of the coffee and tea group according to the increase in TAC tertiles. On the other hand, a decreased consumption of meat and meat products, milk and dairy products, oils and fats groups were observed (Table 3).

Discussion

We evaluated in this paper the dietary TAC characteristics of a sample of older adults from a medium-sized Brazilian city, and, also the foods that contribute the most to TAC. We noted a mean consumption of antioxidants equal to 11.9 (sd 7.1) mmol/d. Additionally, we verified that coffee and tea was the food group that most contributed to dietary TAC. The mean dietary TAC observed is slightly higher than a study conducted with older adults Brazilian population (11.3 mmol/d) (26), middle-aged and older Americans (10.8 mmol/d) (34), but lower compared to older Japanese women (13.6 mmol/d) (35). Few studies have calculated TAC scores based on supplements and food contribution (34,36). In our study the mean TAC considering supplements was higher (35.2 mmol/d) than a study conducted with middle-aged and older Americans (14.0 mmol/d). This difference could be attributed to the different supplement composition tables used, or for other reasons such as a much higher dietary supplement intake in Brazil. However, we cannot prove the last reason.

The FRAP values coverage rate for foods was 93.1%. In general, international studies with older adults evaluating dietary TAC using FRAP had higher values. Studies conducted in the United States (36) and England (37) had a FRAP values coverage rate of 100.0% and 98.5%, respectively. In the latter, the antioxidant capacity was also evaluated by other assays, however, the coverage by the FRAP assay was almost double compared to oxygen radical absorbance capacity (ORAC), Trolox equivalent antioxidant capacity (TEAC) and radical-trapping antioxidant parameter (TRAP). In the study conducted in Japan (35) the same coverage rate (61.2%) was obtained using four assays to evaluate the dietary antioxidant capacity, however, the food data collection tool used in this study had fewer food items (38) than the study conducted in England (134 items) (37). A reasonable comparison of dietary TAC between the above studies can be made due to the use of a similar methodology. However, the measurement of dietary TAC in different populations varies widely among studies. This high variability may result from the application of different analytical methods for the calculation of dietary TAC, lack of standardization involved in the assessment of food consumption, in addition to variations in the antioxidant content of foods that are related to geographic, climatic and food preparation factors (39). Besides, it should be noted that these differences may also be explained by the diversity of eating habits among different populations, which are mainly influenced by culture, especially when it comes to older adults.

Because of their antioxidant content, fruits and vegetables reduce the effects of free radicals that are produced in normal physiological functioning. However, these are not the only sources of antioxidants in the diet and other foods such as coffee, tea, wine, chocolate, and fresh herbs (12,40), also contribute to the antioxidant levels. Coffee was the food that contributed the most to the dietary TAC. Studies conducted with older adults in other countries observed similar results, in which coffee and tea were the foods that contributed the most to the dietary TAC (34,35,37,39–43). In agreement with our results, studies conducted in Sweden that analyzed dietary TAC considering reduced absorption of coffee and tea observed that vegetables, fruits, and whole grains, followed by coffee, were major contributors to dietary TAC (44–46).

Data from the Household Budget Survey (2008/2009) show that coffee stands out among the foods with the highest average daily consumption per capita in the Brazilian population, higher than the consumption of rice, beans (the core of the Brazilian diet), fruits and vegetables. The national mean of coffee intake for the older adults is 246.9 mL/d (18), and in our study, the mean consumption was 254.6 mL/d. The greatest contribution of coffee to the dietary TAC in older adults was not only due to its high antioxidant capacity compared to other foods, but also due to its high consumption. Compared to coffee, tea's contribution to the total value of dietary TAC was limited, since its consumption was low (14.7 mL/d).

Coffee and tea are among the most widely consumed beverages in the world (47), although consumption patterns may vary between countries. Due to the high content of

Table 1. Characteristics of older adults according to dietary total antioxidant capacity (TAC) tertiles.

	Dietary TAC mmol/d (Foods)[a]				Dietary TAC mmol/d (Foods and supplements)[b]			
Characteristics	Tertile 1	Tertile 2	Tertile 3	*p*-values	Tertile 1	Tertile 2	Tertile 3	*p*-values
TAC (mmol/d)	6.6 (4.6–7.7)[a]	10.5 (9.5–11.6)[b]	17.2 (14.5–21.1)[c]	**<0.001**	3.3 (−1.6-6.6)[a]	13.3 (10.9–15.3)[b]	21.9 (10.4–27.8)[c]	**<0.001**
Age (years)	68 (64–76)	70 (64–76)	70 (64–77)	0.453	68 (63–75)[a]	70 (64–76)[ab]	70 (65–77)[b]	**0.043**
BMI (kg/m^2)	26.7 (23.9–30.5)	27.3 (24.4–32.6)	26.9 (23.3–32.5)	0.196	27 (23.9–30.5)	27.1 (23.9–32.6)	27.3 (23.9–32.3)	0.821
Personal income (U$)	1,813.5 (906.7–3,510)[a]	906.8 (906.8–2,730)[b]	906.8 (906.8–1,895.4)[b]	**<0.001**	1,813.5 (906.8–3,817.1)[a]	906.8 (906.8–2,403.4)[b]	906.8 (906.8–1,813.5)[b]	**<0.001**
Sex								
Men	52.2	43.5	44.7	0.152	57.9	48.8	33.5	**<0.001**
Women	47.8	56.5	55.3		42.0	51.2	66.5	
Education level (years) (%)								
≤4	26.9	18.5	17.1	**0.024**	26.9	24.0	11.8	**<0.001**
>4	73.0	81.5	82.9		73.0	75.9	88.2	
Smoking (%)								
Never smoked	50.0	58.8	58.6	0.172	46.1	61.8	59.5	**0.044**
Former smoker	39.2	30.4	30.5		43.1	27.5	29.5	
Smoker	10.8	10.8	10.9		10.8	10.8	10.9	
Sedentary	71.0	68.1	70.8	0.889	69.6	70.5	69.9	0.772
Polypharmacy (%)	38.2	35.1	35.1	0.564	33.8	38.5	36.0	0.451
Supplement use (%)	16.7	10.7	11.4	0.193	10.3	9.7	18.5	**0.005**

Data are median (p25-p75) or relative frequency. P-values were obtained according to Kruskal-Wallis test (continuous variables) or linear trend Chi-square test (categorical variables).
*TAC calculated through foods; **TAC calculated through foods and supplements.
TAC values were adjusted for energy intake using the residual method before calculating the tertiles.
[a,b,c]Different letters show the presence of statistical difference according to dietary TAC categories.
Bold values are statistically significant ($p < 0.05$)

Table 2. FRAP values (mmol TE/100g) of food items from the recall of habitual consumption, contribution (%) of the groups and items, method for FRAP calculation and mean group intake, Viçosa, 2009.

Food groups and items*	FRAP			
	FRAP§ (mmol TE/100g)	% Contribution (Group Dietary TAC)	FRAP value	Mean group intake
Coffee and tea	–	74.1 (5469.91)	–	269.5
Coffee	3.44	99.07	AV	
Fennel tea	0.29	0.37	CV	
Mate tea	0.75	0.21	AV	
Instant coffee	3.12	0.18	CV	
Barley coffee	3.44	0.08	SV	
Vegetables	–	7.5 (553.04)	–	145.5
Kale	1.75	53.98	SV	
Lettuce	0.84	17.93	AV	
Beet	1.54	4.12	AV	
Tomato	0.14	3.89	AV	
Chicory	0.84	3.19	SV	
Fruits and juices	–	6.9 (509.72)	–	204.2
Orange	0.49	32.58	AV	
Orange juice	0.69	23.71	AV	
Banana	0.20	9.11	AV	
Apple	0.31	7.52	AV	
Guava	1.19	7.42	AV	
Cereals and cereal products	–	6.1 (449.23)	–	306.8
Polenta	0.37	36.11	SV	
Bread	0.44	26.36	AV	
Rice baked	0.08	14.01	AV	
Cream cracker	0.52	5.91	AV	
Whole wheat bread	0.12	5.09	AV	
Seeds, nuts, and pulses	–	2.1 (154.82)	–	125.6
Bean baked	0.19	91.96	AV	
Flaxseed	0.85	2.43	AV	
Soy milk	0.12	2.02	AV	
Walnuts	17.08	1.65	AV	
Soy extract	0.99	1.03	SV	
Meat and meat products	–	1.4 (102.79)	–	103.7
Chicken	0.38	90.43	SV	
Meat	0.01	2.35	SV	
Lard	0.85	2.20	SV	
Egg	0.04	1.29	AV	
Mortadella	0.27	0.72	SV	
Milk and dairy products	–	0,7 (51.9)	–	180.4
Milk whole	0.04	49.93	AV	
Milk semi-skimmed	0.04	25.28	AV	
Butter	0.54	7.57	AV	
Cheese	0.05	5.18	SV	
Yogurt	0.05	3.10	AV	
Oils and fats	–	0.5 (39.3)	–	8.9
Margarine	1.29	57.77	AV	
Soy oil	0.44	40.76	AV	
Olive oil	0.29	0.86	AV	
Mayonnaise	1.08	0.60	AV	
Alcoholic beverages	–	0.3 (20.39)	–	21.4
Beer	0.12	72.78	AV	
Wine	1.23	24.73	AV	
Sugar cane spirit	0.01	2.49	SV	
Sweet and miscellaneous food	–	0.2 (15.85)		8.4
Guava paste	0.59	32.30	CV	
Plum in sirup	1.92	24.70	CV	
Jam	0.73	12.00	SV	
Molasses	0.33	5.82	SV	
Peanut brittle	0.53	4.58	SV	
Cocoa products	–	0.1 (5.94)	–	0.4
Dark chocolate	7.40	49.86	AV	
Chocolate milk powder	2.10	22.80	SV	
Chocolate with nuts	3.56	13.61	AV	
Milk chocolate	3.56	9.00	AV	
Cocoa	3.51	4.73	AV	
Nonalcoholic beverages	–	0.1 (5.92)	–	10.1
Instant drink powder	1.23	78.42	SV	
Cola soft drink	0.03	19.35	AV	
Orange soft drink	0.13	2.23	AV	

*Groups and food items were listed in descending order according to ferric reducing antioxidant power (FRAP) contribution.
AV: analytical value; SV: substituted value; CV: calculated value.
TAC, total antioxidant capacity.
§Data source: Carlsen et al. (25) and Koehnlein et al. (26).

Table 3. Food groups consumption according to TAC tertiles.

Characteristics	Dietary TAC mmol/d (Foods) Tertile 1	Tertile 2	Tertile 3	*p*-value
Coffee and tea	125.8 (98.8)[a]	211.2 (102.5)[b]	472.4 (255.6)[c]	**<0.001**
Vegetables	157.4 (131.6)	142.6 (111.5)	136.0 (110.4)	0.326
Fruits and juices	184.8 (220.9)	181.7 (221.6)	196.7 (263.6)	0.991
Cereals and cereal products	328.8 (243.3)	288.4 (176.7)	300.7 (161.9)	0.096
Seeds, nuts, and pulses	0.9 (5.8)	0.5 (2.8)	1.0 (4.8)	0.936
Meat and meat products	102.6 (90.4)[a]	77.8 (67.2)[b]	80.6 (76.9)[b]	**0.019**
Milk and dairy products	252.5 (231.8)[a]	173 (173.3)[b]	115.2 (141.1)[c]	**<0.001**
Oils and fats	9.9 (8.5)[a]	8.5 (7.1)[b]	8.4 (8.4)[b]	**0.007**
Alcoholic beverages	32.6 (255)	23.3 (166.2)	8.3 (87.5)	0.876
Sweet and miscellaneous food	7.6 (23.8)	5 (17.5)	5.5 (24.5)	0.496
Cocoa products	0.6 (3.3)	0.5 (3.5)	0.1 (1.1)	0.878
Nonalcoholic beverages	15.7 (94)	7.4 (38.9)	8.7 (42.8)	0.537

Data are mean (sd). P-values were obtained according to Kruskal-Wallis test followed by Mann-Whitney U test.
[a, b, c:] Different letters show the presence of statistical difference according to dietary TAC categories.
Bold values are $p < 0.05$.
TAC, total antioxidant capacity.
TAC values calculated from foods and adjusted for energy intake by using the residual method before calculating the tertiles.

antioxidants and frequent use, these foods are considered important antioxidant sources in many diets (25). A study with postmenopausal Polish women found that beverages, mainly coffee and tea, contributed with more than 40% of the dietary polyphenol intake and more than half of the TAC (48). In the older Mediterranean population, macromolecular polyphenols were found to be the main source of dietary antioxidants, contributing with 71% of the total intake of phenolic compounds (49). Coffee consumption has been associated with decreased overall mortality in a meta-analysis of prospective cohort studies (50). Studies have shown that habitual coffee consumption is associated with a lower risk of coronary heart disease (51), some types of cancer (52) and that the consumption of coffee and tea is related to lower risk of diabetes *mellitus* type 2 (53,54). Due to the high antioxidant capacity of the coffee components, it has been suggested that long-term consumption can slow the progression of chronic diseases and thus increase life expectancy (50). Despite the beneficial effects evidenced above, coffee consumption has been linked to increased risk of hip fractures, especially in women (55). However, the data on this association have been inconclusive and meta-analyses conducted showed no significant association between coffee consumption and the risk of hip fracture (56,57). Further studies are needed to confirm these findings.

However, despite the beneficial effects of coffee, stimulating consumption due to its high antioxidant capacity needs to be cautioned, as it is usually linked to high consumption of added sugar. In our study, the mean sugar consumption was 30.1 g/d, below the recommended by the World Health Organization (WHO) and the Ministry of Health, which recommends consuming less than 10% of the total daily caloric intake (18,58). However, a research conducted with Brazilian older adults verified that more than 50% consumed above the recommended values of free sugar (18).

The mean consumption of fruits and vegetables of the older adults was 271 g/d. However, WHO defines as adequate a minimum consumption of 400 g/d (excluding potatoes and other tubers rich in starch) for the prevention of chronic diseases and reduction of micronutrient deficiencies, especially in developing countries (38). This protective effect is due to the presence of antioxidant compounds in these foods, including vitamin C, vitamin E, carotenoids, and phytochemicals, which protect cells from oxidative damage induced by free radicals (9,59). In addition to the antioxidants content, fruits and vegetables are sources of fibers and are low-density energy, which also contributes to the beneficial effects on health (60). Since a healthy diet is one composed of various plant and animal foods in adequate quantities, the consumption of fruits and vegetables should be encouraged, as these foods are considered important components of a healthy diet (61).

Cereals and cereal products also contributed to dietary TAC. These foods, despite containing lower amounts of antioxidants, can contribute to the total intake of antioxidants in the diet, as their consumption is often daily (25). In this sense, our results suggest that people consume antioxidant-containing foods from many different food groups, which may help them to boost their total intake of antioxidants. Additionally, we verified a low but significant contribution from foods of animal origin in the dietary TAC. It́s relevant to consider the use of natural antioxidants for industrial purposes. Antioxidants help to preserve the products from the lipid peroxidation, for example (62). This could explain the contribution of foods of animal origin in the dietary TAC.

The consumption of all foods and beverages, sorted by food groups, represented 65.5% of the variability in the dietary TAC. Higher values were found by Costanzo et al. (63) in an Italian study, in which the dietary intake of food groups accounted for more than 85.0% of the total variance of dietary TAC. Another Italian study part of the European Prospective Investigation into Cancer and Nutrition (EPIC) (41) found that the consumption of all foods and beverages, sorted by food group, explained only 58.5% of the dietary TAC variability (measured by TEAC) in middle-aged adults, with coffee, wine and fruits being the main sources of dietary TAC. Although Polish older adults consumed the lowest amounts of antioxidants and flavonoids due to the lowest food intake, the authors verified that the consumption of tea, coffee, and apples was associated with the largest contribution to dietary TAC and flavonoid content (64).

Additionally, a recent meta-analysis showed that a five mmol/d increment in dietary TAC based on FRAP methodology is associated with a seven percent lower risk of all-cause mortality (65). Regarding this, dietary improvements like the insertion of foods that are sources of antioxidants could bring benefits to the health of older adults. It is important to highlight that overconsumption of antioxidant supplements can be unhealthy. A study reported that high doses of vitamin E supplements may increase all-cause of mortality (66). In this sense, an antioxidant paradox can be noted (67).

Dietary TAC seems to be determined both by the type and by the amount of food consumed in the diet. Thus, the choice of foods with high TAC in each food class may be a good approach to increase dietary TAC. Although we have not assessed the relationship between TAC and health outcomes, studies have shown that dietary TAC was inversely associated with dyslipidemia, especially hypertriglyceridemia in Korean adults (68), with a reduced risk of hypertension in French women (69), and was inversely related with the risk of endometrial cancer in Italians (70).

Regarding the relationship between the TAC tertiles and characteristics of the older adults studied, we observed an interesting result. The older adults in the last TAC tertile have a lower personal income compared to those in the first tertile. Additionally, considering dietary TAC from foods and supplements, we noted a tendency of a high frequency of women, >4 years of educational level, older adults that never smoked, and use of supplements according to increase in tertiles. We can suggest that despite having a low income, the older adults tend to make use of supplements, to be women, and have a certain degree of educational level. Contrary to our results, a study that evaluated data from National Health and Nutrition Examination Survey showed that older adults with high income are the highest consumers of supplements (71).

Our study has strengths. To our knowledge, this is the first study to evaluate the antioxidant capacity of the diet considering the use of supplements in Brazilian older adults, with a level of detail not yet seen in Brazil. Besides, the evaluation methodology of the dietary TAC can better identify the antioxidants present in foods, including nutrients with antioxidant properties that have not been well characterized or measured (i.e., flavonoids). Moreover, the dietary TAC taking into account the synergy between the various antioxidants, which is not evaluated when comparing antioxidants individually. However, some limitations of this study need to be considered. Tables with FRAP values for most of the foods consumed by the older adults of this study reflect the antioxidant capacity values of international foods that could differ from those consumed in Brazil, due to changes in antioxidant content, as previously pointed out. This study used additional nutritional information from American tables to complement the missing data. Another limitation of the study refers to not evaluating herbs and spices, which, although consumed in small quantities, are the richest sources of antioxidants (25). Besides, the systematic use of dietary TAC can be difficult due to the diversity of methods used for its estimate and the many factors that influence antioxidant content in foods, which can lead to underestimation or overestimation of the results obtained in the study population. Despite the inherent limitations of this tool, its use provides the scientific community with data that can be used in epidemiological and intervention studies, making it possible to identify and classify complex diets regarding the intake of antioxidants, and to identify potential dietary antioxidant sources. However, it is necessary to expand the antioxidant capacity data of Brazilian foods to increase the reliability of the results obtained.

Conclusion

In conclusion, the older adults studied had a relatively low dietary TAC consumption. Additionally, a high frequency of women, higher schooling, older adults that never smoked, and the use of supplements was observed in the highest tertile of TAC. Besides, coffee and tea was the food group that contribute the most to the dietary TAC of the older adults from Viçosa, Brazil. Our data show the need to implement national strategies aimed at improving the diet quality of older adults, with increased consumption of different food groups, and therefore, increased intake of different compounds with antioxidant capacity, which will contribute to a better dietary TAC.

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Contribution of the authors

The conception and design of the study were performed by MANS, PGP, MSLD, and AQR. The generation and data collection were performed by MANS, PGP, AS, MSLD, and AQR. The assembly and analysis and/or interpretation of the data were performed by MANS, PGP, AS, MSLD, and AQR. All authors read and approved the final manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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