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ORIGINAL CONTRIBUTION

Estimated dietary intake and major food sources of polyphenols in elderly of Viçosa, Brazil: a population-based study

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Abstract

Purpose Epidemiological studies have remarked the beneficial role that polyphenols may have in the elderly population such as cancer and cardiovascular disease prevention. This is particularly relevant considering the global tendency of population aging. Data on polyphenol intake in the elderly population are scarce and usually provide partial information—only for some polyphenol classes. The aim of this study was to estimate the intake of polyphenols and its major dietary contributors in the population of Viçosa.

Methods A cross-sectional population-based survey including 620 elderly was conducted in Viçosa, Brazil. Food intake was estimated by recall of habitual consumption (RHC). Polyphenol intake was calculated by matching food consumption data from the RHC with the polyphenol content in foods listed in the Phenol-Explorer database.

Results The average total polyphenol intake was 1198.6 mg/day (533.7 mg/day as aglycone). The main polyphenol classes were phenolic acids (729.5 mg/day) and flavonoids (444.7 mg/day). The main dietary contributors for total polyphenols were coffee (45.8%), beans (32.8%) and polenta (1.3%). A total of 292 polyphenols divided in 14 classes and 23 subclasses were found. The individual compounds with the highest intake were isomers of chlorogenic acid (*i.e.,* 5-caffeoylquinic acid, 4-caffeoylquinic acid and 3-caffeoylquinic acid) among hydroxycinnamic acids that largely originated from coffee.

Conclusions The data reported here can be used to evaluate the association between the amount and type of ingested polyphenols and health outcomes in epidemiological studies in order to eventually establish nutritional recommendations.

Keywords Dietary polyphenols · Flavonoids · Phenolic acids · Stilbenes · Lignans · Elderly · Dietary intake

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Introduction

Polyphenols are antioxidant compounds contained in foods and beverages. These compounds are divided into five main classes according to their chemical structure: flavonoids, phenolic acids, stilbenes, lignans and others [1]. Clinical and epidemiological studies have shown that polyphenols may have beneficial effects in the regulation of different risk factors for chronic diseases [2, 3] or have even shown inverse association between polyphenol intake and the risk of certain chronic diseases such as cancers, cardiovascular diseases and overall mortality [4–12].

Moreover, during the last years, some studies have remarked the beneficial role that polyphenols may have in the elderly population, such as protecting against frailty [13], cognitive decline [14] and diabetes [15]. This is particularly relevant considering the global tendency of population aging [16].

A proper evaluation of polyphenol intake is a first step for evaluating associations between polyphenols and health-related outcomes. Given the wide variety of compounds included under the term "polyphenols," a comprehensive evaluation of polyphenol intake should include all polyphenol classes and detailed evaluations of the intake of each specific compound. For this, several tools exist, such as Phenol-Explorer (www.phenol-explorer.eu), an online comprehensive database [17] which can be used to estimate polyphenol intake in different populations based on polyphenol content values. Nevertheless, data on polyphenol intake specifically in the elderly population are scarce and usually provide partial information, *i.e.*, only for some polyphenol classes, such as proanthocyanidins in elderly women with chronic kidney disease [18] or flavonoids in Chinese [19], Australian [20] or Polish [21] elderly subjects. A study in elderly Japanese evaluated total polyphenol intake [22], but without assessing the contribution of the different classes, and a recent study described the intake of the different polyphenol classes in elderly subjects of São Paulo [23], but it did not include data for neither individual polyphenols nor aglycones.

Therefore, the purpose of the present study was to estimate the dietary intake of individual polyphenols in an elderly population of Viçosa (Minas Gerais State, Brazil), as well as to document the contribution of specific foods to total and individual polyphenol intake.

Subjects and methods

Study population

This was a cross-sectional study, population based, part of the project "Health conditions, nutrition and use of medication by the elderly in Viçosa (Minas Gerais): a population-based survey." Viçosa is a city located in the region of Zona da Mata in the state of Minas Gerais, Brazil. The population is about 72,000 inhabitants (7034 elderly individuals), the area is 300 km^2, and the Municipal Human Development Index (IDHM) is 0.775 [24]. The diet of this population is based on rice and beans, which are usually consumed daily, with a *per capita* intake of 247.6 g/day. Among fruits and vegetables (271 g/day) the most consumed are orange, banana, kale and tomato (56.2, 38.5, 27.0 and 24.8 g/day, respectively). Coffee is the most consumed beverage (254.6 mL/day), and in the meat and meat product group (78.5 g/day), chicken and red meat are the most consumed (39.5 and 39.0 g/day, respectively).

The population studied consisted of elderly aged 60–98 years, no institutionalized, residents in rural and urban areas of the city. To obtain the source population and subsequent sampling, the elderly were identified by census

during the National Vaccination Campaign for the Elderly in 2008. To complement identification, the databases of the Federal University of Viçosa workers (active and retired), Family Health Strategy, municipal physiotherapy service, Health Center for Women, psychosocial services, Hyperday and Polyclinic were merged. After this, the source population was 7980 elderly in total, which was the basis for the sample size calculation.

To calculate the sample size, the following was considered: a 95% confidence level, 50% estimated prevalence for different outcomes of interest (such as obesity, metabolic syndrome, use of medicines and anemia), 4% tolerated error and 20% to cover losses, giving a total sample of 670 elderly to be included in the study. The elderly were selected by simple random sampling, by drawing from the database. However, there were losses due to refusal (3.6%), selected individuals who were already deceased (1.3%), whose addresses were not found (1.2%) and who had moved from the municipality (1.2%). Thus, the final sample consisted of 620 elderly. Subjects were informed of the objective of the study, and if they agreed to participate, a personal appointment was made to collect data. The study design was approved by the Committee on Ethical Research of the Universidade Federal de Viçosa (Official Letter No. 27/2008/CEP/UFV).

Assessment of food intake

Dietary intake was assessed by means of an individual recall of habitual consumption (RHC), using the multiple-pass method [25]. The elderly 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 [26] 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. Extreme energy intakes were not excluded.

The recipes were divided into individual ingredients to estimate the amount of each food in it. The energy intake estimates were calculated using the Diet Pro® software based on Brazilian and American food composition tables [27, 28].

Correspondence between food items in the RHC and those in the Phenol-Explorer database

Data on the polyphenol content in foods were obtained from the Phenol-Explorer database (www.phenol-explorer.

eu) [17]. The foods that did not contain any polyphenols or that contained only traces were excluded (all foods of animal origin). Some foods that could contain polyphenols and were present in the food recall, but not in the Phenol-Explorer database, such as honey, cassava flour, cassava and manioc starch were excluded. Also, consumption of these foods was low, and therefore, their contribution to the polyphenol intake was considered insignificant. Some foods present in the RHC could be matched to several entries in the Phenol-Explorer database (*i.e.*, olive oil could correspond to extra-virgin, virgin or refined olive oil in Phenol-Explorer database, and rice could correspond to either parboiled or refined rice); thus, the content of polyphenols in foods was considered according to its consumption in the Brazilian population (*i.e.,* virgin olive oil and refined rice).

Recipes were decomposed, and the total polyphenol content was calculated based on the ingredient content. The polyphenol content of each food item was searched in the Phenol-Explorer database as described by Perez-Jimenez et al. [29]. Retention factors included in the database were used to convert polyphenol contents in raw foods to the contents found in the processed foods [30]. Yield factors were applied to take into account weight loss or water gain during cooking, using the following formula:

Concentration in processed food

$$= \frac{\text{Retention factor} \times \text{Concentration in raw food}}{\text{Yield factor}}.$$

Estimation of polyphenol intake and dietary contributors of polyphenols

An advanced search was carried out in the Phenol-Explorer database to retrieve mean content values for all polyphenols contained in the food items consumed in the population and previously linked to Phenol-Explorer entries. The data used to calculate polyphenol intake correspond to reverse-phase high-performance liquid chromatography (HPLC), in the Phenol-Explorer database, for all phenolic compounds, except for proanthocyanidins, where data correspond to normal phase HPLC. In the case of lignans and hydroxycinnamic acids in certain foods (cereals and beans) and ellagic acid in walnuts, which cannot be released with normal extraction conditions, data corresponding to HPLC after hydrolysis were also collected. In addition, when data obtained by chromatography without hydrolysis were unavailable, polyphenol contents obtained by HPLC after hydrolysis were used (*i.e.,* cabbage, cucumber, beetroot and kale).

The individual polyphenol intake from each food was calculated by multiplying the content of each polyphenol by the daily consumption of each food. Total polyphenol intake was calculated as the sum of all individual polyphenol intakes from all food sources reported by the RHC. Moreover, for those polyphenols that are present in foods as glycosides or esters, *i.e.,* associated with other non-phenolic compounds, the polyphenol intake was also calculated as aglycone equivalents, considering only the phenolic part of the molecule.

Statistical analyses

Socio-demographic and lifestyle characteristics included age, gender, educational level, smoking and alcohol drinking habits. Age was categorized from 60 to 74 and greater than 75 years. Educational level was categorized as ≤4 (elementary school) and >4 years. Personal income was categorized into two categories: ≤$130 dollars (465 reais, the equivalent of minimum wage in local money) and >$130 dollars. Occupational level was categorized as low (unskilled/unemployed workers), medium (partially skilled workers) and high (skilled workers). Household situation was categorized as urban and rural. Exercise was categorized as yes or no. Individuals were categorized according to their smoking status as no (non-smoker and former smoker) and yes. Finally, alcohol consumption was categorized no (nondrinker and former alcohol drinker) and yes.

Mean intakes (mg/day per person) of all individual polyphenols, polyphenol groups (phenolic acids, flavonoids, alkylphenols, alkylmethoxyphenols, stilbenes, tyrosols, lignans and other polyphenol groups) and major food contributors (% contribution to polyphenol class) were determined. Data are presented as means and standard deviations, medians and interquartile ranges for continuous variables and frequencies and percentages for categorical variables. Total polyphenol intake was determined for the whole study sample as well as according to the socio-demographic and lifestyle characteristics.

Polyphenol intake distribution was analyzed using the Kolmogorov–Smirnov test, and it did not follow a normal distribution. Thus, differences in intake between groups were statistically analyzed by Mann–Whitney *U* test and the Kruskal–Wallis test and *p* values <0.05 (two-tailed) were considered as significant. Because intake of many nutrients is positively correlated with total energy intake, total and specific classes of polyphenol intake were adjusted for total energy intake (calories) using the residual method [31]. All data were organized and analyzed using Microsoft Excel 2010 software and Stata® statistical software package version 12.

Results

Total polyphenol intake

A total of 620 participants were available for the analyses. The general characteristics of the study population

Table 1 General characteristics of the studied population, Viçosa, Brazil, 2009 (numbers and percentages)

Characteristics	Men		Women		Total population	
	n	*%*	*n*	*%*	*n*	*%*
Age group (years)						
60 a 74	212	73.1	221	67.0	433	69.8
≥75	78	26.9	109	33.0	187	30.2
Educational level (years)						
≤4	217	75.1	273	82.7	490	79.2
>4	72	24.9	57	17.2	129	20.8
Personal income						
≤1 MW	90	31.0	159	48.2	249	40.2
>1 MW	200	69.0	171	51.8	371	59.8
Occupational level						
Low	210	72.4	316	95.8	526	84.8
Medium	68	23.5	12	3.6	80	12.9
High	12	4.4	2	0.6	14	2.3
Household situation						
Urban	251	86,5	294	89,1	545	87.9
Rural	39	13,5	36	10,9	75	12.1
Exercise						
No	216	74.5	219	66.1	434	70.0
Yes	74	25.5	112	33.9	186	30.0
Smoking status						
No	243	83.8	308	93.9	551	89.2
Yes	47	16.2	20	6.1	67	10.8
Alcohol drinking						
No	155	53.5	255	77.5	410	66.2
Yes	135	46.5	74	22.5	209	33.8

MW minimum wage

according to sex are presented in Table 1. Among the 219 food items considered in the RHC, 106 contained polyphenols according to the Phenol-Explorer database. The total polyphenol intake was determined as the sum of all entries of individual polyphenols. The populations' average and median polyphenol intake values were 1198.6 and 1052.7 mg/day, respectively. These values included intakes of sugars and polyols linked to aglycones; thus, the total aglycone intake was determined. The mean and median intake of polyphenols and aglycones was 902.6 ± 536.8 and 779.8 mg/day, respectively. Polyphenol intake adjusted by energy was also calculated, with a mean value of 1198.6 ± 591.1 and median of 1102.8 mg/day.

The polyphenol intake is presented according to sociodemographic characteristics and lifestyle (Table 2). The polyphenol intake among men was higher than women (1313.5 ± 757.3 and 1097.6 ± 616.4 mg/day, respectively; $p = 0.0001$); there was also a significant difference between people with a medium occupational level and the other two categories; however, this difference did not remain significant after adjustment for energy. Education

level, household situation and individual income influenced polyphenol intake, and the elderly with ≤4 years of education, income ≤ MW and living in rural areas had a higher intake of polyphenols. Elderly people who practiced no exercise and are non-alcohol drinkers had significantly higher polyphenol intake when compared to other groups in the analysis adjusted for energy.

Polyphenol intake per classes

Altogether 292 polyphenols divided in 14 classes and 23 subclasses were described in the foods consumed in this population. When calculating dietary polyphenols, those with amounts smaller than 0.0001 per 100 g of food were not included and, in fact, other polyphenols were not present in the diet of the population. The most consumed polyphenol classes were phenolic acids (729.5, 451.5 mg/day as aglycone equivalents) and flavonoids (444.7, 426.8 mg/day as aglycone equivalents), which corresponded to 60.9 and 37.1% of total polyphenol consumption, respectively, whereas lignans (1.1%) and other polyphenols such as

Table 2 Total and energy-adjusted polyphenol intake according to socio-demographic and lifestyle characteristics of the studied population Viçosa, Brazil, 2009

Characteristics[b]	n	Polyphenol intake (mg/day)				Energy-adjusted[a] polyphenol intake (mg/day)			
		Mean ± SD	Median	IQR	p value	Mean ± SD	Median	IQR	p value
Total population	620	1198.6 ± 693.8	1052.7	740.5–1477.9		1198.6 ± 591.1	1102.8	817.3–1504.8	
Sex					**0.0001**				0.7334
Men	290	1313.5 ± 757.3	1169.2	844.7–1610.3		1215.4 ± 639.8	1116.0	829.5–1537.2	
Women	330	1097.6 ± 616.4	949.4	692.4–1407.9		1183.8 ± 545.4	1097.6	816.7–1494.8	
Age group (years)					**0.0019**				0.4603
60 a 74	433	1197.8 ± 619.3	1092.4	806.9–1502.9		1197.8 ± 619.1	1092.4	806.9–1502.9	
≥75	187	1310.2 ± 699.4	1186.9	818.3–1582.2		1200.7 ± 522.1	1143.9	858.5–1508.6	
Educational level (years)					**0.0026**				**0.0000**
≤4	490	1339.1 ± 834.1	1122.9	852.0–1689.3		1266.7 ± 581.0	1154.0	1154.0–1540.7	
>4	93	1214.9 ± 672.7	1089.8	762.5–1506.0		933.8 ± 554.3	855.0	607.48–1242.8	
Personal income					0.6257				**0.0008**
≤1 MW	249	1212.7 ± 697.3	1055.6	759.0–1487.4		1279.5 ± 544.4	1168.9	939.2–1564.4	
>1 MW	371	1189.1 ± 692.2	1051.2	733.1–1477.6		1144.3 ± 615.3	1066	774.9–1398.7	
Occupational level					**0.0167**				0.2138
Low	526	1166.4 ± 674.6	1021.9	732.8–1431.0		1193.3 ± 574.5	1099.6	823.1–1495.8	
Medium	80	1418.0 ± 791.8	1345.0	807.4–1778.5		1275 ± 695.1	1166.6	833.4- 1640.9	
High	14	1154.9 ± 623.2	1259.1	641.9–1539.7		958.5 ± 524.3	882.6	657.3–1233.3	
Household situation					**0.0108**				**0.0022**
Urban	545	1164.8 ± 660.2	1033.7	733.1–1455.1		1172.8 ± 583.9	1090.9	806.5–1473.3	
Rural	75	1444.0 ± 867.2	1189.6	806.1–1893.2		1386.3 ± 613.5	1332.5	962.1–1717.6	
Exercise					0.1406				**0.0491**
No	434	1223.7 ± 710.7	1097.0	757.5–1487.4		1224.6 ± 596.4	1131.1	849.9–1513.0	
Yes	186	1140.1 ± 650.5	998.7	713.8–1465.5		1137.9 ± 575.6	1041.84	760.2–1474.4	
Smoking status					0.2371				0.1212
No	551	1179.8 ± 660.3	1042.5	738.4–1474.0		1181.9 ± 568.2	1097.6	812.1–1494.8	
Yes	67	1353.6 ± 918.1	1187.9	790.8–1664.0		1331.3 ± 751.7	1237.0	898.0–1671.8	
Alcohol drinking					0.7953				**0.0018**
No	410	1198.6 ± 706.8	1034.1	741.1–1478.0		1251.8 ± 599.8	1148.8	854–1540.7	
Yes	209	1195.9 ± 669.6	1076.9	733.12–1464.8		1092.8 ± 561.3	1019.6	760.1–1373.1	

MW minimum wage

Bold indicates *p* <0.05

[a] Adjusted for total energy intake (calories) using the residual method

[b] Comparisons across categories were performed by using the Mann–Whitney *U* test or the Kruskal–Wallis test

stilbenes, alkylmethoxyphenols, alkylphenols, methoxyphenols, tyrosols, hydroxyphenylpropenes, hydroxybenzaldehydes and others presented lower proportions (each <1%) (Table 3). The average daily consumption of hydroxycinnamic acids (726.6 ± 545.6 mg/day) in the phenolic acid group and flavanols (376.8 ± 315.6 mg/day) in the flavonoids group were the highest when compared to the other subclasses in these polyphenol classes. Flavanones (36.4 ± 74.1 mg/day) was the third most consumed polyphenol subgroup. When expressed as aglycone equivalents, the relative contribution of hydroxycinnamic acids decreased from about 60 to 49.7% (448.6 mg/day),

flavanols increased from about 30 to 41.7% (376.2 mg/day) and flavanones increased from about 3 to 3.4% (30.6 mg/day), whereas the relative contributions of the other polyphenol such as lignans, stilbenes and isoflavones subclasses remained similar.

For several polyphenol classes, the intake in women was significantly higher (all *p* < 0.05) than in men: flavanones (46.8 ± 80.5 compared with 24.5 ± 62.0 mg/day), lignans (15.4 ± 26.7 compared with 11.6 ± 23.3 mg/day), flavones (5.4 ± 6.5 compared with 4.0 ± 6.9 mg/day), others polyphenols (3.5 ± 2.7 compared with 3.2 ± 3.0 mg/day), isoflavonoids (0.1 ± 6.5 compared with 0.1 ± 7.5 mg/

Table 3 Total, classes and subclasses of polyphenol intake, according to food group sources and main food contributors, Viçosa, Brazil, 2009

Polyphenol class and subclasses	Alcoholic beverages	Non-alcoholic beverages	Fruits and juices	Vegetables	Cereals	Seeds and oil	Others	Total foods	Main food contributors (% contribution to polyphenol class)
Phenolic acids[b]	0.6 ± 5.0	542.4 ± 472.0	2.1 ± 7.9	14.3 ± 9.2	153.7 ± 258.5	15.9 ± 30.4	0.6 ± 12.6	729.5 ± 545.4	Coffee (74.3), polenta (20.2), bean (1.5)
Hydroxycinnamic acids	0.2 ± 1.6	542.3 ± 472.1	1.7 ± 7.8	12.6 ± 23.1	153.5 ± 258.5	15.8 ± 30.4	0.6 ± 12.6	726.6 ± 545.6	Coffee (74.6), polenta (20.3), bean (1.5)
Hydroxybenzoic acids	0.4 ± 3.4	0.1 ± 1.7	0.4 ± 0.8	1.7 ± 7.3	0.2 ± 0.1	0.1 ± 1.5	–	2.9 ± 9.1	Chicory (56.3), banana (13.4), beer (12.6)
Flavonoids[c]	0.9 ± 11.8	0.9 ± 8.7	46.7 ± 83.7	5.1 ± 7.0	3.2 ± 7.2	382.6 ± 325.0	5.4 ± 45.7	444.7 ± 345.1	Bean (85.8), orange (5.7), orange juice (2.9)
Flavanols	0.6 ± 8.2	0.4 ± 7.6	5.0 ± 18.8	<0.1	0.3 ± 5.0	365.0 ± 311.2	5.3 ± 45.5	376.8 ± 315.6	Bean (96.9), chocolate milk powder (0.7), banana (0.6)
Flavanones	<0.1	–	36.3 ± 74.1	<0.1	–	–	–	36.4 ± 74.1	Orange (69.3), orange juice (30.1), lemon juice (0.5)
Flavonols	0.1 ± 0.7	0.4 ± 2.0	1.7 ± 3.7	4.9 ± 7.0	–	16.6 ± 14.2	0.02 ± 0.3	23.7 ± 16.6	Bean (70.1), kale (10.7), apple (5.2)
Flavones	–	–	1.7 ± 5.0	0.2 ± 0.4	2.9 ± 4.4	–	–	4.7 ± 6.9	Cream cracker (41.9), orange juice (34.9), maize bread (7.6)
Anthocyanins	0.1 ± 2.3	–	2.0 ± 13.0	–	–	–	–	2.2 ± 13.2	Grape nectar (60.0), grape juice (21.9), strawberry (10.9)
Isoflavonoids	–	–	–	–	–	1.0 ± 7.0	–	1.0 ± 7.0	Soy milk (82.1), bean (12.2), flour soy (5.8)
Lignans	–	–	3.9 ± 8.8	7.2 ± 18.0	0.3 ± 0.5	2.2 ± 12.2	0.1 ± 0.4	13.6 ± 25.5	Orange (16.2), broccoli (15.1), flaxseed (14.9)
Alkylmethoxyphenols	<0.1	1.2 ± 1.0	–	–	–	–	–	1.2 ± 1.1	Coffee (61.2), whole wheat bread (37.7), beer (0.7)
Others	0.2 ± 1.2	6.9 ± 5.8	0.7 ± 2.0	–	–	0.1 ± 0.8	–	3.4 ± 3.1	Coffee (80.3), orange juice (19.0), lemon juice (0.7)
Alkylphenols	–	2.3 ± 2.0	–	–	2.9 ± 8.7	–	–	5.2 ± 8.9	Coffee (37.5), pasta (33.5), rye bread (13.0)
Methoxyphenols	–	0.4 ± 0.4	–	–	–	–	–	0.4 ± 0.4	Coffee (100)
Tyrosols	0.1 ± 0.7	–	–	–	–	0.1 ± 0.8	–	0.2 ± 1.0	Olive oil (53.5), beer (33.6), wine (12.7)
Hydroxyphenylpropenes	–	0.2 ± 1.1	–	–	–	–	–	0.2 ± 1.1	Fennel tea (100.0)
Hydroxybenzaldehydes	<0.1	0.1 ± 0.3	–	–	–	–	–	0.1 ± 0.3	Fennel tea (84.9), wine (6.6), beer (5.6)
Total Polyphenols*	1.7 ± 16.1	550.2 ± 477.3	53.3 ± 91.3	26.6 ± 38.0	160.1 ± 259.0	400.7 ± 334.0	6.0 ± 47.5	1.198.6 ± 693.8	Coffee (45.8), bean (32.8), polenta (1.3)

Food group (mg/day per person)[a]

* Do not include hydroxybenzoketones, furanocoumarins, stilbenes and hydroxycoumarins in traces

[a] Values are means ± SDs

[b] Do not include hydroxyphenylacetic acid in traces

[c] Do not include dihydroflavonols and chalcones in traces

day), hydroxyphenylpropenes (0.3 ± 1.3 compared with 0.1 ± 0.7 mg/day) and hydroxybenzaldehydes (0.1 ± 0.4 compared with 0.0 ± 0.2 mg/day). In contrast, men had a higher intake than women (all $p < 0.05$) of anthocyanins (2.4 ± 15.8 compared with 2.0 ± 10.1 mg/day), alkylphenols (2.1 ± 9.1 compared with 1.7 ± 1.8 mg/day) and tyrosols (0.2 ± 1.2 compared with 0.2 ± 0.9 mg/day).

Polyphenol intake per food groups and main food contributors

The contribution of different food groups to the total polyphenol intake as well as the main food contributors in each food group is shown in Table 3. Non-alcoholic beverages, seeds and oils were the main polyphenol suppliers with respective contributions of 550.2 and 400.7 mg/day (281.8 ± 244.3 and 30.2 ± 34.0 mg/day as aglycones), whereas fruits and vegetables accounted for a lower percentage of the total amount of polyphenols in the diet (Table 3).

The main dietary sources for the total polyphenols were coffee (45.8%), beans (32.8%) and polenta (12.3%). Coffee was the food item that contributed most to the intake of phenolic acids (74.3%), mainly for hydroxycinnamic acids (74.6%) and was also the main contributor to alkylmethoxyphenols, alkylphenols, methoxyphenols and others polyphenols. The main contributors to flavonoid intake were beans (85.8%), orange (5.7%) and orange juice (2.9%). Flavanols, the second most consumed polyphenols,

were found in beans, which was almost its only food source. Flavanones were found in orange, orange juice and lemon juice. Lignans were obtained from orange, broccoli and flaxseed and hydroxyphenylpropenes and hydroxybenzaldehydes derived from fennel tea.

Intakes of individual polyphenols

The intake of all individual polyphenols consumed was determined (see supplemental Tables). Forty of them were consumed in amounts greater than 1 mg/day and ten of these were consumed in amounts >10 mg/day, representing together 63.9% of total polyphenol consumption (Table 4). Other polyphenols were consumed in quantities lower than 10 mg/day (Supplementary Table 1). Eleven of the 17 most consumed polyphenols were phenolic acids and five were flavonoids, including two flavanols and three flavanones. Among hydroxycinnamic acids, the most consumed ones were isomers of chlorogenic acid (*i.e.,* 5-caffeoylquinic acid, 4-caffeoylquinic acid and 3-caffeoylquinic acid) that largely originated from coffee. This list also included a lignan and lariciresinol, which originated from broccoli, orange and potato.

The 292 polyphenols consumed in this population corresponded to 145 different aglycones. The polyphenol subclasses that had more aglycones were flavanols (22 compounds), hydroxycinnamic acids (15 compounds) and flavonols (15 compounds). Intakes of all polyphenol aglycones were also determined, and 21 of them

Table 4 Intake of most consumed individual polyphenols and their main food sources

Polyphenol	Polyphenol subclass	Polyphenol intake, mg/day (mean ± SD)	Main food contributors (% contribution to polyphenol class)		
5-Caffeoylquinic acid	Hydroxycinnamic acids	190.0 ± 157.0	Coffee (94.2)	Potato (2.3)	Chicory (1.8)
4-Caffeoylquinic acid	Hydroxycinnamic acids	152.8 ± 132.8	Coffee (97.2)	Tomato (0.2)	Plum in syrup (0.1)
3-Caffeoylquinic acid	Hydroxycinnamic acids	133.4 ± 116.1	Coffee (99.3)	Peach juice (0.3)	Plum in syrup (0.2)
Ferulic acid	Hydroxycinnamic acids	125.6 ± 200.9	Polenta (90.6)	Bean (6.1)	Maize bread (1.7)
5-Feruloylquinic acid	Hydroxycinnamic acids	29.9 ± 26.0	Coffee (99.9)	Carrot (0.1)	
o-Coumaric acid	Hydroxycinnamic acids	22.6 ± 39.0	Polenta (98.3)	Maize bread (1.4)	Beer (0.1)
4-Feruloylquinic acid	Hydroxycinnamic acids	21.9 ± 19.1	Coffee (99.9)		
Hesperetin	Flavanones	18.9 ± 50.1	Orange (100.0)		
p-Coumaric acid	Hydroxycinnamic acids	12.9 ± 18.5	Polenta (79.8)	Bean (17.6)	Maize bread (1.2)
3-Feruloylquinic acid	Hydroxycinnamic acids	10.7 ± 9.3	Coffee (99.7)	Carrot (0.1)	Peach juice (0.1)
Hesperidin	Flavanones	7.6 ± 22.7	Orange juice (98.8)	Lemon juice (1.2)	
3,4-Dicaffeoylquinic acid	Hydroxycinnamic acids	7.0 ± 5.9	Coffee (97.7)	Carrot (1.5)	
Kaempferol 3-*O*-xylosyl-glucoside	Flavonols	6.8 ± 5.6	Bean (100.0)		
Lariciresinol	Lignans	6.8 ± 12.6	Broccoli (22.7)	Orange (19.9)	Potato (8.2)
Kaempferol 3-*O*-glucoside	Flavonols	6.7 ± 5.7	Bean (99.7)	Black tea (0.1)	Wine (0.1)
Naringenin	Flavanones	6.3 ± 16.7	Orange (100.0)		
4,5-Dicaffeoylquinic acid	Hydroxycinnamic acids	5.2 ± 4.6	Coffee (100.0)		

were consumed in amounts >1 mg/day (Supplementary Table 2). The ten aglycones with the highest mean intakes were caffeic acid (248.2 ± 209.7 mg/day), ferulic acid (162.4 ± 203.7 mg/day), hesperetin (22.6 ± 51.1 mg/day), *o*-coumaric acid (22.6 ± 39.0 mg/day), *p*-coumaric acid (14.1 ± 9.4 mg/day), kaempferol (12.2 ± 9.3 mg/day), naringenin (7.1 ± 16.8 mg/day), lariciresinol (6.8 ± 12.5 mg/day), (+)-catechin (4.1 ± 3.5 mg/day) and pinoresinol (4.0 ± 9.6 mg/day).

Discussion

This study explored the polyphenol intake as individual constituents in an elderly population, a demographic group particularly relevant for their worldwide increase. The results showed a mean total polyphenol intake (determined as the sum of individual compounds) of 1198.6 and 533.7 mg/day as aglycones, which was higher than Spanish elderly (358.8 mg/day for men and 279.6 mg/day for women) [32] and lower than Japanese elderly (1492 mg/day) [22].

Regarding previous studies with general population, the intake found here was higher than that previously reported for the Brazilian populations, *i.e.,* 460.2 mg/day [33] and 377.5 mg/day [23]. At the same time, it was lower than that reported for a Polish population (1756.5 mg/day) [34], in the same range than that in France (1193.0 mg/day) [29] and higher than in Spain (820.0 mg/day) [35] or in another Polish study (989.3 mg/day) [36].

Differences were also observed in the consumption of flavonoids and phenolic acids when compared to the previously mentioned studies. Flavonoid intake was 444.7 ± 345.1 mg/day which was considerably higher than what was reported by the other Brazilian studies [23, 33] similar to the results obtained by Spanish [35] and Polish studies [36], but lower than another study conducted in Poland [34] and France [29]. Flavanols were the most abundant flavonoid consumed by the population in this study and by Polish individuals [34, 36]. In regard to phenolic acids, the average intake (729.5 ± 545.4 mg/day) was higher than what was found in other studies, such as two Brazilian studies [23, 33], a French study [29] a Spanish study [35] and a Polish study [36], though slightly lower than another Polish study [34].

In all these studies, hydroxycinnamic acids were the most consumed subclass of phenolic acids. In contrast to flavonoids and phenolic acids, other classes of polyphenols were scarcely consumed, accounting for about 1 mg/day per person, due to its poor content in foods (*i.e.,* lignans and stilbenes) or due to the low consumption of their main food sources (*i.e.,* isoflavones).

This high variability between dietary intake estimates of these compounds may result from different methods of assessment of food consumption, application of different analytical methods for the determination of polyphenols, the absence of polyphenol content for certain foods in the databases used, in addition to variations related to environmental factors, variety, processing and storage [37]. However, a reasonable comparison of polyphenol intake between the above studies is possible due to the use of similar methodology.

Coffee and beans were the main dietary contributors to polyphenol intake in our population. On the other hand, vegetables and fruits showed limited contribution, similar to the results found by Miranda et al. (2016) and Correa et al. (2015). Studies in other countries have reported a greater contribution of polyphenol intake from coffee, but also from fruits, vegetables and wine. These foods were important contributors to total phenols and their subclasses [29, 35]. One possible explanation for the reduced contribution of polyphenols from fruits and vegetables is due to the low consumption of these foods in the Brazilian population [38]. The average consumption by the elderly was 271 g/day, far below the level recommended by WHO, which defines the appropriate minimum consumption of 400 g/day [39].

Coffee and tea are the two most widely consumed beverages in the world, although consumption patterns vary between countries. In Brazil, coffee stands out among the foods with the highest average daily consumption per capita, higher than the consumption of rice and beans, core of the Brazilian diet, fruits and vegetables [38]. More specifically, coffee was the main dietary source of hydroxycinnamic acids, increasing the total intake of phenolic acids which is consistent with other studies [29, 34–36, 40]. Overall, the elderly Brazilian have an average consumption of coffee of 246.9 mL/day [38]; in our study, the average consumption was 254.4 mL/day. Furthermore, about 93.0% of the elderly were coffee drinkers. This result was similar to that found by Miranda et al. (2016) for the Brazilian population. In the Polish population, 83.0% were coffee drinkers, with an average consumption of 237.0 mL/day [34] and 92.0% of French adults were also coffee drinkers [29].

One point to be considered with regard to the results of total polyphenol consumption is that the determination of the major sources of polyphenols in foods can be made by evaluating the amount of polyphenols in each food and also the amount of food consumed [41]. In this sense, coffee and beans account for the largest share of the total polyphenol consumption not only because they are consumed in high quantities but also because they are foods with high polyphenol content.

Tea was also observed among the main sources of compounds in other countries [29, 34, 35]. However, the

importance of this beverage in the consumption of phenolic compounds in Brazil can be considered very low, which was in line with other Brazilian studies [23, 33]. Another notable difference between the polyphenol intake in European countries and the population of Viçosa was the significant contribution of beans and corn derived products to the total polyphenol amount. Beans were the main food item that contributed to flavonoid intake. In this study, chicory was the main dietary source of hydroxybenzoic acids. In other studies, the main dietary sources of hydroxybenzoic acids were tea [29, 35, 36], olives [35] and beer [23]. The aforementioned differences in polyphenol intake could be explained by the diversity of eating habits among different populations, which are often dictated by culture. Moreover, the specific food preferences of each country affect the intake of subgroups and the amount of polyphenols. Another remarkable difference between the polyphenol intake in European countries and the population of Viçosa was the relevant contribution of polenta, which is a preparation based on maize flour.

Previous studies have reported that polyphenol intake was influenced by gender, with men having higher absolute total polyphenol consumption than women [29, 34]. In this study, average polyphenol intake was higher in men than in women; however, this difference did not remain significant after adjusting for the total energy intake (calories) using the residual method. To the best of our knowledge, previous studies on polyphenol intake in different populations did not include this kind of adjustment; our results show the need of performing it, since it actually changed the statistical differences on polyphenol intake, not only between genders, but also between alcohol drinkers and nondrinkers. Differences in polyphenol intake in this study were observed in relation to education level (≤4 years), personal income (≤MW), exercise (no), household situation (rural) and alcohol drinking (no). One can speculate that elderly who live in rural areas have lower education levels, which is linked to lower individual income, which can lead to unhealthy lifestyles, which would include not practicing exercises and food monotony. In addition, these individuals consumed more coffee, polenta and beans, which are foods that are part of Viçosa's food habit and were also the main contributors of polyphenol intake.

This study presents some limitations. First, although Phenol-Explorer is the most comprehensive database available to date, the information on some foods widely consumed in Brazil is still scarce because they have not been characterized or only poorly characterized (i.e., guava, mango, cassava). Secondly, although the data source for the polyphenols is the same across studies, using different tools for evaluating the consumption may overestimate or underestimate the results. In our study, the instrument used to assess dietary intake differed from other studies. However,

the RHC gives a more complete estimate of food consumption when compared to other instruments used in studies of the elderly (i.e., FFQ) since there is no limit to the amount of items evaluated. Moreover, the results obtained by this instrument can be more consistent since they are less affected by memory bias. Although it has not been validated for use with the elderly, this instrument has shown consistent results when compared to other methods used to evaluate food consumption. Finally, the consumption of some polyphenol-rich foods such as herbs and spices was not reported. Although these foods are consumed in small quantities, they are the richest dietary sources of polyphenols [42], which may have led to a possible bias in the assessment of total polyphenol intake.

Conclusions

This study has provided information on the consumption of polyphenols and their main food contributors in elderly population of Viçosa, Brazil. Polyphenol intake was in the same range than that reported for other populations, mostly in Europe, but it showed significant differences as regards to the main food contributors, with a higher contribution of food items such as beans or polenta, and a lower contribution of fruits and vegetables. The data reported here can be used to evaluate the association between the amount and type of ingested polyphenols and health outcomes in epidemiological studies in order to eventually establish nutritional recommendations.

Compliance with ethical standards

Conflict of interest Authors declare that they have no conflict of interest.

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