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Association between total dietary antioxidant capacity and food groups and incidence of depression in a cohort of Brazilian graduates (CUME Project)

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Abstract

This study aims to evaluate the association between Dietary Total Antioxidant Capacity (dTAC) and Total Antioxidant Capacity of food groups (fgTAC) with the incidence of depression in Brazilian graduates participating in the Cohort of Universities of Minas Gerais (CUME Study). The sample consisted of 2572 participants without a medical diagnosis of depression at baseline who responded to at least one follow-up questionnaire from the CUME Project. The Ferric Reducing Antioxidant Power assay was used to determine dTAC. Incidence of depression was estimated by self-reported medical diagnosis of depression during the years of cohort follow-up. Cox regression models were used to relate dTAC and fgTAC to the incidence of depression. The mean follow-up time was 2·96 (1·00) years, and 246 cases of depression were observed (32·3/1000 person-years). The mean dTAC was 11·03 (4·84) mmol/d. We found no associations between higher dTAC and lower risk of developing depression after adjusting for possible confounders. The incidence of depression was inversely associated with fgTAC of the beans and lentils group (hazard ratio (HR): 0·61; 95 % CI 0·41, 0·90). The fgTAC of the junk food group was positively associated with higher incidence of depression after all adjustments (HR: 1·57; 95 % CI 1·08, 2·26). Our findings do not support an association between dTAC and the incidence of depression in a highly educated Brazilian population. However, associations of fgTAC show the importance of analysing the food matrix in which these antioxidants are inserted. We highlight the need for more prospective studies with different nationalities to confirm these results.

Key words: **Dietary Total Antioxidant Capacity: Depression: Epidemiology: Oxidative stress**

Depression is a chronic mental illness with great worldwide prevalence[1]. Data indicate that 3·8 % of the world population is affected by depression, affecting about 5 % of the adult population and 5·7 % of the population over 60 years old[1]. The main characteristics of depressive disorder are depressed mood, feelings of guilt or low self-esteem, changes in sleep and appetite, lack of disposition and poor concentration. In many cases, these symptoms can be accompanied by feelings of anxiety[2]. In moderate or severe intensities, depression can greatly affect an individual's daily life in work, studies and family relationships, and in its most severe forms, it can lead to suicide[1,2].

In this sense, much has been investigated about the pathogenesis of depression, and oxidative stress has stood out among the risk factors[3,4]. Oxidative stress can be characterised as an imbalance between the antioxidant defences of the organism and the presence of free radicals, a pathogenic process related to cell injury and death[3–5]. It is noteworthy that the brain, compared with other organs, is highly vulnerable to oxidative stress due to its high metabolism[5,6]. Thus, redox imbalance may be related to depression through mechanisms such as inflammation and neurodegeneration, impairing neuronal and neurotransmitter function[3,4,7].

Due to the need for new approaches to treat and prevent depression, antioxidants such as vitamins C, E and Zn have been associated with improvements in neurocognitive function, bringing therapeutic benefits to depression[8]. A recent cross-sectional study with 14 737 individuals participating in the Brazilian Longitudinal Study of Adult Health (ELSA) reported,

Abbreviations: dTAC, Dietary Total Antioxidant Capacity; fgTAC, Total Antioxidant Capacity of food groups; FRAP, Ferric Reducing Antioxidant Power.

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for Brazilian women, an inverse association of the consumption of Zn, Se, vitamin A and C with depression[9]. Inverse associations of Zn and Se consumption with depression were also found for 14 834 adults participating in the National Health and Nutrition Examination Survey 2009–2014[10].

Despite the results obtained so far between nutrient intake and the occurrence of depression, the isolated assessment of antioxidants may not be as effective as the assessment of the interaction of different dietary antioxidants[11]. Therefore, the Dietary Total Antioxidant Capacity (dTAC), an index capable of measuring the global content of dietary antioxidants[12], has proved to be a helpful tool for investigating the interaction between dietary antioxidants and health outcomes[13–15]. However, investigations into the relationship between dTAC and depression are still limited, mostly being cross-sectional studies with the Iranian population[16–19]. Unfortunately, as far as we know, no prospective study has investigated the association between dTAC and depression in Brazilians, nor has it analysed this relationship through the Total Antioxidant Capacity of food groups (fgTAC)[16]. Thus, the present study aimed to assess the association between dTAC and fgTAC with the incidence of depression in Brazilian graduates participating in the Cohort of Universities of Minas Gerais (CUME Study).

Methodology

Cohort of Universities of Minas Gerais (CUME Study)

The CUME Study is an open, prospective cohort conducted with alumni from universities located in the state of Minas Gerais (Brazil), whose main objective is to assess the impact of the Brazilian dietary pattern, specific diet factors and the nutritional transition in the incidence of chronic non-communicable diseases, as previously detailed[20].

The CUME Study questionnaires were developed on the Alchemer (www.alchemer.com) online interface by specialists. The team conducted pilot studies with the baseline questionnaire to assess its applicability[20]. The CUME Study began in 2016 with the application of the baseline questionnaire Q_0, and its recruitment has been periodic since then. Invitations to participate were sent to all volunteers who had emails available. Thus, every 2 years, the participants are invited to answer follow-up questionnaires (Q_2, Q_4 . . . Q_n) to update their information about lifestyle, the emergence of new diseases and changes in dietary patterns, among others, while new potential participants are recruited and invited to answer the baseline cohort questionnaire (Q_0). Characteristics related to project design and recruitment of the first volunteers were described in a previous study[20].

The questionnaires are answered in a virtual environment of the CUME Study. Q_0 is divided into two phases: the first phase with questions about socio-demographic characteristics, lifestyle, biochemical markers (TAG concentrations, total cholesterol, HDL-cholesterol, LDL-cholesterol, blood glucose concentration) and related to the individual's health outcomes; the second phase that is answered after 1 week contains a FFQ and questions related to dietary practices. On the other hand, Q_2 is composed of questions related to changes in lifestyle, eating habits and health conditions. Finally, the follow-up questionnaire Q_4 has questions related to socio-demographic characteristics, lifestyle, biochemical markers, health outcomes and insomnia severity.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Human Research Ethics Committees of all participating institutions: Federal University of Minas Gerais (CAAE registration number: 07223812.3.3001.5153); Federal University of Viçosa (CAAE registration number: 4483415.5.1001.5149); Federal University of Ouro Preto (CAAE registration number: 44483415.5.2003.5150); Federal University of Lavras (CAAE registration number: 44483415.5.2002.5148); Federal University of Juiz de Fora (CAAE registration number: 4483415.5.5133); Federal University of Vale do Jequitinhonha e Mucuri (CAAE registration number: 44483415.5.2005.5103) and Federal University of Alfenas (CAAE registration number: 4.501.344). Written informed consent was obtained from all subjects[20].

Data collection

Information from the Q_0 questionnaires for the years 2016, 2018 and 2020 composed the baseline of the present study. We used data from the 2-year follow-up Q_2 and the 4-year follow-up Q_4 to investigate the incidence of the depression outcome.

The first collection related to the 2-year follow-up occurred in 2018, answered by participants who started the baseline (Q_0) in 2016. The second collection, associated with Q_2, occurred in 2020 when we invited participants who completed the Q_0 follow-up questionnaire in 2018. Finally, the collection related to the Q_4 follow-up questionnaire occurred in 2020. Participants who answered Q_2 in 2018 were invited to fill it out.

Study population

The CUME Study has responses from 7710 participants. For the present study, of the total number of respondents, we excluded 4084 participants who had not accomplished at least the 2-year follow-up. We also excluded women who were pregnant or had been pregnant in the last year (n 430), participants with energy consumption < 2092 or > 25104 kJ per day (< 500 kcal or > 6000 kcal) (n 79)[21], participants who reported not having lived in Brazil in the last year (n 135) and foreigners living in Brazil (n 10) and participants who reported a diagnosis of depression at baseline (n 400). The final sample consisted of 2572 participants who answered at least one follow-up questionnaire (Fig. 1).

Outcome variable: incidence of depression

We considered incident cases of depression in those participants who were disease-free at the beginning of the follow-up and were classified as having the disease during Q_2 or Q_4 follow-up. For it, we considered incident depression when participants answered yes to the following question: 'Since the previous questionnaire, were you clinically diagnosed with depression for the first time?'. Individuals who reported using antidepressants but did not confirm the diagnosis of depression

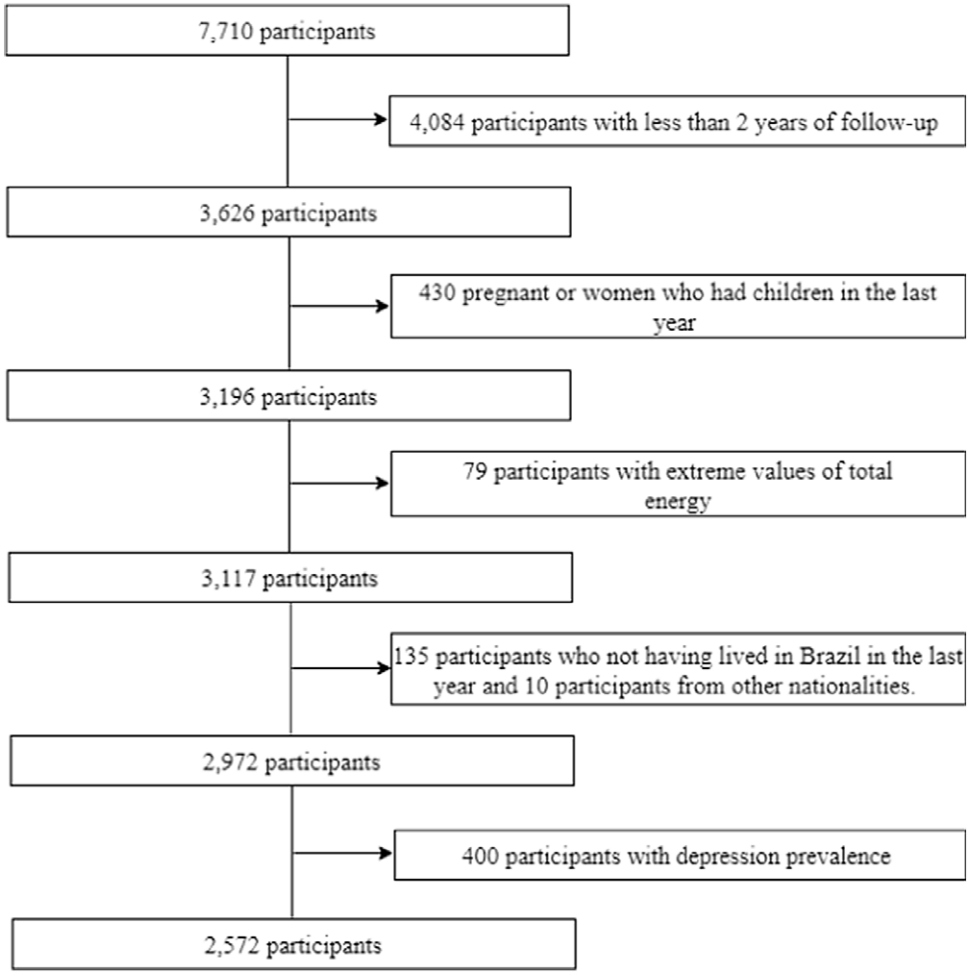

Fig. 1. Flow chart of participant selection.

were not included due to the possibility of the therapeutic use of such drugs in diseases other than depression. The reliability between medical diagnosis and self-report depression in this cohort was validated in a subsample of participants showing good agreement (81·0 %) with a κ value of 0·62[22].

Food consumption and estimation of Dietary Total Antioxidant Capacity

We assessed habitual food consumption using FFQ, previously validated for the study population[23], which includes 144 food items presented in the following groups: dairy products, meat and fish, cereals and legumes, fruits, vegetables, fats, and oils, beverages and other foods. Each participant reported the frequency of consumption of a particular food (daily, weekly, monthly or yearly), the number of times they consumed it (0–9 or more times) and the portion size. To facilitate filling in the portion sizes of food items and obtain the most reliable information possible, participants had access, at the time of answering the FFQ, to images of portions of food and serving utensils from the photo album with ninety-six pictures prepared by the CUME Study team[20]. The consumption of macro and micronutrients was calculated using primarily data from the Table of Nutritional Composition of Foods consumed in Brazil[24] and, in the absence of information in this table, we consulted the Brazilian Table of Food Composition[25] and the USDA National Nutrient Database[26].

We used the values from the Ferric Reducing Antioxidant Power (FRAP) assay to estimate dTAC, which measures the antioxidant capacity of food in the presence of Fe. We consulted previously published databases to obtain the FRAP values[12,27]. Thus, the dTAC of each food item resulted from the multiplication between the amount in grams of food consumed and its corresponding FRAP value in mmol per gram of food (mmol/g).

We used the following criteria to assign the FRAP value to a portion of food: when there was more than one FRAP analysis value for the same food, we considered the mean value; in the absence of a FRAP value for a particular food, when possible, we used the value of a similar food from the same botanical group, or the same food in a different way of preparation. We did not assign FRAP values to foods where there was no record of this value, and it was not possible to estimate for foods from similar botanical groups or different methods of preparation

A total of 133 food items were covered with FRAP values. We summed all FRAP values of foods reported in the FFQ to estimate the total dTAC of each participant. In order to perform a

sensitivity analysis, we also calculated dTAC values, excluding coffee values, as this is a beverage that greatly contributes to dTAC values in our population[13]. We also calculated fgTAC values according to food groups (fruits, vegetables, beans and lentils, oilseeds, dairy products, meats and eggs, pasta, breads and cereals, oils and fats, junk food, natural juices, teas and coffees, artificial juices and sodas, and alcoholic beverages) (online Supplementary Table 1).

We adjusted all food consumption variables for daily energetic intake using the residual method[28], including dTAC.

Covariates

We obtained the other variables from self-reported information in the baseline questionnaire Q_0, including socio-demographic variables (sex, skin colour, marital status, professional status), use of vitamin supplements and smoking habits (non-smoker, smoker or ex-smoker). The frequency of heavy episodic consumption of alcoholic beverages (1–2 d/month, 3–4 d/month and 5 or more days/month) was also a variable included in this study, with heavy episodic consumption considered as 4 or more doses of alcoholic beverage on a single occasion for women and 5 or more doses of alcoholic beverage on a single occasion for men[29]. We also assessed physical activity using a list of twenty-four activities expressed in minutes per week. Participants with ≥ 150 min/week of moderate-intensity activity or ≥ 75 min/week of vigorous-intensity activity were considered active; participants with < 150 min/week of moderate-intensity activity or < 75 min/week of vigorous-intensity activity were classified as insufficiently active and those who reported no leisure-time physical activity were classified as inactive[30]. We obtained the BMI from the self-reported weight and height in the baseline questionnaire, dividing weight (kg) by height (m) squared. BMI values ≥ 30 kg/m^2 were classified as obesity[31,32]. The BMI based on self-reported weight and height was also validated, in a previous study, for the population participating in the CUME Project, indicating excellent agreement with the measured intra-class correlation coefficient 0·989[33].

Statistical analysis

We performed the analyses with Stata SE 15·0. A two-tailed *P*-value less than 0·05 was considered statistically significant.

We described socio-demographic, lifestyle, health and food consumption characteristics in absolute or relative frequency or as mean and standard deviation according to the dTAC quartiles baseline. We calculated the *P*-value using Pearson's chi-squared tests for categorical variables and ANOVA for continuous variables to compare the categories.

The follow-up time was calculated in person-years for each participant: difference between the date of completion of the follow-up questionnaire in which depression was diagnosed and the date of completion of the baseline questionnaire. In this sense, we created Cox regression models to assess the association between dTAC in quartiles and the incidence of depression. We used the lowest quartile as the reference category to compare the incidence of depression among the dTAC categories (exposure variable). As a guide for selecting the covariates included in the analyses, we constructed a directed acyclic graph (DAG) using the DAGitty program. DAG are a strategy that helps identify a minimum set of confounding covariates in the analysis of causal relationships, helping to estimate less biased measures of effect[34,35] (online Supplementary Fig. 1). Thus, we adjusted the final model for potential confounders such as sex, age (continuous), smoking habit (non-smoker/smoker/ex-smoker), frequency of heavy episodic alcohol consumption (never/from 1 to 2 days per month/from 3 to 4 days per month/5 or more days per month), marital status (single/married or stable union/separated or divorced or widowed), skin colour (white/non-white), professional status, physical activity (inactive/insufficiently active/active), use of vitamin supplements (yes/no), BMI (continuous) and energetic intake (kcal/d) and vitamin D consumption (μg/d). Linear trends were tested using the median values of each quartile of the exposure variable ordered in Cox regression models. We also performed a sensitivity analysis excluding coffee items from the dTAC computation. In addition, we analysed the relationship between fgTAC and the incidence of depression (fruits, vegetables, beans and lentils, oilseeds, dairy products, meat and eggs, breads, pasta and cereals, oils and fats, 'junk food', natural juices, teas and coffees, artificial juices and soda and alcoholic beverages), considering that antioxidants present in diet may be inserted in different proportions in food matrices[15,36].

Results

During the average time of 2·96 (1·00) years of monitoring of the present study, 246 new cases of depression (32·3/1000 person-years) were observed and the mean age of the participants was 36·09 (SD 9·63). The mean dTAC was 11·03 (4·84 mmol/d).

Participants included in the highest quartile for dTAC (> 13·32 mmol/d) are mostly older, married or in a stable union, employed workers, smokers and physically active, in addition to having a higher frequency of heavy episodic alcohol consumption (Table 1). Regarding food consumption, individuals belonging to the fourth quartile of dTAC, when compared with the first quartile (< 7·92 mmol/d), had a higher intake of carbohydrates, *n*-3, alcohol, vitamins A, E, C and B_9, Mg, fibre, as well as higher consumption of fruits and vegetables (Table 2).

There was no association between dTAC and incidence of depression (Table 3), regardless of adjustment for confounding variables. The results of the analysis of dTAC without coffee and incidence of depression remained similar. When we assessed the associations between fgTAC and the incidence of depression (Tables 4 and 5), we observed a lower incidence of depression according to the quartiles of fgTAC of natural juices in the model adjusted by age and sex (hazard ratio: 0·70; 95 % CI 0·49, 0·99). Still, the significance of this association was lost after the total adjustment of the model. On the other hand, the TAC of the beans and lentils was inversely associated with the incidence of depression in our cohort (hazard ratio: 0·61; 95 % CI 0·41, 0·90) (Table 4). Interestingly, a higher fgTAC from the junk food group was positively associated with a higher incidence of depression among participants after all adjustments (hazard ratio: 1·57; 95 % CI 1·08, 2·26).

Table 1. Baseline socio-demographic and health characteristics according to energy-adjusted dTAC (mmol/d) quartiles, CUME Project (*n* 2572) (Mean values and standard deviations; numbers and percentages)

	Q1		Q2		Q3		Q4		
Mean	6·02		9·09		11·69		17·33		
SD	1·80		0·67		0·85		4·49		
	n	%	*n*	%	*n*	%	*n*	%	*P*
Age									
<40 years	517	80·4	476	74·0	421	65·5	393	61·1	<0·001
40–59 years	115	17·9	152	23·6	200	31·1	231	35·9	
≥ 60 years	11	1·7	15	2·4	22	3·4	19	3·0	
Sex									
Male	251	39·0	214	33·3	219	34·1	252	39·2	0·040
Female	392	61·0	429	66·7	424	65·9	391	60·8	
Skin colour									
White	406	63·1	403	62·7	418	65·0	434	67·5	0·257
Non-white	237	36·9	240	37·3	225	35·0	209	32·5	
Marital status									
Single	370	57·5	315	49·0	281	43·7	277	43·1	
Married/stable union	250	38·9	296	46·0	322	50·1	313	48·7	<0·001
Separated/divorced/widower/other	23	3·6	32	5·0	40	6·2	53	8·2	
Professional situation									
Employee	445	69·2	506	78·7	495	77·0	508	79·0	
Student	126	19·6	87	13·5	92	14·3	86	13·4	<0·001
Retired	9	1·4	9	1·4	17	2·6	18	2·8	
Unemployed	63	9·8	41	6·4	39	6·1	31	4·8	
Smoking status									
No	565	87·9	533	82·9	502	78·1	475	73·9	
Past	38	5·9	69	10·7	86	13·4	91	14·2	<0·001
Current	40	6·2	41	6·4	55	8·6	77	12·0	
Binge frequency									
None	401	62·4	402	62·5	370	57·5	327	50·9	
1–2 times a month	124	19·3	130	20·2	148	23·0	147	22·9	<0·001
3–4 times a month	75	11·7	75	11·7	69	10·7	89	13·8	
5 or more times a month	43	6·7	36	5·6	56	8·7	80	12·4	
Physical activity									
Inactive	204	31,7	156	24,3	128	19,9	110	17,1	
Insufficiently active	134	20,8	141	21,9	130	20,2	118	18,4	<0·001
Active	305	47,4	346	53,8	385	59,9	415	64,5	
Use of supplements									
Yes	149	23·2	157	24·4	181	28·1	182	28·3	0·078
No	494	76·8	486	75·6	462	71·9	461	71·7	
Obesity									
No	561	87·2	574	89·3	582	90·5	579	90·0	0·242
Yes	82	12·8	69	10·7	61	9·5	64	10·0	

dTAC, Dietary Total Antioxidant Capacity.
P values according to trend chi-squared test.

Discussion

In the present study, we found no association between total dTAC and incidence of depression. Still, fgTAC from specific food groups, such as natural juice, beans and lentils, and junk foods, showed associations. As far as we know, this is the first prospective study to investigate the association between dTAC and fgTAC by different food groups with the incidence of depression in Brazilian graduates.

When analysing the fgTAC, we observed an inverse association between the fgTAC of the beans and lentils group with the incidence of depression. A study from the National Health Survey in Brazil with 46 785 adults showed an inverse association between bean consumption and depression[37]. Bean consumption was also inversely associated with mental disorders in a study with 712 Brazilian pregnant women[38]. It is noteworthy that beans, besides being sources of antioxidants such as polyphenols, are sources of B vitamins and minerals such as Fe, K and Mg, in addition to dietary fibre[39,40]. In a previous study, beans proved to be an important contributor to folate consumption in part of the CUME Project baseline population[41]. In fact, in addition to antioxidants, folate consumption has been inversely associated with depression[42,43]. Another point worth mentioning is the fact that the regular consumption of beans may be related to a higher quality dietary pattern, characterised by a diversity of in natura and minimally processed foods, while low intake may be associated with an increase in the consumption of ultra-processed foods[40,44,45]. We emphasise that the dietary pattern rich in ultra-processed foods is positively related to the incidence of depression[37,46].

We observed that higher fgTAC of junk food was positively associated with higher incidence of depression in our cohort. This fact raises the question of the importance of the food matrix in which antioxidants are inserted. Although some ultra-processed foods have vitamins and minerals with antioxidant

Table 2. Baseline dietary intake according to the energy-adjusted dTAC (mmol/d) quartiles, CUME Project (*n* 2572) (Mean values and standard deviations)

	Q1		Q2		Q3		Q4		
Mean	6·02		9·09		11·69		17·33		
SD	1·80		0·67		0·85		4·49		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P**
Total energy intake, kcal/d	2662·50	1027·93[a]	2091·645	761·19[b]	2200·05	793·04[b]	2504·59	986·68[c]	<0·001
Carbohydrates, g/d	241·54	67·05[a]	259·92	44·43[b]	265·17	54·59[b,c]	272·72	69·11[c]	<0·001
Protein, g/d	113·17	36·38[a]	105·92	23·26[b]	103·60	28·00[b]	99·39	30·82[c]	<0·001
Lipids, g/d	101·63	23·60[a]	96·14	16·13[b]	93·93	19·02[b,c]	90·99	24·36[c]	<0·001
SFA, g/d	36·09	10·28[a]	33·58	6·80[b]	32·51	8·94[b,c]	30·93	9·62[c]	<0·001
MUFA, g/d	36·15	10·46[a]	35·07	7·52[a,b]	34·48	9·25[b,c]	33·28	11·11[c]	<0·001
PUFA, g/d	18·36	6·99[a]	19·24	5·08[a]	19·33	5·40[a]	19·15	7·38[a]	0·021
TRANS, g/d	1·41	1·27[a]	1·22	0·73[b]	1·10	0·70[b]	0·93	0·80[c]	<0·001
n-3 fatty acids, g/d	2·09	0·73[a]	2·30	0·55[b,c]	2·38	0·55[c]	2·60	0·87[d]	<0·001
Alcohol intake, g/d	4·43	9·89[a]	5·14	6·46[a,b]	6·31	7·97[b]	8·17	11·92[c]	<0·001
Vitamin C, mg/d	161·34	134·79[a]	236·67	151·71[b]	277·50	196·60[c]	335·43	286·27[d]	<0·001
Vitamin A, µg/d	761·89	324·25[a]	835·82	291·15[b]	869·10	280·26[b,c]	912·19	546·31[c]	<0·001
Vitamin E, mg/d	7·39	3·16[a]	8·51	2·64[b]	9·11	3·16[c]	9·95	4·75[d]	<0·001
Folic acid, µg/d	450·31	179·77[a]	497·34	113·24[b]	497·45	124·52[b]	509·58	142·11[b]	<0·001
Vitamin B_{12}, µg/dc	4·55	3·13[a]	4·22	1·81[b,a]	4·05	1·65[b]	3·84	3·11[b]	<0·001
Vitamin D, µg/d	4·22	3·57[a]	4·20	2·82[a]	4·04	2·57[a,b]	3·73	2·67[b]	0·008
Mg, mg/d	324·88	81·93[a]	366·15	72·53[b]	391·66	77·50[c]	424·95	98·65[d]	<0·001
Fibre, g/d	21·06	9·70[a]	25·88	7·07[b]	28·10	8·59[c]	30·80	12·22[d]	<0·001
Fruit, g/d	267·45	248·88[a]	414·15	218·94[b]	491·77	290·02[c]	598·97	441·48[d]	<0·001
Vegetables, g/d	188·75	142·55[a]	222·26	121·12[b]	245·91	132·15[c,d]	262·90	178·20[d]	<0·001
Legumes, g/d	93·46	120·75[a]	80·65	83·50[a,b]	75·78	83·46[b]	80·15	84·14[a,b]	0·005

Data expressed as mean (standard deviation).
* *P* values by ANOVA test. Different letters show statistically significant differences between groups according to Bonferroni's post hoc test.

Table 3. Hazard ratios and 95 % CI of depression incidence according to dTAC and dTAC without coffee, CUME Project (*n* 2572) (Mean values and standard deviations)

	Total dTAC						
	Q1	Q2		Q3		Q4	$P_{for\ trend}$
Mean	6·02	9·09		11·69		17·33	
SD	1·80	0·67		0·85		4·49	
Crude	1·00	0·98	0·68, 1·41	1·15	0·81, 1·63	1·07	0·75, 1·52	0·591
Model 1*	1·00	0·98	0·68, 1·41	1·16	0·81, 1·67	1·10	0·77, 1·59	0·460
Model 2†	1·00	0·97	0·67, 1·40	1·14	0·79, 1·64	1·09	0·75, 1·58	0·521
Model 3‡	1·00	1·10	0·75, 1·62	1·29	0·88, 1·87	1·18	0·81, 1·72	0·342
	dTAC without coffee						
	Q1	Q2		Q3		Q4	$P_{for\ trend}$
Mean	4·08	6·29		7·76		11·79	
SD	1·42	0·39		0·49		3·85	
Crude	1·00	1·16	0·81, 1·65	0·94	0·65, 1·36	1·23	0·86, 1·76	0·370
Model 1*	1·00	1·12	0·78, 1·59	0·88	0·61, 1·29	1·15	0·79, 1·66	0·605
Model 2†	1·00	1·11	0·78, 1·59	0·88	0·60, 1·28	1·16	0·80, 1·68	0·562
Model 3‡	1·00	1·29	0·89, 1·87	1·02	0·69, 1·50	1·32	0·91, 1·91	0·246

dTAC, Dietary Total Antioxidant Capacity.
* Adjusted – Sex and age.
† Adjusted – Model 1 + smoking status (never, current, former), alcohol consumption (BINGE frequency) and vitamin D consumption (mcg).
‡ Adjusted – Model 2 + marital status (single/married or stable union/separated or divorced or widowed), skin colour (white and not white), physical activity (inactive/insufficiently active/active), use of supplements (yes or no), energy intake (continuous, kcal/d), baseline BMI (continuous kg/m^2), professional situation.

potential added to their composition to increase their shelf life, these are generally rich in simple sugars, fats, flavourings and preservatives that can contribute to a pro-oxidant and inflammatory state, closely related to depression[47–49]. In addition, a diet rich in fast food can contain a lower amount of vitamins and minerals than in natura or minimally processed foods. The deficient consumption of several nutrients is related to depression[50,51].

We did not observe any association between total dTAC and incidence of depression. These findings agree with a prospective study with 911 Japanese workers, with no associations between dTAC and incidence of depressive symptoms after 3 years of

Table 4. Hazard ratios and 95 % CI of depression incidence according to fgTAC from food groups, CUME Project (*n* 2572) (Mean values and standard deviations)

	fgTAC from fruits								
	Q1		Q2		Q3		Q4		$P_{for\ trend}$
Mean	0·49		1·76		2·68		5·39		
SD	0·79		0·25		0·30		3·32		
Crude	1·00	1·14	0·80, 1·62	0·97	0·67, 1·40	1·13	0·79, 1·61		0·668
Model 1*	1·00	1·06	0·74, 1·51	0·87	0·60, 1·26	1·03	0·71, 1·49		0·962
Model 2†	1·00	1·06	0·74, 1·51	0·87	0·60, 1·27	1·04	0·72, 1·50		0·996
Model 3‡	1·00	1·26	0·87, 1·83	1·03	0·70, 1·53	1·23	0·84, 1·80		0·473
	fgTAC from vegetables								
	Q1		Q2		Q3		Q4		$P_{for\ trend}$
Mean	0·26		0·53		0·72		1·29		
SD	0·15		0·05		0·06		0·60		
Crude	1·00	0·84	0·59, 1·18	0·96	0·68, 1·36	0·75	0·53, 1·08		0·187
Model 1*	1·00	0·79	0·56, 1·11	0·89	0·63, 1·25	0·72	0·50, 1·14		0·135
Model 2†	1·00	0·78	0·55, 1·11	0·88	0·62, 1·25	0·71	0·49, 1·03		0·121
Model 3‡	1·00	0·86	0·60, 1·23	0·96	0·67, 1·37	0·77	0·53, 1·11		0·216
	fgTAC from beans and lentils								
	Q1		Q2		Q3		Q4		$P_{for\ trend}$
Mean	0·02		0·15		0·26		0·60		
SD	0·07		0·03		0·03		0·35		
Crude	1·00	1·09	0·79, 1·49	0·63	0·44, 0·90	0·56	0·38, 0·81		0·001
Model 1*	1·00	1·06	0·77, 1·45	0·63	0·44, 0·90	0·59	0·40, 0·86		0·001
Model 2†	1·00	1·03	0·75, 1·43	0·61	0·42, 0·88	0·57	0·38, 0·83		0·001
Model 3‡	1·00	1·14	0·81, 1·60	0·68	0·46, 1·00	0·61	0·41 - 0·90		0·002
	fgTAC from oil seeds								
	Q1		Q2		Q3		Q4		$P_{for\ trend}$
Mean	0·01		0·19		0·43		1·73		
SD	0·24		0·07		0·08		1·47		
Crude	1·00	0·71	0·49, 1·03	0·96	0·67–1·36	1·08	0·76, 1·51		0·216
Model 1*	1·00	0·65	0·44, 0·94	0·84	0·59, 1·21	0·98	0·69, 1·39		0·353
Model 2†	1·00	0·65	0·45, 0·95	0·85	0·60, 1·23	0·99	0·69, 1·40		0·351
Model 3‡	1·00	0·76	0·50, 1·15	1·05	0·69, 1·60	1·13	0·79, 1·61		0·183
	fgTAC from dairy products								
	Q1		Q2		Q3		Q4		$P_{for\ trend}$
Mean	0·03		0·09		0·15		0·29		
SD	0·03		0·01		0·02		0·11		
Crude	1·00	0·92	0·63, 1·34	1·03	0·72, 1·48	1·19	0·83, 1·70		0·215
Model 1*	1·00	0·90	0·62, 1·30	0·99	0·69, 1·42	1·15	0·80, 1·64		0·296
Model 2†	1·00	0·92	0·63, 1·34	1·02	0·70, 1·48	1·20	0·83, 1·75		0·217
Model 3‡	1·00	0·96	0·66, 1·39	1·05	0·73, 1·52	1·22	0·84, 1·78		0·204
	fgTAC from meat and eggs								
	Q1		Q2		Q3		Q4		$P_{for\ trend}$
Mean	0·06		0·15		0·21		0·39		
SD	0·06		0·01		0·09		0·18		
Crude	1·00	0·94	0·66, 1·34	0·86	0·60, 1·24	1·06	0·75, 1·49		0·777
Model 1*	1·00	0·88	0·62, 1·25	0·82	0·57, 1·18	1·00	0·71, 1·42		0·948
Model 2†	1·00	0·90	0·63, 1·27	0·84	0·58, 1·21	1·01	0·69, 1·47		0·929
Model 3‡	1·00	0·98	0·67, 1·42	0·92	0·62, 1·36	1·03	0·70, 1·52		0·872
	fgTAC from bread, pasta and cereals								
	Q1		Q2		Q3		Q4		$P_{for\ trend}$
Mean	0·21		0·40		0·56		0·97		
SD	0·12		0·03		0·06		0·35		

Table 4. (*Continued*)

	fgTAC from bread, pasta and cereals							
	Q1		Q2		Q3		Q4	$P_{for\ trend}$
Crude	1·00	0·81	0·56, 1·16	0·87	0·62, 1·24	0·89	0·63, 1·26	0·753
Model 1*	1·00	0·79	0·55, 1·13	0·84	0·59, 1·19	0·87	0·61, 1·24	0·676
Model 2†	1·00	0·78	0·54, 1·12	0·84	0·59, 1·19	0·87	0·61, 1·24	0·706
Model 3‡	1·00	0·85	0·59, 1·23	0·88	0·61, 1·26	0·92	0·65, 1·31	0·822
	fgTAC from oils and fats							
	Q1		Q2		Q3		Q4	$P_{for\ trend}$
Mean	0·01		0·07		0·13		0·30	
SD	0·04		0·01		0·02		0·14	
Crude	1·00	0·89	0·62, 1·29	1·22	0·87, 1·73	1·06	0·75, 1·52	0·499
Model 1*	1·00	0·84	0·58, 1·22	1·17	0·83, 1·65	1·03	0·72, 1·46	0·587
Model 2†	1·00	0·86	0·60, 1·24	1·17	0·82, 1·65	1·01	0·71, 1·46	0·683
Model 3‡	1·00	0·96	0·66, 1·40	1·24	0·86, 1·77	1·04	0·72, 1·51	0·704
	fgTAC from junk food							
	Q1		Q2		Q3		Q4	$P_{for\ trend}$
Mean	0·04		0·39		0·62		1·74	
SD	0·24		0·06		0·08		1·22	
Crude	1·00	1·25	0·86, 1·81	1·01	0·68, 1·49	1·63	1·15, 2·31	0·007
Model 1*	1·00	1·15	0·79, 1·67	0·91	0·61, 1·35	1·46	1·02, 2·09	0·031
Model 2†	1·00	1·15	0·79, 1·69	0·91	0·61, 1·35	1·46	1·01, 2·10	0·034
Model 3‡	1·00	1·31	0·88, 1·95	1·06	0·69, 1·62	1·57	1·08, 2·26	0·020

fgTAC, Total Antioxidant Capacity of food groups.
* Adjusted – Sex and age.
† Adjusted - Model 1 + smoking status (never, current, former), alcohol consumption (BINGE frequency) and vitamin D consumption (mcg).
‡ Adjusted – Model 2 + marital status (single/married or stable union/separated or divorced or widowed), skin colour (white and not white), physical activity (inactive/insufficiently active/active), use of supplements (yes or no), energy intake (continuous, kcal/d), baseline BMI (continuous kg/m²), professional situation.

Table 5. Hazard ratios and 95 % CI of depression incidence according to consumption of fgTAC by beverages, CUME Project (*n* 2572) (Mean values and standard deviations)

	fgTAC from natural juices							
	Q1		Q2		Q3		Q4	$P_{for\ trend}$
Mean	0·02	0·26		0·54		1·33		
SD	0·13	0·05		0·12		0·75		
Crude	1·00	0·78	0·55, 1·11	0·80	0·57, 1·12	0·71	0·50, 1·01	0·099
Model 1*	1·00	0·74	0·52, 1·05	0·78	0·55, 1·10	0·70	0·49, 0·99	0·100
Model 2†	1·00	0·74	0·52, 1·05	0·78	0·55, 1·09	0·70	0·50, 1·00	0·114
Model 3‡	1·00	0·82	0·57, 1·19	0·85	0·60, 1·22	0·77	0·54, 1·11	0·235
	fgTAC from teas and coffee							
	Q1		Q2		Q3		Q4	$P_{for\ trend}$
Mean	0·42		2·25		4·19		9·14	
SD	0·68		0·48		0·72		3·90	
Crude	1·00	0·88	0·61, 1·25	0·89	0·63, 1·27	1·01	0·71, 1·42	0·807
Model 1*	1·00	0·85	0·59–1·21	0·91	0·63, 1·30	1·06	0·74, 1·51	0·533
Model 2†	1·00	0·83	0·58, 1·18	0·88	0·61, 1·27	1·02	0·71, 1·45	0·678
Model 3‡	1·00	0·85	0·59, 1·22	0·93	0·64, 1·34	1·03	0·72, 1·48	0·636
	fgTAC from artificial juices and sodas							
	Q1		Q2		Q3		Q4	$P_{for\ trend}$
Mean	0·01		0·05		0·16		0·72	
SD	0·04		0·01		0·05		0·53	
Crude	1·00	1·00	0·70, 1·45	1·00	0·70, 1·43	1·12	0·79, 1·58	0·443

Table 5. (*Continued*)

	fgTAC from artificial juices and sodas							
	Q1	Q2		Q3		Q4		$P_{for\ trend}$
Model 1*	1·00	0·94	0·66, 1·36	0·93	0·65, 1·34	1·10	0·78, 1·55	0·389
Model 2†	1·00	0·95	0·66, 1·38	0·94	0·65, 1·35	1·09	0·77, 1·55	0·426
Model 3‡	1·00	1·09	0·73, 1·63	1·02	0·69, 1·51	1·12	0·79, 1·61	0·568
	fgTAC from alcoholic beverages							
	Q1	Q2		Q3		Q4		$P_{for\ trend}$
Mean	0·01	0·13		0·34		1·32		
SD	0·10	0·03		0·09		1·11		
Crude	1·00	0·82	0·57, 1·17	0·81	0·58, 1·14	0·85	0·60, 1·20	0·596
Model 1*	1·00	0·77	0·54, 1·11	0·82	0·58, 1·16	0·91	0·64, 1·29	0·996
Model 2†	1·00	0·79	0·55, 1·14	0·85	0·59, 1·23	0·98	0·67, 1·43	0·694
Model 3‡	1·00	0·93	0·60, 1·43	1·02	0·67, 1·55	1·16	0·75, 1·77	0·323

fgTAC, Total Antioxidant Capacity of food groups.
* Adjusted – Sex and age.
† Adjusted – Model 1 + smoking status (never, current, former), alcohol consumption (BINGE frequency) and vitamin D consumption (mcg).
‡ Adjusted – Model 2 + marital status (single/married or stable union/separated or divorced or widowedd), skin colour (white and not white), physical activity (inactive/insufficiently active/active), use of supplements (yes or no), energy intake (continuous, kcal/d), baseline BMI (continuous kg/m²), professional situation.

monitoring[52]. In the same way, two cross-sectional articles, one with climacteric women and another with sixty Iranian men, found no association between dTAC, depressive symptoms or diagnosed depression[53,54]. Contrary to our findings, three cross-sectional Iranian studies observed positive associations between dTAC and the prevalence of depressive symptoms[17–19]. In a recent systematic review, our group analysed existing studies that linked dTAC and depression, concluding that consumption of an antioxidant-rich diet characterised by high dTAC scores appears to be inversely associated with depression, anxiety and sleep disorders. However, we emphasise that there are few studies available in the literature, and most have a cross-sectional design and methodological limitations, as they were conducted with Iranian individuals and, most of them, with women[16].

Contrary to our expectations, we did not find associations between the fgTAC of the fruit and vegetables group and the incidence of depression. On the other hand, for the fgTAC of the natural juices group, the inverse association with depression remained only for the first adjustments (sex, age), not being maintained for total adjustments. A longitudinal study with Add Health Study data, which monitored 3696 17-year-old participants for 12 years, found no association between fruit and vegetables consumption and the incidence of depression either[55]. In turn, another longitudinal study with 8353 Canadians that observed inverse associations between fruit and vegetable consumption and depression being attenuated after adjusting variables such as smoking and physical activity[56]. Although the results of the consumption of fruits and vegetables are contradictory, a meta-analysis with observational studies found a reduction in the risk of depression with the increase in the consumption of fruits and vegetables[57]. It is worth mentioning that fruits and vegetables and natural juices are sources of antioxidants that modulate oxidative stress, and their consumption is related to mental health[56,57]. In addition, they are related to healthier eating patterns[45]. However, the association between the consumption of fruits and vegetables and other behavioural factors in the incidence of depression can be complex[56]. Thus, some behavioural factors such as physical activity, use of supplements, BMI and professional situation may have a more important impact on depression when compared with, fruits, vegetables and natural juices consumption.

The strengths of this study are its prospective design and the use of the quantitative FFQ previously validated for the study population, with good validity and reproducibility, ensuring good consistency in food consumption analyses[23]. In addition, we highlight that the self-report of depression was previously validated for the study population[22]. Another point is the high level of education of the participants, which can result in more reliable answers and greater adherence to the study[58]. Finally, we highlight the use of several confounding factors for our adjustments, carefully chosen after literature reviews and with the help of a directed acyclic graph[34,35].

As limitations, we highlight that although the FFQ has good reproducibility, we cannot guarantee that the baseline FRAP values represent the habitual long-term dietary intake precisely. Another point is the lack of national tables for FRAP values, requiring the use of values arranged in international tables for most calculations. Such factors may mediate the results observed here. Nor can we discard the possibility of residual confounding by some unmeasured or not precisely measured factors. We highlight the non-assessment of plasma TAC, but it is worth mentioning that plasma TAC may not be reflected in long-term diets, which limits its comparison with dTAC[14,59]. In addition, dTAC proves to be a handy tool in assessing the relationship between diet and health outcomes[14,59]. Finally, although the collection of data from the follow-up questionnaire Q_4 was carried out in the initial months of the COVID 19 pandemic, we cannot guarantee that this short period of time had an influence on the increase in medical diagnosis of depression. However, future analyses carried out with the next years of follow-up of the cohort may provide answers about the impact of the pandemic on the incidence of depression.

Conclusion

Our findings do not support an association between dTAC and the incidence of depression after an average of 2·96 (1·00) years of follow-up in a highly educated Brazilian population. However, the inverse association of fgTAC from beans and lentils and the direct association of junk food with the incidence of depression in the population indicate that not only the presence of antioxidants but also the food matrix in which these antioxidants are inserted should be considered to explain the associations between diet and health outcomes. We highlight the need for further prospective studies with different nationalities to confirm these results.

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Supplementary material

For supplementary materials referred to in this article, please visit https://doi.org/10.1017/S0007114523000181

References

1. World Health Organization (2021) Depression. https://www.who.int/news-room/fact-sheets/detail/depression (accessed April 2022).
2. Marcus M, Yasamy M, van Ommeren MV, *et al.* (2012) Depression: a Global Public Health Concern. WHO Department of Mental Health and Substance Abuse. –https://psycnet.apa.org/get-pe-doi.cfm?doi=10.1037/e517532013–004 (accessed April 2022).
3. Ng F, Berk M, Dean O, *et al.* (2008) Oxidative stress in psychiatric disorders: evidence base and therapeutic implications. *Int J Neuropsychopharmacol* **11**, 851–876. https://doi.org/10.1017/S1461145707008401
4. Visentin APV, Colombo R, Scotton E, *et al.* (2020) Targeting inflammatory-mitochondrial response in major depression: current evidence and further challenges. *Oxid Med Cell Longev* **2020**, 2972968. https://doi.org/10.1155/2020/2972968
5. Kruk J, Aboul-Enein HY, Kładna A, *et al.* (2019) Oxidative stress in biological systems and its relation with pathophysiological functions: the effect of physical activity on cellular redox homeostasis. *Free Radic Res* **53**, 497–521. https://doi.org/10.1080/10715762.2019.1612059
6. Lehtinen M & Bonni A (2006) Modeling oxidative stress in the central nervous system. *Curr Mol Med* **6**, 871–881. https://doi.org/10.2174/156652406779010786
7. Bajpai A, Verma AK, Srivastava M, *et al.* (2014) Oxidative stress and major depression. *J Clin Diagn Res* **8**, CC04–CC07. https://doi.org/10.7860/JCDR/2014/10258.5292
8. Du J, Zhu M, Bao H, *et al.* (2016) The role of nutrients in protecting mitochondrial function and neurotransmitter signaling: implications for the treatment of depression, PTSD, and suicidal behaviors. *Crit Rev Food Sci Nutr* **56**, 2560–2578. https://doi.org/10.1080/10408398.2013.876960
9. Ferriani LO, Silva DA, Molina MD, *et al.* (2022) Associations of depression and intake of antioxidants and vitamin B complex: results of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). *J Affect Disord* **297**, 259–268. https://doi.org/10.1016/j.jad.2021.10.027
10. Li Z, Wang W, Xin X, *et al.* (2018) Association of total zinc, iron, copper and selenium intakes with depression in the US adults. *J Affect Disord* **228**, 68–74. https://doi.org/10.1016/J.JAD.2017.12.004
11. Serafini M & Del Rio D (2004) Understanding the association between dietary antioxidants, redox status and disease: is the Total Antioxidant Capacity the right tool? *Redox Rep* **9**, 145–152. https://doi.org/10.1179/135100004225004814
12. Carlsen MH, Halvorsen BL, Holte K, *et al.* (2010) The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. *Nutr J* **9**, 1–11. https://doi.org/10.1186/1475–2891–9–3
13. Sabião TS, Bressan J, Pimenta AM, *et al.* (2021) Influence of dietary total antioxidant capacity on the association between smoking and hypertension in Brazilian graduates (CUME project). *Nutr Metab Cardiovasc Dis* **31**, 2628–2636. https://doi.org/10.1016/J.NUMECD.2021.05.025
14. Nascimento-Souza MA, Paiva PG, Martino HSD, *et al.* (2018) Dietary total antioxidant capacity as a tool in health outcomes in middle-aged and older adults: a systematic review. *Crit Rev Food Sci Nutr* **58**, 905–912. https://doi.org/10.1080/10408398.2016.1230089
15. Hermsdorff HHM, Puchau B, Volp ACP, *et al.* (2011) Dietary total antioxidant capacity is inversely related to central adiposity as well as to metabolic and oxidative stress markers in healthy young adults. *Nutr Metab* **8**, 1–8. https://doi.org/10.1186/1743–7075–8–59/FIGURES/2
16. Pereira GA, Da Silva A, Hermana H, *et al.* (2021) Association of dietary total antioxidant capacity with depression, anxiety, and sleep disorders: a systematic review of observational studies. *J Clin Transl Res* **7**, 631. https://doi.org/10.18053/jctres.07.202105.005
17. Abshirini M, Siassi F, Koohdani F, *et al.* (2019) Dietary total antioxidant capacity is inversely associated with depression, anxiety and some oxidative stress biomarkers in postmenopausal women: a cross-sectional study. *Ann Gen Psychiatry* **18**, 1–9. https://doi.org/10.1186/S12991–019–0225–7
18. Daneshzad E, Keshavarz SA, Qorbani M, *et al.* (2020) Dietary total antioxidant capacity and its association with sleep, stress, anxiety, and depression score: a cross-sectional study among diabetic women. *Clin Nutr ESPEN* **37**, 187–194. https://doi.org/10.1016/J.CLNESP.2020.03.002
19. Milajerdi A, Keshteli AH, Afshar H, *et al.* (2019) Dietary total antioxidant capacity in relation to depression and anxiety in

Iranian adults. *Nutrition* **65**, 85–90. https://doi.org/10.1016/J.NUT.2018.11.017
20. Domingos ALG, Da Silva Miranda AE, Pimenta AM, *et al.* (2018) Cohort profile: the Cohort of Universities of Minas Gerais (CUME). *Int J Epidemiol* **47**, 1743–1744h. https://doi.org/10.1093/IJE/DYY152
21. Schmidt MI, Duncan BB, Mill JG, *et al.* (2015) Cohort profile: longitudinal study of adult health (ELSA-Brasil). *Int J Epidemiol* **44**, 68–75. https://doi.org/10.1093/IJE/DYU027
22. Santos BF, Oliveira HN, Miranda AES, *et al.* (2021) Research quality assessment: reliability and validation of the self-reported diagnosis of depression for participants of the Cohort of Universities of Minas Gerais (CUME project). *J Affect Disord Rep* **6**, 100238. https://doi.org/10.1016/J.JADR.2021.100238
23. Azarias HG, Marques-Rocha JL, Miranda AE, *et al.* (2021) Online food frequency questionnaire from the cohort of Universities of Minas Gerais (CUME Project, Brazil): construction, validity, and reproducibility. *Front Nutr* **8**, 649. https://doi.org/10.3389/FNUT.2021.709915
24. Instituto Brasileiro de Geografia e Estatística-IBGE (2011) Table of Nutritional Composition of Food Consumed in Brazil. Rio de Janeiro, Brazil. https://biblioteca.ibge.gov.br/visualizacao/livros/liv50002.pdf?gathStatIcon=true (accessed April 2022).
25. Universidade Estadual de Campinas - UNICAMP (2011) TACO project (Brazilian Table of Food Composition), 4th ed. NEPA- UNICAMP, Campinas-SP. https://www.cfn.org.br/wp-content/uploads/2017/03/taco_4_edicao_ampliada_e_revisada.pdf (accessed April 2022).
26. Gebhardt SE & Thomas RG (2002) *Nutritive Value of Foods*. US Government Printing Office: Department of Agriculture, Agricultural Research Service.
27. Koehnlein EA, Bracht A, Nishida VS, *et al.* (2014) Total antioxidant capacity and phenolic content of the Brazilian diet: a real scenario. *Int J Food Sci Nutr* **65**, 293–298. https://doi.org/10.3109/09637486.2013.879285
28. Willett W (1998) *Nutritional Epidemiology*, 2nd ed. New York: Oxford University Press.
29. National Institute on Alcohol Abuse and Alcoholism (2022) Drinking Levels Defined. https://www.niaaa.nih.gov/alcohol-health/overview-alcohol-consumption/moderate-binge-drinking (accessed April 2022).
30. World Health Organization (2010) Global Recommendations on Physical Activity for Health. https://www.who.int/publications/i/item/9789241599979 (accessed April 2022).
31. World Health Organization/WHO. (1998) Obesity: Preventing and Managing the Global Epidemic. WHO Technical Report Series 894, Geneva. https://www.who.int/publications/i/item/9789241599979 (accessed April 2022).
32. Organización Panamericana de La Salud XXXVI (2001) Meeting of the Health Research Advisory Committee – Multicentric Survey – Wellbeing and Aging Health (SABE) in Latin America and the Caribbean – Preliminary report.http://www.opas.org/program/sabe.htm (accessed April 2022).
33. Miranda AD, Ferreira AV, Oliveira FD, *et al.* (2017) Validation of metabolic syndrome and its self reported components in the CUME study. *REME Rev Min Enferm* **21**, e1069. –https://doi.org/10.5935/1415–2762.20170079
34. Textor J & Hardt J (2011) DAGitty: a graphical tool for analyzing causal diagrams. *Epidemiol* **22**, 745. https://doi.org/10.1097/EDE.0B013E318225C2BE
35. Greenland S, Pearl J & Robins JM (1999) Causal diagrams for epidemiologic research. *Epidemiol* **10**, 37–48. https://doi.org/10.1097/00001648–199901000–00008
36. Hermsdorff HHM, Zulet MÁ, Puchau B, *et al.* (2010) Fruit and vegetable consumption and proinflammatory gene expression from peripheral blood mononuclear cells in young adults: a translational study. *Nutr Metab* **7**, 1–11. https://doi.org/10.1186/1743–7075–7–42/TABLES/5
37. Sousa KT, Marques ES, Levy RB, *et al.* (2019) Food consumption and depression among Brazilian adults: results from the Brazilian National Health Survey, 2013. *Cad Saude Publica* **36**, 00245818. https://doi.org/10.1590/0102–311X00245818
38. Paskulin JTA, Drehmer M, Olinto MT, *et al.* (2017) Association between dietary patterns and mental disorders in pregnant women in Southern Brazil. *Rev Bras Psiquiatr* **39**, 208–215.
39. Silva AG, Rocha SG & Brazaca C (2009) Physico-chemical characterization, protein digestibility and antioxidant activity of commun bean (Phaseolus vulgaris L.). *Braz J Food Nutr* **20**, 591–589.
40. Velásquez-Meléndez G, Mendes LL, Pessoa MC, *et al.* (2012) Trends in frequency of consumption of beans assessed by means of a telephone survey in Brazilian state capitals between 2006 and 2009. *Cien Saude Colet* **17**, 3363–3370. –https://doi.org/10.1590/S1413–81232012001200021
41. Pereira GA, Bressan J, Oliveira FLP, *et al.* (2019) Dietary folate intake is negatively associated with excess body weight in Brazilian graduates and postgraduates (CUME Project). *Nutrients* **11**, 518. https://doi.org/10.3390/NU11030518
42. Miyaki K, Song Y, Htun NC, *et al.* (2012) Folate intake and depressive symptoms in Japanese workers considering SES and job stress factors: J-HOPE study. *BMC Psychiatry* **12**, 1–8. https://doi.org/10.1186/1471–244X-12–33
43. Murakami K, Miyake Y, Sasaki S, *et al.* (2010) Dietary folate, riboflavin, vitamin B-6, and vitamin B-12 and depressive symptoms in early adolescence: the Ryukyus Child Health Study. *Psychosom Med* **72**, 763–768. https://doi.org/10.1097/PSY.0B013E3181F02F15
44. Rodrigues AGM, da Costa Proença RP, Calvo, MC, *et al.* (2013) Profile of the rice and beans food option when eating away from home at a buffet-by-weight restaurant. *Cien Saude Colet* **18**, 335–346. https://doi.org/10.1590/s1413-81232013000200005
45. Silveira BKS, de Novaes JF, Vieira SA, *et al.* (2019) Sociodemographic characteristics and dietary patterns in cardiometabolic risk subjects. *Br Food J* **121**, 2780–2790. https://doi.org/10.1108/BFJ-04–2019–0259
46. Adjibade M, Julia C, Allès B, *et al.* (2019) Prospective association between ultra-processed food consumption and incident depressive symptoms in the French NutriNet-Santé cohort. *BMC Med* **17**, 1–13. https://doi.org/10.1186/S12916–019–1312-Y
47. Lobo AS & Tramonte VL (2004) Effects of supplementation and food fortification on mineral bioavailability. *Rev Nutr* **17**, 107–113. https://doi.org/10.1590/S1415–52732004000100012
48. Juul F, Vaidean G & Parekh N (2021) Ultra-processed foods and cardiovascular diseases: potential mechanisms of action. *Adv Nutr* **12**, 1673–1680. https://doi.org/10.1093/ADVANCES/NMAB049
49. Contreras-Rodriguez O, Solanas M & Escorihuela RM (2022) Dissecting ultra-processed foods and drinks: do they have a potential to impact the brain? *Rev Endocr Metab Disord* **23**, 697–717. https://doi.org/10.1007/S11154–022–09711–2
50. Louzada ML, Martins AP, Canella DS, *et al.* (2015) Impacto de alimentos ultraprocessados sobre o teor de micronutrientes da dieta no Brasil. *Rev Saude Publica* **49**, 45. –https://doi.org/10.1590/S0034–8910.2015049006211
51. Wang J, Um P, Dickerman BA, *et al.* (2018) Zinc, magnesium, selenium and depression: a review of the evidence, potential

mechanisms and implications. *Nutrients* **10**, 584. https://doi.org/10.3390/nu10050584
52. Miki T, Eguchi M, Kochi T, *et al.* (2020) Prospective study on the association between dietary non-enzymatic antioxidant capacity and depressive symptoms. *Clin Nutr ESPEN* **36**, 91–98. https://doi.org/10.1016/J.CLNESP.2020.01.010
53. De Oliveira NG, Teixeira IT, Theodoro H, *et al.* (2019) Dietary total antioxidant capacity as a preventive factor against depression in climacteric women. *Dement Neuropsychol* **13**, 305–311. https://doi.org/10.1590/1980–57642018dn13–030007
54. Prohan M, Amani R, Nematpour S, *et al.* (2014) Total antioxidant capacity of diet and serum, dietary antioxidant vitamins intake, and serum hs-CRP levels in relation to depression scales in university male students. *Redox Rep* **19**, 133–139. https://doi.org/10.1179/1351000214Y.0000000085
55. Hoare E, Hockey M, Ruusunen A, *et al.* (2018) Does Fruit and vegetable consumption during adolescence predict adult depression? A longitudinal study of US adolescents. *Front Psychiatry* **9**, 581. https://doi.org/10.3389/FPSYT.2018.00581
56. Kingsbury M, Dupuis G, Jacka F, *et al.* (2016) Associations between fruit and vegetable consumption and depressive symptoms: evidence from a national Canadian longitudinal survey. *J Epidemiol Community Health* **70**, 155–161. https://doi.org/10.1136/JECH-2015–205858
57. Opie RS, Itsiopoulos C, Parletta N, *et al.* (2017) Dietary recommendations for the prevention of depression. *Nutr Neurosci* **20**, 161–171. https://doi.org/10.1179/1476830515Y.0000000043
58. Seguí-Gómez M, de la Fuente C, Vázquez Z, *et al.* (2006) Cohort profile: the 'Seguimiento Universidad de Navarra' (SUN) study. *Int J Epidemiol* **35**, 1417–1422. https://doi.org/10.1093/IJE/DYL223
59. Pellegrini N, Vitaglione P, Granato D, *et al.* (2018) Twenty-five years of total antioxidant capacity measurement of foods and biological fluids: merits and limitations *J Sci Food Agric* **100**, 5064–5078. https://doi.org/10.1002/jsfa.9550

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