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Adherence to mediterranean diet and aromatic plants intake are related with gustatory function: A case-study from a Portuguese region

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A R T I C L E I N F O

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A B S T R A C T

The Mediterranean Diet has been recognized as one of the healthiest and most sustainable dietary patterns and is flavor rich due to the use of different seasonings, such as aromatic plants, in dish confection. Based on the hypotheses that: 1) gustatory function will affect food choices; 2) seasoning flavors may be differently accepted according to individuals' gustatory functions; the aim of the present study was to assess the association between taste sensitivity and/or preference with Mediterranean Diet adherence and seasoning consumption. A total of 383 adults (18–59 years old; 198 female, 185 male) from North Alentejo region of Portugal were enrolled in this study, with 291 (145 female and 146 male) also evaluated for gustatory function. Recognition thresholds were obtained for four tastes (sweet, sour, salty, and bitter) and astringency, as well as preference level for the highest concentration of each stimulus tested. A validated Food Frequency Questionnaire was filled out, and MD adherence was extrapolated from the answers of the Food Frequency Questionnaire according to the Mediterranean Diet Adherence Screener (MEDAS) score.

In total, 20.8% of the individuals presented low, 58.2% medium, and 21.0% high adherence. Adherence was higher in women than men and in older individuals than younger adults. Adherence to the Mediterranean Diet was positively correlated with aromatic plants consumption but not spices. Seasonings were associated with gustatory function, and the cluster with higher consumption presented higher preferences for bitter and salty tastes. Total sodium intake was also higher in this cluster, suggesting that these individuals prefer stronger oral sensations. In conclusion, this study shows that MD adherence is not high, even in regions with rural characteristics. The observed association of MD and seasoning intake with gustatory function do underline the usefulness of this information in strategies aimed at promoting healthy and sustainable eating patterns.

1. Introduction

The Mediterranean Diet (MD) is recognized as one of the healthiest dietary patterns in the world (Dinu, Pagliai, Casini, & Sofi, 2018). MD is characterized by high consumption of foods from vegetable origin, such as fruits, vegetables, legumes, nuts, and cereals; the use of olive oil as the main fat source; a moderate intake of fish (higher or lower dependent on geographic position); moderate intake of dairy products, and a low intake of sweets; red and processed meat, and saturated lipids (Davis, Bryan, Hodgson, & Murphy, 2015; Kiani et al., 2022). Alcohol is included in this dietary pattern, but only wine, at low-moderate levels at main meals (Santos-Buelga, González-Manzano, & González-Paramás, 2021). Different tools have been proposed to assess MD adherence. The Mediterranean Diet Adherence Screener (MEDAS) is a tool developed in Spain for the PREDIMED project (Martínez-González et al., 2012) and is based only on food patterns (relative amounts of food groups eaten), ranging from 0 to 14 points, according to the accomplishment of each item concerning food groups daily portions and/or proportion.

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However, despite all the existing evidence about the benefits of MD, adherence to this food pattern is decreasing in Mediterranean countries, particularly in the younger generation that has dietary patterns with higher levels of energy, rich in saturated fats, and low in micronutrients (Mattavelli et al., 2022). For Portugal, this tendency is also true, and data from the Portuguese Directorate General of Health from 2020 shows that less than ¼ of the adult Portuguese population has high adherence to MD (Gregório, Sousa, Chkoniya, & Graça, 2020). This document reported that, among different factors, the taste of foods like vegetables and legumes is perceived by consumer as a barrier to higher intake. This reinforces the need to go deeper into the knowledge about how sensory aspects and individual perception can affect MD acceptance.

One of the usually reported characteristics of MD is its richness in flavour, brought about by the use of aromatic herbs and spices. Its use is even pointed out as one health advantage, for making foods more palatable, reducing the use of salt (Dougkas, Vannereux, & Giboreau, 2019), and for its antioxidant content (Yashin, Yashin, Xia, & Nemzer, 2017). Some of the most well-known aromatic plants used in Mediterranean diets are oregano (*Origanum vulgare L.*), thyme (*Thymus vulgaris L.*), sage (*Salvia officinalis L.*), rosemary (*Rosmarinus officinalis L.*), coriander (*Coriandrum sativum*), mints (genus Mentha) (Delgado, Gonçalves, & Romano, 2023), and other seasonings considerably used, namely cinnamon (genus Cinnamomum), different types of pepper (*Piper nigrum* and *Capsicum annuum*), garlic (*Allium sativum*), among others, although some of these have been introduced lately in Mediterranean countries.

Spices and culinary herbs are used to increase colors, aromas, and textures that are associated with Mediterranean cuisine, and this is mainly due to the phenolic compounds they contain (Delgado et al., 2023). Polyphenolic compounds are recognized for their positive health effects, including antioxidant and anti-inflammatory properties. In addition to these important aspects, they also have sensory attributes, like sourness, bitterness, or even astringency, that can also affect the aroma of the vegetable product that contain those compounds.

The MD is a vegetable-based food pattern that, although including foods from animal origin, gets the higher proportion of nutrients and energy from products of vegetable origin which are sensory challenging. For example, products with high content of legume protein were reported to have increased unpleasant taste and/or oral sensations, such as bitter, and astringency (Saint-Eve, Granda, Legay, Cuvelier, & Delarue, 2019). Furthermore, it was recently reviewed that flavour, which considers taste, aroma, and trigeminal sensations, is one of the main barriers in the acceptance of foods of plant origin (Laureati et al., 2024). Whereas vegetable products acceptance (and intake) has been observed to be associated with taste sensitivity (Agovi et al., 2022; De Toffoli et al., 2019; Louro et al., 2021), less is known for plants used as seasonings.

The objective of the present study was to evaluate the relationship between MD adherence and seasonings intake in a Portuguese population, as well as to investigate if sensory sensitivity (taste and astringency) is linked to either adherence to MD or preference and intake of seasonings.

2. Material and methods

2.1. Participants

The number of participants was calculated to allow a representative sample of the Portuguese region evaluated (North Alentejo region, Portugal), based on Census of this region of Portugal reported in the Official National Database Contemporary Portugal (PORDATA; https://www.pordata.pt/Home; accessed on March 15, 2016). Based on that calculation, a convenience sample of 400 participants, with ages between 20 and 59 years old, was considered, with a final number of 383 participants (198 female and 185 male). Participants were randomly recruited from all the municipalities of the referred region (Portalegre district) in order to be representative of the region. On the data collection day, participants were asked to arrive at the test room between 10:00 a.m. and 11:00 a.m., at least 90 min after breakfast intake. Before the beginning of the study, written informed consent was obtained from all participants. Data was collected between 2017 and 2018.

The study was conducted according to the guidelines of the Declaration of Helsinki. Ethical review and approval were waived for this study (GD/50418/2017), due to the non-invasive nature of the same and the existence of an informed consent statement. Written informed consent was obtained from all subjects involved in the study.

2.2. Anthropometric data collection

Height and weight were measured according to the European Health Examination Survey procedures. The participants were in a standing position, wearing light cloths and barefoot. A portable stadiometer (Seca 214) and a digital scale accurate to the nearest 0.1 kg (Seca 803) were used to access height and weight, respectively. The body mass index (BMI) was calculated by dividing the weight (kg) by the square of the height (m^2). Normal weight, overweight, and obesity were considered for the values: BMI<25, 25 < BMI<30 and BMI>30, respectively.

2.3. Mediterranean diet adherence and seasonings consumption

Participants were evaluated about their adherence to the Mediterranean Diet (MD) by converting their dietary intake, accessed through a self-administered, semi-quantitative Food Frequency Questionnaire (FFQ), validated for Portuguese adults (86 food items) (Lopes, Aro, Azevedo, Ramos, & Barros, 2007). Before questionnaire completion, participants were instructed about how questionnaires should be filled out. Data was extracted using an adapted Portuguese version of the nutritional analysis software Food Processor Plus (ESHA Research Inc., Salem, OR, USA). Further, the results from frequency of intake were converted into an MD adherence score using Mediterranean Diet Adherence Screener (MEDAS) questionnaire, which was proposed by the PREDIMED study (Martínez-González et al., 2012). The MEDAS is a 14-item questionnaire where participants are requested to report their habitual frequency of consumption or amount consumed of 12 foods characteristics of MD and two cooking habits related to MD. Each of these items is scored 1 or 0, depending on their positive relation to a MD pattern. The scores were obtained by calculating them from the FFQ considering the criteria previously used in the Portuguese population (Gregório, Rodrigues, et al., 2020). For categorization of the adherence to MD, we applied the following criteria: weak adherence, ≤5; moderate to fair adherence, 6–9; good or very good adherence, ≥10 (Martínez-González et al., 2012). Considering that the use of seasonings may mask the absence of sodium (Taladrid, Laguna, Bartolomé, & Moreno-Arribas, 2020), FFQ was also used to estimate sodium intake from the listed food groups.

In addition to the FFQ, a subsample of 287 participants responded to a questionnaire about aromatic herbs and spices' intake. An adapted questionnaire was used, with frequency options, for a period of 1 year, similar to the Food Frequency Questionnaire (FFQ). The list of 45 aromatic herbs and spices included considered all the seasonings traditionally used in the cuisine of the studied region, previously compiled and documented by the local association dedicated to regional gastronomy.

2.4. Taste sensitivity assessment

Taste perception was evaluated using filter paper taste strips (laboratory-made), as previously described and validated for the Portuguese population (Ribeiro et al., 2016). Taste strips (2 cm in diameter of the disc contacting the tongue) were prepared using 4 concentrations of each basic taste in distilled water (bitter 0.0004, 0.0009, 0.0024, 0.0060 g/mL quinine hydrochloride; sweet 0.05, 0.10, 0.20, 0.40 g/mL sucrose; salty 0.016, 0.040, 0.100, 0.250 g/mL NaCl; and sour 0.050, 0.090, 0.165, 0.300 g/mL citric acid). The filter papers were soaked in the solutions, and oven-dried at 60 °C. Control taste strips were prepared by soaking filter paper in distilled water without tastants. Taste detection thresholds, suprathresholds, and hedonics (preference) were evaluated by requiring participants to answer three types of questions: 1) if he/she perceived any taste different from the control taste strip (made using distilled water), for each of the taste strips (yes/no response); for each of the stimulus, taste threshold detection was considered the smallest concentration that individuals were able to perceive as different from control strip; a threshold level was only considered valid if it was followed by another consonant response (i.e., two consecutive detections). 2) for the highest concentration of each stimulus, an intensity judgment on a Labeled Magnitude Scale (LMS) (ranging from "barely detectable" to "strongest imaginable sensation") was provided as previously described (Green et al., 1996). 3) for the highest concentration of each stimulus, the preference level on a 5-point scale (being 1 "hated" and 5 "highly preferred") was also provided; in this case a 5-point scale was chosen to differentiate from the LMS of the suprathresholds, to avoid confusion by participants. The sensory evaluation was performed in a quiet room, guaranteeing all the participants rameined calm and concentrated on the tasks requested.

2.5. Statistical analysis

Statistical analysis was performed using SPSS 28.0 software, considering an alpha level of 5%. Normality and homoscedasticity were tested through the Shapiro–Wilk and Levene tests, respectively.

To compare groups of MD adherence concerning categorical variables, such as sex and BMI groups, the Chi-square test was used. For continuous variables, such as age, ANOVA was run with Tukey post-hoc.

Linear regression analysis was run to assess how taste sensitivity (detection thresholds) and/or taste preferences contribute to predicting the MD score. A stepwise backward procedure was used to obtain the final model after looking for changes in adjusted R2 and F values for each retained variable; the assumptions of collinearity (VIF and tolerance), non-dependent errors (Dur-Bin–Watson), and homoscedasticity (residual analysis) were also considered.

Principal component analysis (PCA) was used to estimate the number of components emerging from seasoning consumption. First, the correlation matrix of the standardized variables was examined, and the number of components to retain was based on eigenvalues, total explained variance, and Scree plot examination. The Varimax rotation was chosen, and the overall Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity were examined as assumptions of the test. Further, hierarchical cluster analysis using the farthest neighbour method for calculating distances between clusters was performed to obtain the dendrogram and analyse the range of clusters for further running the K-means method (Marquezin et al., 2019). Cluster analysis aimed at identifying groups of participants with similar age, sex, BMI, seasoning intake, sodium intake, and taste parameters. The analysis included the following variables: age, sex, BMI, the six component loadings generated from principal component analysis, sodium intake, and sweet, acid, bitter, and salt intensity and preference. The final number of clusters was based on the interpretability and reliability of the cluster solution; the silhouette coefficient and the differences between clusters assessed by the F-test were used for clustering validation.

3. Results

3.1. Association between age, sex, BMI, and MD adherence

Considering the total number of participants, 21.0% presented a high adherence to MD, 58.2% a mean, and 20.8% a low adherence to this dietary pattern.

Comparing the age of participants from the 3 groups of MD adherence, a lower mean age was observed for the participants in low-adherence group compared to the high-adherence group (Table 1). Moreover, MD adherence also differed between sexes, with a higher proportion of women showing higher adherence than men (Table 1).

Concerning BMI, in this study, 38.6% of participants presented a normal weight, whereas 35.7% were overweight and 25.5% were obese (0.2% underweight). Normal-weight adults present lower mean ages than overweight or obesity classifications [37.8 ± 10.5, 42.8 ± 10.8, and 43.4 ± 11.1 years old, respectively (mean ± standard deviation)]. In terms of BMI, no differences were observed among MD adherence groups (Table 1).

Considering the differences among ages and between sexes in MD adherence according to the MEDAS score, a deeper analysis was performed to ascertain how each of the 14 MEDAS items differed between subgroups. Descriptive statistics of the 14 MEDAS items according to the age ranges (18–34, 35–49, and 50–59 years) and sexes (men and women) are presented in Table 2. Although no differences were observed among age groups, a tendency for higher percentage of individuals with low adherence was observed in the youngest group.

Looking at each of the MEDAS items, it is of note that young adults have lower frequencies of olive oil intake, with a lower proportion of individuals using it as the main source of fat compared to older adults. This age group (18–34 years old) also presented a higher proportion of individuals with high consumption of sugar-sweetened beverages. Older adults also have a higher proportion of individuals meeting fresh fruit requirements, although the consumption of wine, at levels higher than those considered "moderate", is also higher in this age group.

Concerning sex, the differences in the items considered to classify MD adherence are mainly for red meat consumption, with a greater proportion of men consuming quantities above recommendations and consuming even more red meat than white meat. Moreover, a higher proportion of men consume high amounts of wine, sugar-sweetened beverages, and pastry.

3.2. MD adherence relationship with taste sensitivity and taste hedonics

The significant associations between sweet taste sensitivity, age, and MEDAS score are presented in Table 3. An association between sweet taste sensitivity and MD adherence score was observed. A higher MEDAS score tends to be found (6.7% of explanation), in older women with higher sweet taste sensitivity. Concerning taste (or astringency) preferences, no statistically significant association was observed.

3.3. Seasoning intake and relationship with taste sensitivity and taste hedonics

The MEDAS score was observed to be significantly and positively correlated with aromatic plant consumption but not with spices. Apart

Table 1
Demographics of the study sample according to Mediterranean Diet adherence.

		Mediterranean Diet adherence groups			p-value
		Low (N = 80)	Medium (N = 223)	High (N = 60)	
Proportion of participants (%)		20.8	58.2	21.0	
Age (mean±standard deviation)		38.2 ±11.2[a]	41.2±10.8[a,b]	43.8 ±11.1[b]	0.007[a]
Sex (%)	Women	16.3	55.3	28.4	0.002[b]
	Men	24.7	61.5	13.8	
BMI group (%)	Normal weight	25.0	57.5	17.5	0.214[b]
	Overweight	18.9	54.1	27.0	
	obesity	21.3	63.8	15.0	

[a] One-way ANOVA.
[b] Pearson chi-square. Different uppercase letters mean statistically significant differences between columns.

Table 2
Detailed results of Mediterranean Diet Adherence Screener (MEDAS) individual items, according to age and sex.

MEDAS items	Meet criteria	Age classes			p-value	Sex		p-value
		18–34	35–49	50–65		Women	Men	
Olive oil consumed in higher proportion than other vegetable oils, margarine, and butter	Yes	70 (61.9%)	118 (77.1%)	82 (79.6%)	0.012*	142 (74.7%)	125 (71.8%)	0.532
	No	43 (38.1%)	35 (22.9%)	21 (20.4%)		48 (25.3%)	49 (28.2%)	
Quantity of olive oil consumed >54 g per day	Yes	52 (46.0%)	82 (53.6%)	68 (66.0%)	0.018*	112 (58.9%)	89 (51.1%)	0.135
	No	61 (54.0%)	71 (46.4%)	35 (34.0%)		78 (41.1%)	85 (48.9%)	
Mean frequency of consumption of total vegetables ≥2–3 portions per day	Yes	19 (16.8%)	26 (17.0%)	18 (17.5%)	0.974	38 (20.0%)	24 (13.8%)	0.116
	No	94 (83.2%)	127 (83.0%)	85 (82.5%)		152 (80.0%)	150 (86.2%)	
Mean frequency of consumption of total fresh fruit ≥2–3 portions per day	Yes	39 (34.5%)	57 (37.3%)	52 (51.0%)	0.029*	87 (46.0%)	63 (36.2%)	0.058
	No	74 (65.5%)	96 (62.7%)	50 (49.0%)		102 (54.0%)	111 (63.8%)	
Quantity of beef, veal, pork, lamb, and hamburgers <100 g	Yes	87 (77.0%)	125 (81.2%)	80 (77.7%)	0.664	166 (87.4%)	120 (69.0%)	<0.001*
	No	26 (23.0%)	29 (18.8%)	23 (22.3%)		24 (12.6%)	54 (31.0%)	
Quantity of butter and margarine consumed <12 g per day	Yes	92 (81.4%)	130 (84.4%)	91 (88.3%)	0.369	159 (83.7%)	151 (86.8%)	0.406
	No	21 (18.6%)	24 (15.6%)	12 (11.7%)		31 (16.3%)	23 (13.2%)	
Mean frequency of sugar-sweetened beverages <1 portion per day	Yes	76 (67.3%)	121 (78.6%)	88 (85.4%)	0.005*	163 (85.8%)	121 (69.5%)	<0.001*
	No	37 (32.7%)	33 (21.4%)	15 (14.6%)		27 (14.2%)	53 (30.5%)	
Frequency of wine consumption≥1 portion per day	Yes	2 (1.8%)	25 (16.2%)	28 (27.2%)	<0.001*	13 (6.8%)	41 (23.6%)	<0.001*
	No	111 (98.2%)	129 (83.8%)	75 (72.8%)		177 (93.2%)	133 (73.4%)	
Frequency of pulses consumption ≥3–4 portions per week	Yes	27 (23.9%)	39 (25.3%)	35 (34.0%)	0.194	39 (20.5%)	61 (35.1%)	0.002*
	No	86 (76.1%)	115 (74.7%)	68 (66.0%)		151 (79.5%)	113 (64.9%)	
Mean frequency of consumption of all fish and seafood items of FFQ ≥2–3 portions per day	Yes	68 (60.2%)	96 (62.3%)	69 (67.0%)	0.572	126 (66.3%)	105 (60.3%)	0.237
	No	45 (39.8%)	58 (37.7%)	34 (33.0%)		64 (33.7%)	69 (39.7%)	
Mean frequency of all pastry items of FFQ ≥2–3 portions per day	Yes	83 (73.5%)	118 (76.6%)	82 (79.6%)	0.566	158 (83.2%)	121 (69.5%)	0.002*
	No	30 (26.5%)	36 (23.4%)	21 (20.4%)		32 (16.8%)	53 (30.5%)	
Frequency of consumption of all nuts of FFQ ≥2–3 portions per week	Yes	55 (49.1%)	69 (45.1%)	46 (45.5%)	0.793	90 (47.9%)	82 (47.4%)	0.928
	No	57 (50.9%)	84 (54.9%)	55 (54.5%)		98 (52.1%)	91 (52.6%)	
Quantity of white meat consumed in grams per day (poultry, chicken, rabbit) higher than the quantity of red meat (beef, veal, pork, lamb, processed meat)	Yes	62 (54.9%)	71 (46.1%)	43 (41.7%)	0.139	122 (64.2%)	55 (31.6%)	<0.001*
	No	51 (45.1%)	83 (53.9%)	60 (58.3%)		68 (35.8%)	119 (68.4%)	
Frequency of consumption of tomato, onion, and olive oil ≥2 week	Yes	43 (38.7%)	58 (37.7%)	42 (40.8%)	0.881	71 (37.4%)	66 (38.4%)	0.844
	No	68 (61.3%)	96 (62.3%)	61 (59.2%)		119 (62.6%)	106 (61.6%)	

from aromatic plants, the only seasoning showing a significant correlation with the MD adherence score was garlic. Nevertheless, the correlations were weak, being moderated only for coriander (Table 4).

PCA with Varimax rotation was run to identify seasoning consumption patterns within the study population. The suitability of PCA was assessed prior to analysis; the overall Kaiser-Meyer-Olkin (KMO) measure was 0.73, and the Bartlett's test of sphericity was statistically significant ($p < 0.001$), indicating that the data was likely factorable.

After Varimax rotation of the factors, PCA revealed six components that explained 60% of the total variance, as confirmed by visual inspection of the scree plot below (Supplementary Fig 1), which were retained and detailed in Table 5. For interpretation purposes, it can be assumed that for Component 1: the higher the component, the higher the consumption of spicy seasonings, such as chilli, powder white, black and rose pepper, and dry oregano; for Component 2: the higher the component, the higher the consumption of fresh pepper, green pepper, and red pepper. Component 3: higher consumption of garlic, cinnamon, coriander, sweet pepper, mint, bay leaf, parsley, and thyme; Component 4: pennyroyal and thyme; Component 5: powdered garlic and pink pepper intake; Component 6: lower intake of rosemary but higher intake of sweet pepper, bay leaf, and flower pepper.

Further, K-means analysis included the following variables: age, sex, BMI, the six component loadings generated from principal component analysis, sodium intake, and sweet, acid, bitter, and salt intensities and

Table 3
Linear multiple regression models[1] between sensory function (detection thresholds and preferences) and Mediterranean Diet adherence.

Dependent variable	Independent variable	Standardized Coeff (ß)	CI (95%)	t	P value	F	R2 adj	Durbin-Watson
MEDAS score	constant		4.205 to 8.494	5.833	<0.001*	3.844	0.067	1.872
	Age	0.179	0.011 to 0.064	2.769	0.006*			
	Sex	0.146	0.090 to 1.276	2.271	0.024*			
	BMI	−0.013	−0.056 to 0.046	−0.196	0.845			
	Threshold Sweet	−0.169	−3.979 to −0.448	−2.471	0.014*			
	Threshold Salty	0.070	−1.317 to 4.108	1.014	0.312			
	Threshold Astringency	−0.116	−2.263 to 0.090	−1.820	0.070			
MEDAS score	Constant		4.071 to 8.448	5.651	<0.001*	3.014	0.048	1.943
	Age	0.200	0.008 to 0.072	2.478	0.014*			
	Sex	0.608	−0.058 to 1.275	1.804	0.073			
	BMI	−0.034	−0.091 to 0.024	−1.162	0.247			
	Bitter preference	−0.350	−0.927 to 0.226	−1.200	0.232			

[1]All the models were adjusted for age, sex, and body mass index (BMI).
MEDAS, Mediterranean Diet Adherence Screener.

Table 4
Correlation between the MEDAS score and consumption of aromatic plants (A) and spices (B).

A

		Fresh Rosemary	Coriander	Mint	Bay	Oregano	Fresh pepper	Pennyroyal	Parsley	Thyme
MD Score	Pearson rho	−0.041	0.353[a]	0.166[a]	0.149*	0.158*	0.042	0.186[a]	0.222[a]	0.225[a]
	p-value	0.511	0.000	0.007	0.015	0.010	0.506	0.003	0.000	0.000
	N	264	265	264	263	261	258	258	261	262

B

		Garlic	Cinammon	Sweet pepper	Chilli	White pepper	Black Pepper	Pink pepper
MD Score	rho	0.226[a]	0.026	−0.105	0.011	−0.030	0.035	0.054
	p-value	0.000	0.676	0.088	0.856	0.626	0.567	0.378
	N	263	267	265	265	263	265	265

MD, Mediterranean Diet.
[a] Statistically significant at 0.001.

Table 5
Component loadings of seasoning consumption patterns obtained by principal component analysis with Varimax rotation.

	Component					
	1	2	3	4	5	6
Explained variance (%)	*23*	*33*	*41*	*48*	*54*	*60*
Rosemary		0.303			0.310	−0.415
Powder garlic					0.785	
Garlic			0.639			0.311
Cinnamon			0.493			
Coriander			0.731			
Sweet Pepper			0.403			0.557
Mint			0.528			
Bay leaf			0.465			0.385
Chilli	0.630					
Dry oregano	0.632					
White Pepper	0.812					
Black Pepper	0.824					
Pink Pepper	0.476				0.655	
Fresh Pepper		0.689				
Flower Pepper						0.664
Green Pepper		0.914				
Red Pepper		0.887				
Fresh Pennyroyal				0.773		
Dry Pennyroyal				0.864		
Parsley	0.374	0.374	0.383			
Thyme			0.411	0.482		

Coefficients less than 0.3 are omitted.

preferences to generate three clusters, as suggested by the dendrogram (Supplementary Fig 2). In this case, sodium intake was obtained from FFQ data and was included in the model due to its participation in flavoring foods as seasoning, sometimes replaced by aromatic plants and spices. The analysis identified three reliable clusters (Table 6), with an average silhouette coefficient of 0.53. The histogram indicates that there is a good structure to the clusters, with most observations having positive coefficients (Supplementary Fig 3).

Clusters varied according to sodium intake, Component 1, 3, and 6 scores, sweet, bitter, and salty preference, and bitter and salty suprathresholds. Table 6 shows the taxonomy description of the three clusters: Cluster 1 (named "low seasonings intake"; n = 132) was characterized by the lower intake of sodium, chilli, dry oregano, and powder white, black, and pink pepper (Component 1), garlic, cinnamon, coriander, paprika, mint, bay leaf, parsley, and thyme (Component 3), paprika, bay leaf, and pepper flower (Component 6); at the same time, the participants in Cluster 1 also showed lower preferences for bitter and salt tastes.

Cluster 2 (named 'high seasonings intake'; n = 41) was characterized by the opposite profile, that is, the highest intake of sodium and seasonings grouped in Components 1, 3, and 6. The participants showed higher preferences for sweet, bitter, and salt tastes and lower intensities for bitter and salt tastes.

Finally, Cluster 3 (named 'higher bitter and salt intensities'; n = 114) was characterized by higher bitter and salty sensitivities, moderate total sodium intake, and low intake of seasonings.

4. Discussion

The results obtained showed that a reduced proportion of adults have high adherence to MD. The percentage of individuals with high adherence (21%) was even lower than the one reported for the whole Portuguese population in 2020, which was 26% (Gregório, Sousa, et al., 2020). It was interesting to observe that the mean age of participants with high adherence is significantly higher than the one of participants with low adherence, suggesting that young adults have higher deviations from traditional MD food patterns than older adults, which was

Table 6
Final cluster centers (means) of seasonings and gustatory variables (important differences that identify the clusters are colored).

	Cluster 1 Low seasonings intake	Cluster 2 High seasonings intake	Cluster 3 High sensitivity to salty and bitter	F test
Number of cases	132	41	114	
Sodium intake (from FFQ)	**1578.44**	**4221.03**	2638.62	533.1
Component 1 scores	**-0.16**	**0.43**	-0.06	6.3
Component 2 scores	-0.08	0.08	0.01	0.4
Component 3 scores	**-0.30**	**0.55**	0.09	10.5
Component 4 scores	-0.01	0.03	-0.07	0.2
Component 5 scores	0.02	0.18	0.03	0.3
Component 6 scores	**-0.15**	**0.19**	-0.12	2.1
Sex	0.47	0.56	0.50	0.4
Age	42.29	40.14	41.27	0.6
BMI	26.96	26.71	27.08	0.1
Sweet suprathresholds	2.72	3.07	2.92	0.6
Sweet Pref	3.65	**3.97**	3.63	2.4
Bitter suprathresholds	4.95	**4.06**	**5.34**	2.4
Bitter Pref	**1.43**	**1.68**	1.50	2.0
Sour suprathresholds	5.64	6.11	6.11	0.7
Sour Pref	1.70	1.81	1.64	0.4
Salty suprathresholds	3.87	**3.23**	**4.45**	3.0
Salty Pref	**2.19**	**2.72**	2.30	3.5

not reported in the 2020 Portuguese survey (Gregório, Sousa, et al., 2020). It is possible to hypothesize that these differences can be due to the characteristics of the studied population, which comes from the countryside of Portugal (rural region). Some authors report differences in food habits between urban and rural populations. For example, Nabdi and colleagues reported high percentage of people from Morocco rural areas adhering to Mediterranean Diet compared to the urban areas of the same country (Nabdi, Boujraf, & Benzagmout, 2022). At the same time, studies from other locations report that dietary habits are not so dependent on rurality, but reinforce the effect of age, observing that young adults have higher deviation from food recommendations than older adults (Pullen, Kent, Sharman, Schumacher, & Brown, 2021). The lack of time to prepare meals, as well as the limited skills and knowledge about how to prepare healthy and tasty foods, and less stable financial situation are factors that can explain the poor dietary habits of young adults compared to older ones (Jurado-Gonzalez, Xavier Medina, & Bach-Faig, 2024; Mazurek-Kusiak, Kobyłka, Korcz, & Sosnowska, 2021; Whatnall et al., 2022).

In order to assess which food items limited the achievement of higher MEDAS scores, we analyzed the accomplishments of each individual food item by participants. It was possible to confirm that it is at the level of vegetables and pulses that most participants fail, with fresh fruit and nuts also failing in more than 50% of participants. These are products of vegetable origin, with the associated bitter and sour tastes present at variable levels, together with a higher fibrous texture. These are sensory characteristics usually linked to lower food preferences. In the previously referred study of the Portuguese population, when participants were asked about the reason for lower intakes of vegetables, vegetable soup, and legumes, many reported flavor as the main reason, reinforcing the importance of the sensory aspects of these foods for low intakes. Different authors highlighted the relevance of sensory characteristics of foods as responsible for food choices and health performance (Vignini et al., 2019).

We also observed a significant association between MD adherence scores and sweet taste sensitivity. The association between higher sweet taste sensitivity and higher preferences for vegetables and fruits was previously observed in adults (Louro et al., 2021). This is also consistent with studies made for other age classes: i) In children, it was observed that girls with a higher preference for bitter or sour vegetables have higher sweet taste sensitivity (Rodrigues et al., 2020); ii) In pre-adolescents, the sensitivity to sweet taste was reported as influencing the sweetness-suppressing effect on bitterness and acidity, which is important to the liking of bitter or sour foods (Ervina et al., 2021). In summary, higher sensitivity to sweet taste may allow for a higher intensity of a preferred taste in a low-sweet matrix, such as vegetables. Even existing, the lack of a stronger association between MD and sweetness sensitivity can be due to the way through which MEDAS score is obtained, which allow the same score for individuals with differences in the intake of some food groups (as an example, a score of 10 can be obtained by individuals failing to achieve the recommended amounts of pulses, vegetables, fruits and nuts, or by individuals failing to achieve the recommendations to sugar, red meat, butter and margarine and cereals). Apart from sweetness, the influence of other basic tastes (particularly bitter taste) on vegetable foods acceptance has been reported in different studies (De Toffoli et al., 2019; Louro et al., 2021; Ma & Lu, 2023).

MD adherence is linked with higher consumption of aromatic plants and garlic. Aromatic plants can be a good source of some bioactives, including polyphenols (Delgado et al., 2023; Pinto et al., 2021), and their use in cuisine can have the potential to lower the use of salt or sodium (Dougkas et al., 2019; Ghawi, Rowland, & Methven, 2014; Rosa, Pinna, Piras, Porcedda, & Masala, 2022; Wang, Lee, & Lee, 2014), which is associated with severe cardiovascular problems (Dougkas et al., 2019).

It is interesting to observe that other spicy seasonings, like pepper or paprika, known to be considerably used in the geographic region studied, are not correlated with adherence to MD, highlighting that most of the distinctive flavors of this food pattern are due to aromatic plants rather than other seasonings.

Based on the assumption that aromatic plants and seasonings in general might contribute to a lower need for salt or sodium to increase food acceptability, it was expected that participants with higher seasoning consumption would be the ones with lower sodium intake. However, cluster analysis showed the opposite, with the cluster presenting higher scores for the components related to seasoning consumption being the one that also presented higher sodium intake. Given the design of the study, we cannot infer with absolute certainty about the levels of salt added to foods, particularly in culinary practices, nor can we assume that a participant with higher aromatic plant consumption will also add higher amounts of salt to foods. But it seems to be true that, in general, those who consume more seasonings have dietary habits high in sodium. The higher bitter and salty preferences for Cluster 2 allow us to hypothesize that this sodium/seasonings consumption is due to a higher preference for stronger tastes and flavors, which may result in higher intakes of processed meats, fast-food products, and salty snacks, and, consequently, higher sodium intake. A systematic review concluded that hedonics for salty taste (more than saltiness sensitivity) predict dietary intake, particularly of salt or sodium (Tan et al., 2021). The reason why a higher bitter taste preference (i.e. lower bitter taste aversion) was associated with higher sodium intake is not so obvious and needs to be clarified in further studies. The intake of sodium in MD has been accessed in different populations and, unfortunately, without a reduction in sodium intake associated with higher MD adherence (Malavolti et al., 2021; Viroli et al., 2021).

The observed relationship between taste sensitivity and preferences and seasoning intake reinforces how individual gustatory function may be important in food choices and dietary habits. The present results, showing that by using aromatic plants, no sodium intake is necessarily reduced, suggest that cooking literacy may be of particular relevance to achieve the benefits of including aromatic plants in dishes.

The present study is innovative by studying the relationship between gustatory function and MD adherence, focusing on the characteristic habits of Mediterranean cuisine, and rising awareness of the widespread thought that healthy eating habits can be achieved only through the use of aromatic plants and spices. Among the five existing basic tastes (sweet, bitter, sour, salty and umami), umami was the only one not tested in this study. Umami was definitely accepted as basic taste in 2000, when receptors for glutamate in taste cells were discovered (Beauchamp, 2024). However, until now, some researchers continue arguing that it has a mouthfeel component associated, which is different from the other four basic tastes, besides being not easily recognized by individuals, particularly not Asian ones (Beauchamp, 2024). Therefore, only sweetness, bitterness, sourness and saltiness were assessed. Despite that, umami taste sensitivity had been linked to dietary habits, with some authors reporting higher vegetable intake by umami high-sensitive individuals compared to low-sensitive ones (Fluitman et al., 2021). Further studies assessing the effect of umami taste sensitivity in adhere to MD would be of interest.

The study has some limitations that need to be highlighted. One of the limitations is the way how seasoning consumption was assessed. The questionnaire used here allow for an estimate of the frequency of consumption of the seasoning items included but does not allow for a good evaluation of the amounts used since no standard portions exist for these items. Most of the recipes do not define quantities, making the use of these constituents very variable from person to person. As well, sodium intake was calculated from data obtained from FFQ, which may be prone to errors. No information about the amounts of salt added to foods when cooking, was collected. To do this, it would be necessary to have different experimental conditions that allowed participants to simulate food cooking. Nevertheless, for the general purpose of the present study, the data gathered from participants reports allowed the understanding of the relation between intake, preferences and flavor intensity perception of foods, opening new venues for further studies that aim to evaluate dietary habits and food choices according to sensory profiles, rather than uniquely by nutritional profiles.

5. Conclusions

The present work evidences the low MD adherence in this Portuguese region, in line with what can be found in other countries with Mediterranean traditions, showing also that this is mainly due to intakes of vegetables and pulses in lower amounts than recommended. However, it is important to consider other aspects when explaining food choices, and taste sensitivity must be considered when studying the factors responsible for MD adherence.

The traditional MD uses seasonings and aromatic plants, which are referred to as having a healthy effect on decreasing salt intake. The present study shows that, although MD is associated with seasoning intake, this does not necessarily mean a lower intake of salt. Taste preferences may play an important role, indicating that individuals who prefer intense flavour have greater consumption of seasonings and sodium. This highlights that nutritional recommendations need to go deeper than simply recommending the use of seasonings to try to reduce salt intake, it is important to teach individuals to do it. In the sequence of this study, it would be of interest to deeply look at the individual level of perception of other sensory qualities, as well as investigating how different combinations of aromatic plants and spices can increase acceptance of vegetable based products, according with the individual sensitivity.

Ethical statement

Study was performed in accordance with the Declaration of Helsinki and approval by the Ethical Committee for Human Studies, from the University of Evora, was obtained.

Participants were informed about the objectives and procedures and signed informed consent before participation.

All the procedure and Ethical approval reference are presented in Material and Methods section of the present manuscript.

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Institutional Review Board statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of the University of Evora (GD/50418/2017).

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

CRediT authorship contribution statement

Teresa Louro: Writing – original draft, Investigation, Formal analysis. **Paula Midori Castelo:** Writing – review & editing, Formal analysis, Data curation. **Carla Simões:** Writing – review & editing, Investigation. **Fernando Capela e Silva:** Writing – review & editing, Formal analysis. **Henrique Luís:** Writing – review & editing, Supervision, Formal analysis. **Pedro Moreira:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Elsa Lamy:** Writing – original draft, Supervision, Project administration, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2024.107581.

References

Agovi, H., Pierguidi, L., Dinnella, C., Viggiano, M. P., Monteleone, E., & Spinelli, S. (2022). Attentional bias for vegetables is negatively associated with acceptability and is related to sensory properties. *Food Quality and Preference, 96*. https://doi.org/10.1016/j.foodqual.2021.104429

Beauchamp, G. (2024). *Introduction: Umami as a taste Percept*. https://doi.org/10.1007/978-3-031-32692-9_1

Davis, C., Bryan, J., Hodgson, J., & Murphy, K. (2015). Definition of the mediterranean diet: A literature review. *Nutrients, 7*(11). https://doi.org/10.3390/nu7115459

De Toffoli, A., Spinelli, S., Monteleone, E., Arena, E., Di Monaco, R., Endrizzi, I., et al. (2019). Influences of psychological traits and PROP taster status on familiarity with and choice of phenol-rich foods and beverages. *Nutrients, 11*(6). https://doi.org/10.3390/nu11061329

Delgado, A., Gonçalves, S., & Romano, A. (2023). Mediterranean diet: The role of phenolic compounds from aromatic plant foods. *Foods, 12*(4). https://doi.org/10.3390/foods12040840

Dinu, M., Pagliai, G., Casini, A., & Sofi, F. (2018). Mediterranean diet and multiple health outcomes: An umbrella review of meta-analyses of observational studies and randomised trials. *European Journal of Clinical Nutrition, 72*(1). https://doi.org/10.1038/ejcn.2017.58

Dougkas, A., Vannereux, M., & Giboreau, A. (2019). The impact of herbs and spices on increasing the appreciation and intake of low-salt legume-based meals. *Nutrients, 11*(12). https://doi.org/10.3390/nu11122901

Ervina, E., Almli, V. L., Berget, I., Spinelli, S., Sick, J., & Dinnella, C. (2021). Does responsiveness to basic tastes influence preadolescents' food liking? Investigating taste responsiveness segment on bitter-sour-sweet and salty-umami model food samples. *Nutrients, 13*(8). https://doi.org/10.3390/nu13082721

Fluitman, K. S., Hesp, A. C., Kaihatu, R. F., Nieuwdorp, M., Keijser, B. J. F., Ijzerman, R. G., et al. (2021). Poor taste and smell are associated with poor appetite, macronutrient intake, and dietary quality but not with undernutrition in older adults. *Journal of Nutrition, 151*(3). https://doi.org/10.1093/jn/nxaa400

Ghawi, S. K., Rowland, I., & Methven, L. (2014). Enhancing consumer liking of low salt tomato soup over repeated exposure by herb and spice seasonings. *Appetite, 81*. https://doi.org/10.1016/j.appet.2014.05.029

Green, B. G., Dalton, P., Cowart, B., Shaffer, G., Rankin, K., & Higgins, J. (1996). Evaluating the "Labeled Magnitude Scale" for measuring sensations of taste and smell. *Chemical Senses, 21*(3), 323–334. http://www.ncbi.nlm.nih.gov/pubmed/8670711.

Gregório, M. J., Rodrigues, A. M., Salvador, C., Dias, S. S., de Sousa, R. D., Mendes, J. M., et al. (2020). Validation of the telephone-administered version of the mediterranean diet adherence screener (Medas) questionnaire. *Nutrients, 12*(5). https://doi.org/10.3390/nu12051511

Gregório, M. J., Sousa, S. M. de, Chkoniya, V., & Graça, P. (2020). Estudo de adesão ao padrão alimentar Mediterrânico. https://nutrimento.pt/activeapp/wp-content/uploads/2020/10/Estudo-de-adesão-ao-padrão-alimentar-mediterrânico.pdf.

Jurado-Gonzalez, P., Xavier Medina, F., & Bach-Faig, A. (2024). Barriers to home food preparation and healthy eating among university students in Catalonia. *Appetite, 194*. https://doi.org/10.1016/j.appet.2023.107159

Kiani, A. K., Medori, M. C., Bonetti, G., Aquilanti, B., Velluti, V., Matera, G., et al. (2022). Modern vision of the Mediterranean diet. *Journal of Preventive Medicine and Hygiene, 63*(2). https://doi.org/10.15167/2421-4248/jpmh2022.63.2S3.2745

Laureati, M., De Boni, A., Saba, A., Lamy, E., Minervini, F., Delgado, A. M., et al. (2024). Determinants of consumers' acceptance and adoption of novel food in view of more resilient and sustainable food systems in the eu: A systematic literature review. *Foods, 13*(10), 1534.

Lopes, C., Aro, A., Azevedo, A., Ramos, E., & Barros, H. (2007). Intake and adipose tissue composition of fatty acids and risk of myocardial infarction in a male Portuguese community sample. *Journal of the American Dietetic Association, 107*(2), 276–286. https://doi.org/10.1016/j.jada.2006.11.008

Louro, T., Simões, C., Castelo, P. M., Capela e Silva, F., Luis, H., Moreira, P., et al. (2021). How individual variations in the perception of basic tastes and astringency relate with dietary intake and preferences for fruits and vegetables. *Foods, 10*(8). https://doi.org/10.3390/foods10081961

Ma, S., & Lu, S. (2023). Bitter taste sensitivity, cruciferous vegetable intake, obesity, and diabetes in American adults: A cross-sectional study of NHANES 2013-2014. *Food & Function, 14*(20). https://doi.org/10.1039/d3fo02175k

Malavolti, M., Naska, A., Fairweather-Tait, S. J., Malagoli, C., Vescovi, L., Marchesi, C., et al. (2021). Sodium and potassium content of foods consumed in an Italian population and the impact of adherence to a mediterranean diet on their intake. *Nutrients, 13*(8). https://doi.org/10.3390/nu13082681

Martínez-González, M. A., García-Arellano, A., Toledo, E., Salas-Salvadó, J., Buil-Cosiales, P., Corella, D., et al. (2012). A 14-item mediterranean diet assessment tool and obesity indexes among high-risk subjects: The PREDIMED trial. *PLoS One*. https://doi.org/10.1371/journal.pone.0043134

Mattavelli, E., Olmastroni, E., Bonofiglio, D., Catapano, A. L., Baragetti, A., & Magni, P. (2022). Adherence to the mediterranean diet: Impact of geographical location of the observations. *Nutrients, 14*(10). https://doi.org/10.3390/nu14102040

Mazurek-Kusiak, A. K., Kobyłka, A., Korcz, N., & Sosnowska, M. (2021). Analysis of eating habits and body composition of young adult poles. *Nutrients, 13*(11). https://doi.org/10.3390/nu13114083

Nabdi, S., Boujraf, S., & Benzagmout, M. (2022). Evaluation of rural-urban patterns in dietary intake: A descriptive analytical study – case series. *Annals of Medicine and Surgery, 84*. https://doi.org/10.1016/j.amsu.2022.104972

Pinto, T., Aires, A., Cosme, F., Bacelar, E., Morais, M. C., Oliveira, I., et al. (2021). Bioactive (Poly)phenols, volatile compounds from vegetables, medicinal and aromatic plants. *Foods, 10*(1). https://doi.org/10.3390/foods10010106

Pullen, R., Kent, K., Sharman, M. J., Schumacher, T. L., & Brown, L. J. (2021). A comparison of diet quality in a sample of rural and urban australian adults. *Nutrients, 13*(11). https://doi.org/10.3390/nu13114130

Ribeiro, J. C., Chaves, M., Chaves, C., Lemos, L., Silva, E. D., Paiva, A., et al. (2016). Cross-cultural validation of a taste test with paper strips. *European Archives of Oto-Rhino-Laryngology: Official Journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS): Affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery, 273*(10), 3407–3411. https://doi.org/10.1007/s00405-016-4037-y

Rodrigues, L., Silverio, R., Costa, A. R., Antunes, C., Pomar, C., Infante, P., et al. (2020). Taste sensitivity and lifestyle are associated with food preferences and BMI in children. *International Journal of Food Sciences & Nutrition*, 1–9. https://doi.org/10.1080/09637486.2020.1738354

Rosa, A., Pinna, I., Piras, A., Porcedda, S., & Masala, C. (2022). Flavoring of sea salt with Mediterranean aromatic plants affects salty taste perception. *Journal of the Science of Food and Agriculture*. https://doi.org/10.1002/jsfa.11953

Saint-Eve, A., Granda, P., Legay, G., Cuvelier, G., & Delarue, J. (2019). Consumer acceptance and sensory drivers of liking for high plant protein snacks. *Journal of the Science of Food and Agriculture, 99*(8). https://doi.org/10.1002/jsfa.9624

Santos-Buelga, C., González-Manzano, S., & González-Paramás, A. M. (2021). Wine, polyphenols, and mediterranean diets. What else is there to say? *Molecules, 26*(18). https://doi.org/10.3390/molecules26185537

Taladrid, D., Laguna, L., Bartolomé, B., & Moreno-Arribas, M. V. (2020). Plant-derived seasonings as sodium salt replacers in food. *Trends in Food Science and Technology, 99*. https://doi.org/10.1016/j.tifs.2020.03.002

Tan, S. Y., Sotirelis, E., Bojeh, R., Maan, I., Medalle, M., Chik, X. S. F., et al. (2021). Is dietary intake associated with salt taste function and perception in adults? A systematic review. *Food Quality and Preference, 92*. https://doi.org/10.1016/j.foodqual.2021.104174

Vignini, A., Borroni, F., Sabbatinelli, J., Pugnaloni, S., Alia, S., Taus, M., et al. (2019). General decrease of taste sensitivity is related to increase of BMI: A simple method to monitor eating behavior. *Disease Markers, 2019*. https://doi.org/10.1155/2019/2978026

Viroli, G., Gonçalves, C., Pinho, O., Silva-santos, T., Padrão, P., & Moreira, P. (2021). High adherence to mediterranean diet is not associated with an improved sodium and potassium intake. *Nutrients, 13*(11). https://doi.org/10.3390/nu13114151

Wang, C., Lee, Y., & Lee, S. Y. (2014). Consumer acceptance of model soup system with varying levels of herbs and salt. *Journal of Food Science, 79*(10). https://doi.org/10.1111/1750-3841.12637

Whatnall, M., Ashton, L. M., Adam, M. T. P., McCormick, H., Clarke, E. D., Lavelle, F., et al. (2022). How can we support healthy eating in young adults with low diet quality? A survey of users of the 'No money No time' healthy eating website. *Nutrients, 14*(24). https://doi.org/10.3390/nu14245218

Yashin, A., Yashin, Y., Xia, X., & Nemzer, B. (2017). Antioxidant activity of spices and their impact on human health: A review. *Antioxidants, 6*(3). https://doi.org/10.3390/antiox6030070