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Nutritional composition and antioxidant properties of mediterranean diet traditional recipes: MEDIET4ALL project

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ABSTRACT

The Mediterranean diet (MD) is known for its high antioxidant content, which contributes to a balanced diet and reduces the risk of chronic diseases. This study, within the framework of the MEDIET4ALL project, evaluates the nutritional and antioxidant properties of selected recipes from 6 Mediterranean countries (Algeria, Tunisia, Morocco, France, Italy, and Spain) and 2 non-Mediterranean countries (Germany and Luxembourg). Nutritional profiles were obtained using the EasyDiet program, and antioxidants (ORAC, TEAC, and total polyphenols (TP) methods) were retrieved from databases and literature. In the African Mediterranean countries, such as Tunisia and Morocco, dishes combine animal proteins (meat, chicken) and plant-based proteins (legumes, cereals) with a high fiber content (e.g., Tunisian couscous with 10.4 g per serving), minerals such as zinc, and vitamins C, E, and carotenoids with antioxidant capacity. Mediterranean European dishes, such as *Valencian paella* (Spain) and *ratatouille* (France), feature a good balance between animal and plant proteins, along with a significant amount of fiber and healthy fats, thanks to olive oil. In non-Mediterranean European countries like Germany, *königsberger meatballs* combine pork and onions, providing a high protein content and a moderate lipid intake. African Mediterranean dishes like Tunisian lentil soup (2646.5 mg Gallic Acid Equivalent (GAE)/100 g) and *Moroccan chicken vermicelli* (1107 and 28,803 μmol Trolox Equivalent (TE)/100 g TEAC and ORAC, respectively) have high antioxidant capacity due to the spices and olive oil. In Mediterranean European countries, *Valencian paella* (12,898.1 μmol TE/100 g ORAC) and *torrija with horchata* (1825.9 μmol Trolox/100 g TEAC) stand out for their antioxidant capacity or meatballs with sauce in France with 410.1 mg GAE/100 g in polyphenols. In non-Mediterranean countries, *königsberger meatballs* in Germany have an ORAC value of 9823.2 μmol Trolox/100 g, and *tarte tatin with vanilla ice cream* in Luxembourg contains in TEAC 960 μmol Trolox/100g and 748.4 mg GAE/100g in polyphenols, highlighting their high antioxidant content. The antioxidant values highlight the functional potential of the MD, and although most non-MD have a lower antioxidant capacity, some show significant potential.

1. Introduction

An increasing number of studies demonstrate a positive correlation between the consumption of a diet rich in antioxidants and a lower predisposition to degenerative diseases (Valtueña et al., 2008; Prior, 2015; Nascimento-Souza et al., 2018; Pérez et al., 2023). Dietary antioxidants, which include vitamins A, C and E, minerals such as Se and Zn, carotenoids, plant sterols and phenolic compounds, among others, are primarily found in plant-based foods like fruits and vegetables. The MD stands out for its abundance of these compounds, which are essential for combating free radicals responsible for oxidative stress (Pérez-Jiménez et al., 2015; Barbouti and Goulas, 2021).

A pioneering study conducted in Spain in 2013 to investigate the benefits of the MD, PREDIMED trial, found that participants at high cardiovascular risk assigned to a MD supplemented with extra-virgin olive oil (EVOO) or nuts had lower incidence of major cardiovascular

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events than among those assigned to a reduced-fat diet (Ros et al., 2014; Salas-Salvadó and Mena-Sánchez, 2017; Singh et al., 2022). Likewise, another more recent Spanish study (CORDIOPREV) reported that participants with previous cardiovascular events but no incidents in the last 6 months prior to the study that followed MD compared to a low-fat, high-carbohydrate diet presented greater prevention against major cardiovascular events and deaths (Delgado-Lista et al., 2022; Sebastian et al., 2024). Similarly, studies on the Brazilian diet (Koehnlein et al., 2014) highlight its richness in phenols and flavonoids, which positively impact cardiovascular diseases (CVD) due to their TAC. Foods like coffee, beans, tea, bread, and rice help counteract excess reactive oxygen and nitrogen species in the body, and the daily intake of these compounds is higher than in countries like Spain, Greece, the USA, and Finland. Despite different methodologies for analysing these compounds, both the Brazilian and traditional Mexican diets provide polyphenols that can contribute the health, particularly in populations at risk of obesity, diabetes, and CVD. For example, traditional Mexican dishes such as *mole poblano* are rich in polyphenols from ingredients like chili peppers, spices, chocolate, and dried fruits (Alatorre-Cruz et al., 2023). These compounds may help mitigate oxidative stress and support overall metabolic health, like the beneficial effects observed in the Brazilian diet. However, adherence to an antioxidant diet, such as the MD, can be affected by factors such as the cost and availability of fresh foods, as well as the time required to prepare the recipes. Psychological and cultural factors also play a role. Therefore, it is crucial to provide education and resources for those who wish to follow this healthy dietary pattern (Buscemi, 2021; Sotos-Prieto et al., 2022).

There is little information on total polyphenols (TP) and TAC in complete dishes of the diet, unlike studies on individual foods. Some Italian (Durazzo et al., 2017, 2019) and Spanish (González et al., 2019; Martínez-Zamora et al., 2021; Cuenca-Ortolá et al., 2023) studies have measured antioxidants using analytical methods, distinguishing between extractable antioxidants (through aqueous-organic extracts) and non-extractable antioxidants (via acid hydrolysis) (see supplementary material SM1). Generally, these dishes are not subjected to aggressive cooking methods. The diversity of antioxidant properties in these dishes highlights their potential for a balanced and healthy diet, providing a variety of nutrients in appropriate amounts and quality to maintain overall health. Furthermore, it emphasizes the importance of evaluating the antioxidant properties of complete dishes to better understand their nutritional composition and antioxidant properties, since not only offer an abundant combination of antioxidants but also provide a synergistic interaction between antioxidants during its preparation, resulting in a greater overall antioxidant capacity compared than the sum of their isolated ingredients (Cuenca-Ortolá et al., 2023). Additionally, the antioxidant potential of a dish can vary depending on the ingredients; for example, *pizza margherita* shows greater antioxidant capacity depending on the cheese used, with *mozzarella di bufala* and *mozzarella fiordilatte* being the most effective (Piscopo et al., 2024).

The European MEDIET4ALL project aims to facilitate the transition from a culture of ultra-processed foods to a modern and sustainable MD by creating a transnational movement to implement best practices that promote healthy and sustainable dietary patterns (MEDIET4ALL, 2023). Among its overall goals is the development of "quick and easy" recipes based on traditional MD dishes, maintaining their nutritional composition, antioxidant capacity, and sustainability. Within this framework, the specific objective of the present preliminary study is to assess, using databases and literature, the total antioxidant capacity —measured by the *Oxygen Radical Absorbance Capacity* (ORAC) and *Trolox Equivalent Antioxidant Capacity* (TEAC) methods—, the TP (Folin–Ciocalteu method), and the nutritional composition of a selection of traditional recipes representative of the MD from eight consortium countries, including 6 Mediterranean and 2 European non-Mediterranean. This evaluation will allow quantification and comparison of the antioxidant content and nutritional quality of different dishes within and across countries, providing valuable information on their properties with potential health benefits for consumers. Furthermore, the results of this study will allow for the updating and improvement of traditional Mediterranean diet recipes in a future study.

2. Materials and methods

2.1. Bibliographic search

The purpose of this bibliographic search was to collect relevant and comparable data on TAC, TP, and nutritional information of traditional MD recipes. This information serves as the basis for evaluating and comparing the antioxidant and nutritional profiles of selected recipes across the eight countries included in the consortium, contributing to the objectives of this preliminary study within the project, and directly supporting the study's aim to systematically assess and compare antioxidant and nutritional characteristics across Mediterranean countries, for this systematic review.

The literature search was conducted in accordance with the PRISMA guidelines (Page et al., 2021) in four scientific databases: Medline (via PubMed), Scopus, Google Scholar, and Web of Science. Full texts were accessed through the institutional subscriptions of the University of Valencia whenever they were not freely available. The last search was performed on December 21, 2024. Initially, the time frame was restricted to the last 10 years, but due to the limited number of studies directly addressing the main objective of this research, the search period was extended to include publications from the year 2000 onwards.

The following search terms were applied in each database using Boolean operators (OR, AND): "Recipes" OR "Mediterranean Diet" OR "Antioxidant Capacity" OR "Ingredient + Total Polyphenols" OR "Ingredient + ORAC" OR "Ingredient + TEAC" OR "nutritional information" OR "spices". Only studies published in English or Spanish were considered.

A total of 218 records were identified (Medline = 39; Scopus = 41; Google Scholar = 80; Web of Science = 58). Duplicate records (n = 59) and those excluded for other reasons, such as conference abstracts or non-scientific documents (n = 54), were removed before screening. This resulted in 105 unique records, of which 20 were excluded because the full text could not be obtained despite institutional access.

The remaining 85 records were screened by title and abstract. Studies written in languages other than English or Spanish (n = 2) or published before year 2000 (n = 2) were excluded. This left 81 full-text articles that were assessed for eligibility. No additional exclusions were made at the full-text stage.

Subsequently, a manual screening was conducted, where studies that do not address antioxidant capacity in ingredients or complete dishes were excluded. Finally, these 42 documents were selected. As shown in Fig. 1, the following exclusion criteria were applied: (i) studies not addressing the topic of interest, (ii) opinions or narrative reviews rather than empirical studies, (iii) articles published in languages other than English or Spanish, and (iv) publications not presenting consistent and original data. Finally, the bibliographic manager Mendeley was used to register and manage the selected articles from the searches conducted in the scientific databases.

2.2. Participating countries

The MEDIET4ALL project involves a total of 8 countries, including 6 Mediterranean (France, Italy, Spain, Algeria, Morocco and Tunisia) and 2 non-Mediterranean (Luxembourg and Germany). These countries were selected for their geographical, cultural and socioeconomic diversity, providing complementarity in the knowledge, skills and experience necessary to achieve the scientific, technological and educational objectives. The great versatility of these countries allows for a holistic approach to promoting the MD and healthy lifestyles, making them ideal candidates for analysing both traditional and modernized Mediterranean recipes. The participating entities include universities, research

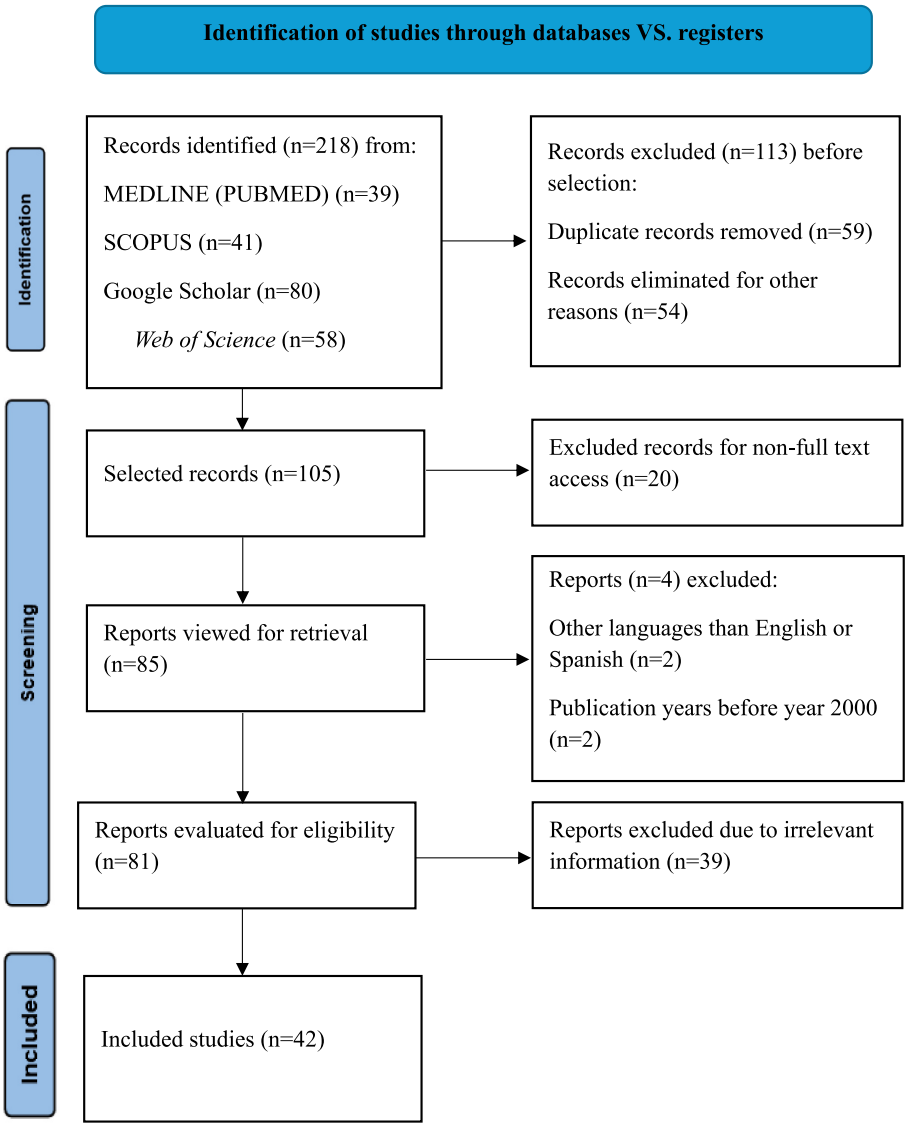

Fig. 1. Outline of the methodology used for the literature review, according to the PRISMA methodology (Page et al., 2021).

Table 1
Selected recipes in each of the MEDIET4ALL participating countries.

Mediterranean European Countries			Mediterranean African Countries			Non-Mediterranean European Countries	
France	Italy	Spain	Algeria	Morocco	Tunisia	Germany	Luxembourg
Ratatouille	Stewed dolphinfish	Garlic rabbit	Rechta	Bissara	Djerbian rice	Gulasch	Judd with broad beans
Fish stew	Sardine meatballs	Valencian hake	Chorba beïda	Harira	Tunisian lentill soup	Königsberger meatballs	Green bean soup
Cassoulet	Green olive patè	Potato omelette	Mtewem	Moroccan chicken vermicelli	Ojja with merguez	Pea soup	Plum tart
Basque pepper stew	Raw of sea bream and croaker fish with mango and green olives	Fish suquet	Dobara	Chicken tagine with olives and preserved lemons	Kafteji	Rice pudding with sugar and cinnamon	Tarte tatin with vanilla ice cream
Meatballs with sauce	Sicilian caponata	Valencian titaina	Olive tajine	Moroccan lamb/beef tagine with peas and artichokes	Tunisian couscous with meat and vegetables		
French beef stew	Bread and chickpea flour fritters	Zarangollo	Couscous with beans and olive oil	Moroccan tagine with quinces and honey	Mloukhia		
Tielle sétoise	Margherita pizza	Valencian paella	Sweet Lamb	Beef tagine with apricots, prunes and almonds	Kamounia		
Basque cake	Tiramisu	Torrija with horchata	Ej jauozia	Minichicken bastilla	Assidat zgougou		

centres and specialized organizations in areas such as project management, communication, innovation and development.

2.3. MD traditional recipe selection criteria

A total of 56 recipes has been collected from 8 different countries (48 from Mediterranean countries and 8 from non-Mediterranean countries) (see Table 1). Firstly, each country contributed with 10–18 traditional and representative recipes. Later, Microtarians, a social impact company and accredited training institute from Luxembourg, applied several selection criteria: (i) whether the recipe was traditional or had undergone modifications over time, aiming to prioritize dishes deeply rooted in the culinary heritage of the respective countries; (ii) the ease of cooking, recognizing the importance of accessibility for individuals preparing the dish, regardless of their culinary expertise; (iii) the cultural perspective, ensuing that the chosen recipe reflected the cultural identity and diversity of each nation; (iv) variety, emphasizing the inclusion of recipes that showcased the breadth of flavours and ingredients within a country's cuisine; (v) the ease of packaging to assess the practicality of distributing and transporting the recipe; and (vi) the potential for improvement in terms of antioxidants and nutritional composition, with the aim of selecting recipes that could be enhanced or adapted without compromising the authenticity. Finally, 8 recipes from Mediterranean countries and 4 from non-Mediterranean ones were selected. Each list was ensured to include at least one typical dessert from each region, with the aim of having a fair and varied representation of each cuisine, as well as being more appealing to children and seniors.

2.4. Nutritional profile assessment

Nutritional assessment of selected representative dishes was carried out using EasyDiet software (DietSource® 3.8) (EasyDiet, n.d) which uses the CESNID food composition table (CESNID, 2008), calculating total calories, proteins, carbohydrates, fiber, fats, cholesterol, vitamins and minerals. The ingredients, expressed in fresh weight (FW), used to prepare the analysed dishes are shown in supplementary material (SM2). Nutrient and antioxidant values were calculated using raw ingredients, as most items in the database are listed in this form and using cooked values would have introduced additional variability. Nutrient values were compared with the Dietary Reference Intakes (DRI) for adults, considering standard age, sex, and activity level, using the DRI Calculator for Healthcare Professionals (https://www.nal.usda.gov/human-nutrition-and-food-safety/dri-calculator) to provide context for recommended intake levels.

2.5. Total antioxidant capacity and total polyphenols compilation

Since no standard and universal TAC determination method exists, the use of two or more different methods with different chemistry and reaction mechanisms are encouraged. The TAC needs to reflect and differentiate both hydrogen atom transfer (HAT) (radical quenching) and electron transfer (ET) (radical reduction). ORAC represent a HAT reaction mechanism, which is most relevant to human biology, while TP (Folin−Ciocalteu method) and TEAC represent ET assays. These methods were chosen since have been traditionally proposed for the evaluation of antioxidant capacity in foods and dietary supplements (Prior et al., 2005; Munteanu and Apetrei, 2021).

Data on the TAC (ORAC and TEAC methods) and TP content of individual foods or ingredients in the proportion present in each selected MD recipe were collected from different databases and when this was not possible, from specific publications. Due to the lack of studies on total TAC and TP content in complete dishes, data were searched by ingredient, expressed in FW, in each recipe (see supplementary material (SM3-SM5)).

For ORAC antioxidant capacity the USDA database for the ORAC of selected foods (USDA, 2010), although withdrawn, was mainly used combined with specific articles. This database contained antioxidant activity for 326 selected foods. ORAC values are reported for hydrophilic-ORAC (H-ORAC), lipophilic-ORAC (L-ORAC), Total-ORAC, and TP. H-ORAC, L-ORAC and total-ORAC are reported in μmol of Trolox equivalents (TE) per 100 g (μmol TE/100 g), while TP is reported in mg gallic acid equivalents (GAE) per 100 g (mg GAE/100 g).

Regarding TEAC antioxidant capacity, there is no available database, and it was necessary to rely solely on articles using the manuscript of Pellegrini et al. (2003) as a base, complemented with other papers when possible.

The TP content of foods was estimated mainly using the online database Phenol-Explorer (Phenol-Explorer, n.d.) which includes information on 502 polyphenols present in 452 foods (Neveu et al., 2010) as well as the abovementioned ORAC database.

3. Results and discussion

3.1. Nutritional profile in the most representative recipes of each country

The nutritional composition of the most representative recipes in each of the 8 participating countries in the MEDIET4ALL project is shown in Table 2. The most common criteria considered for their selection were their history and tradition, local popularity, locally produced ingredients, versatility, quality and above all, international recognition. The nutritional composition of all the remaining MD traditional recipes is available as supplementary material (SM2).

According to the nutritional composition of the most representative recipe in each MEDIET4ALL country (Table 2) and the DRI from the USDA database presented in Table 3, the percentages of energy and nutrients provided by the intake of these recipes per serving have been evaluated, considering values for both genders (men/women %).

3.1.1. Energy

The energy percentage and content per portion of the recipes varies significantly. *Ratatouille* (France), with 5.1/6.3 % DRI (male/female) (132 Kcal), is primarily composed of vegetables that are low in calories and high in water and fiber with a small amount of extra virgin olive oil (EVOO). On the other hand, *judd with broad beans* (Luxembourg), at 7.1/8.7 % DRI (182 Kcal), combines animal-based proteins and fats, while vegetables help keeping the caloric content at moderate levels.

In contrast, recipes like the Spanish *Valencian paella* (32.4/40.0 % DRI) (838.1 Kcal), Algerian *couscous with broad beans and olive oil* (33.8/42.1 % DRI) (883.4 Kcal), and *Tunisian couscous with meat and vegetables* (34.2/42.5 % DRI) (890.6 Kcal) provide a higher energy contribution. These are rich in carbohydrates, mainly from rice and couscous, complemented by proteins and fats from meats such as rabbit, chicken, and other animal species, along with a wide range of vegetables, legumes, and a touch of EVOO. In addition, the usual portion consumed is higher than in the abovementioned low-calorie recipes, a fact that also contributes to their higher energy values.

3.1.2. Lipids

According to the authorised health claims established in Regulation (EU) N° 432/2012 of May 16, 2012, a lower intake of saturated fats and the replacement with unsaturated fats (such as MUFA and PUFA) contributes to maintaining normal blood cholesterol levels (Commision Regulation, 2012). The daily fat intake should not exceed 35 % of total calories for the adult population. Among the analysed recipes, *ratatouille* stands out for having the lowest fat content, with only 11 g (13.7/16.8 % DRI) (male/female), of which 6.8 g are monounsaturated fatty acids (MUFA). This is due to its mainly vegetable ingredients, such as zucchini and tomatoes, along with a small amount of EVOO. On the other hand, *judd with broad beans* from Luxembourg has also a low moderate fat content of 12.2 g (15.2/18.8 % DRI), with 4.5 g of MUFA, thanks to the inclusion of legumes.

In contrast, the German recipe *königsberger meatballs* has a high total

Table 2
Nutritional composition in the most representative recipes (per portion).

Recipe	Mediterranean European Countries			Mediterranean African Countries			Non- Mediterranean European Countries	
	France	Italy	Spain	Algeria	Morocco	Tunisia	Germany	Luxembourg
	Ratatouille	Margherita Pizza	Valencian Paella	Couscous with beans and olive oil	Chicken Tagine with olives and preserved lemons	Tunisian couscous with meat and vegetables	Königsberger Meatballs	Judd with broad beans
Portion (g)	150	250	360	360	360	360	400	150
Energy (Kcal)	132	523	838.1	883.4	385.9	890.6	733.6	182
Lipids								
Total lipids (g)	11	19.8	23.8	32.8	24.5	34.6	61.6	12.2
Monounsaturated fatty acids (g)	6.8	6.5	13	22.7	15.1	17.3	18.8	4.5
Polyunsaturated fatty acids (g)	1.8	2.5	4	3.6	3.6	5	19.2	0.9
Saturated fatty acids (g)	1.7	9	5.4	4.7	4	5.8	20	6
Cholesterol (mg)	0	33.8	85	0	36.4	2343.6	151.2	48
Salt (g)	0.5	3.5	3.8	28.8	1.7	4.1	7.5	0.1
Carbohydrates								
Total carbohydrates (g)	6.5	67.8	115.6	144	21.2	112	21.2	4.8
Digestible sugars (g)	4.5	2.8	2.5	2.9	16.2	4.7	6	2.3
Digestible polysaccharides (g)	2	65	113	141.1	5	107.3	15.2	3.6
Total dietary fibre (g)	3	4.5	5	4.3	9	10.4	5.2	3.2
Proteins								
Total protein (g)	1.8	18.6	40.3	3.2	18	33.1	22.8	13.5
Animal protein (g)	0	8.3	28.4	0	12.6	11.5	12.4	10.7
Plant protein (g)	1.8	10.3	11.5	3.2	5.8	21.6	10.4	2.9
Minerals								
Calcium (mg)	28.2	255.5	69.8	61.9	124.2	93.6	745.2	25.8
Phosphorus (mg)	41	295.5	445.7	85	230.4	625	326.8	122.9
Iron (mg)	1.2	2	4	2.2	6.1	6.8	3.6	1.1
Zinc (mg)	0.3	1.3	4.3	0.7	1.8	6.8	4	1.5
Magnesium (mg)	18.6	43.3	110.9	169.9	72	113.8	102.8	19.2
Potassium (mg)	504.8	380.8	816.1	307.1	937.8	961.9	496.4	271.7
Vitamins								
B1 (mg)	0	0.3	0.4	0	0.4	0.7	0.4	0.3
B2 (mg)	0.2	0.3	0.4	0	0.4	0.4	0.4	0.2
B3 (mg)	0.9	1.5	15.5	1.1	7.2	9	3.6	2.6
B6 (mg)	0.2	0.3	1.1	0.4	0.7	0.7	0.4	0.3
B9 (μg)	43.1	67	56.5	82.4	47.2	75.2	81.6	39.2
B12 (μg)	0	0.5	7.9	0	0	11.2	1.2	0.3
C (mg)	32.4	13	22.3	24.5	61.2	43.6	20.8	11.4
A (μg)	443.1	259.5	287.6	49	757.8	472	160.8	99.3
D (μg)	0	0	0	0	0	0	0.4	0.2
E (mg)	2	1.3	3.2	4.3	4.7	4.7	2.8	0.6
Others								
Total retinoids (μg)	0	131.3	6.8	0	0	0	139.2	53.1
Carotenoids (μg)	2658.5	771.3	1684.1	291.6	4546.4	2832.8	129.2	276.8
Water (g)	126.3	133.8	163.4	127.8	280.4	161.3	275.2	114.9

fat content of 61.1 g (77.2/94.8 % DRI), due to the combination of ground meat, cream, and butter, which are rich in saturated fats. Its MUFA content is also notable, at 18.8 g, coming from the mix of meat and cream. Meanwhile, the *Tunisian couscous with meat and vegetables*, although not one of the fattier recipes, has a significant cholesterol content due to the use of beef brain meat (2343.6 mg), contributing to fats in 43.2 % for men and 53.3 % for women according to the DRIs.

3.1.3. Carbohydrates

Regarding carbohydrate content, the Luxembourg (4.8 g) (1.4/1.7 % DRI) (male/female) and French (6.5 g) (1.8/2.3 % DRI) recipes have low amounts, while the Algerian recipe has a higher value of 144 g (40.3/49.7 % DRI). This is due to the ingredients used: in Luxembourg, *judd with broad beans* contains few carbohydrates because its main ingredient, pork, is primarily a source of protein and fat. *Ratatouille* is also low in carbohydrates due to its vegetable ingredients, while *couscous with broad beans and olive oil* from Algeria is a significant source of complex carbohydrates.

Dietary recommendations suggest that carbohydrates should represent between 45 and 65 % of total daily calories. According to the DRIs, the carbohydrate percentages in the Luxembourg and French recipes are low (1.4/1.7 % and 1.8/2.3 %, respectively), while the Algerian recipe aligns with recommendations (40.3/49.7 %).

3.1.4. Fibre

According to the Commission Regulation (EU) N° 432/2012 states that fibre contributes to the acceleration of intestinal transit and the increase in stool volume (Commision Regulation, 2012). The daily fibre recommendations are 38 g for men and 25 g for women. The analysed recipes are not particularly high in fibre, with *ratatouille, pizza margherita, couscous with broad beans,* and *judd with broad beans* providing between 3 and 4.5 g. In contrast, the *Tunisian couscous with meat and vegetables* stands out with 10.4 g of fiber (27.4/41.6 % DRI) (male/female), due to its greater variety of vegetables and legumes. Ingredients explain these values: recipes with vegetables and flour, like *ratatouille* and *pizza margherita*, have moderate fibre content, while *judd with broad beans* and *couscous with broad beans* contain less due to the presence of meat and fewer legumes.

Table 3
Percentage of the dietary reference intakes (DRI) provided by the most representative recipes (per portion).

Recipe Portion (g)	DRI[b]		Mediterranean European Countries						Mediterranean African Countries						Non-Mediterranean European Countries			
			France		Italy		Spain		Algeria		Morocco		Tunisia		Germany		Luxembourg	
			Ratatouille 150		Margherita Pizza 250		Valencian Paella 360		Couscous with beans and olive oil 360		Chicken Tagine with olives and preserved lemons 360		Tunisian couscous with meat and vegetables 360		Königsberger Meatballs 400		Judd with broad beans 150	
Gender (Male/Female)	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Energy (Kcal)[a]	2600	2100	5.1	6.3	20.0	25.0	32.4	40.0	33.8	42.1	14.8	18.4	34.2	42.5	28.4	34.8	7.1	8.7
Lipids (g)	80	65	13.7	16.8	24.8	30.5	29.9	36.7	41.0	50.4	30.6	37.8	43.2	53.3	77.2	94.8	15.2	18.8
Salt (g)	5.8	5.8	8.7	8.7	60.3	60.3	65.5	65.5	496.6	496.6	29.3	29.3	70.7	70.7	129.6	129.6	1.7	1.7
Carbohydrates(g)	358	289	1.8	2.3	19.0	23.5	32.4	40.0	40.3	49.7	5.8	7.2	31.3	38.9	6.0	7.2	1.4	1.7
Total dietary fibre (g)	38	25	7.9	12	11.8	18	13.2	20	11.3	17.2	23.7	36	27.4	41.6	13.7	20.8	8.4	12.8
Proteins (g)	160	130	1.1	1.4	11.6	14.3	25.1	31	2	2.5	11.3	13.4	20.7	25.5	14.3	17.5	8.4	10.4
Minerals																		
Calcium (mg)	1000	1000	2.8	2.8	25.6	25.6	7	7	6.2	6.2	12.4	12.4	9.4	9.4	74.5	74.5	2.6	2.6
Phosphorus (mg)	700	700	5.9	5.9	42.3	42.3	63.7	63.7	12.2	12.2	32.8	32.8	89.3	89.3	46.8	46.8	17.6	17.6
Iron (mg)	8	18	15.0	6.6	25.0	11.0	49.7	22.0	27.0	11.9	76.7	33.8	85.7	38.2	45.2	20.0	13.2	5.9
Zinc (mg)	11	8	2.7	3.8	11.3	15.8	39.2	54.0	6.5	9.0	16.2	22.7	62.3	85.7	36.4	50.0	13.7	18.8
Magnesium (mg)	420	320	4.5	5.9	10.3	13.5	26.3	34.6	40.3	52.9	17.3	22.7	27.0	35.6	24.4	32.0	4.5	6.0
Potassium (mg)	2600	3400	19.4	14.9	14.8	11.3	31.3	24.1	11.9	9.0	36.0	27.7	37.1	28.4	19.2	14.8	10.5	8.0
Vitamins																		
B1 (mg)	1.2	1.1	0.0	0.0	20.8	22.8	29.9	32.8	0.0	0.0	29.9	32.8	60.1	65.5	33.2	36.4	25.1	27.3
B2 (mg)	1.3	1.1	11.6	13.7	19.3	22.8	27.7	32.8	0.0	0.0	27.7	32.8	27.7	32.8	30.8	36.4	11.6	13.7
B3 (mg)	16	14	5.7	6.5	9.5	10.8	96.8	110.5	6.8	7.6	45.0	51.5	56.2	64.4	22.4	25.6	15.9	18.2
B6 (mg)	1.3	1.3	11.6	11.6	19.3	19.3	83.2	83.2	27.7	27.7	55.4	55.4	55.4	55.4	30.8	30.8	23.1	23.1
B9 (μg)	400	400	10.8	10.8	16.8	16.8	14.0	14.0	20.5	20.5	11.9	11.9	18.7	18.7	20.4	20.4	9.8	9.8
B12 (μg)	2.4	2.4	0.0	0.0	20.8	20.8	330.1	330.1	0.0	0.0	0.0	0.0	465.1	465.1	50.0	50.0	12.5	12.5
C (mg)	90	75	36.0	43.2	14.5	17.3	24.8	29.9	27.4	32.8	68.0	81.7	48.2	58.0	23.2	27.6	12.6	15.2
A (μg)	900	700	49.2	63.3	28.8	37.0	32.0	41.0	5.4	6.8	84.2	108.4	52.6	67.3	18.0	22.8	11.1	14.3
D (μg)	15	15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	2.8	1.1	1.1
E (mg)	15	15	13.1	13.1	8.3	8.3	21.6	21.6	28.8	28.8	31.3	31.3	31.3	31.3	18.8	18.8	4.1	4.1

[a] It has been considered for male (♂) and female (♀) subjects, caloric intake ranges between 2000–3200 and 1800–2400 Kcal, respectively: age between 19 and 50 years old and with a moderate activity level. These values are determined by reference height and weight that align with a healthy body mass index (BMI). Caloric needs can differ based on various factors.

[b] DRI Calculator for Healthcare Professionals by the USDA, accessible at https://www.nal.usda.gov/human-nutrition-and-food-safety/dri-calculator, helps estimate calorie requirements considering age, sex, height, weight, and physical activity level.

3.1.5. Proteins

Commission Regulation (EU) No 432/2012 of May 16, 2012 states that proteins contribute to the maintenance of normal blood pressure, the increase and maintenance of muscle mass, and the maintenance of normal bones (Commision Regulation, 2012). According to European regulations 1924/2006 and 116/2010, for a product to be considered a "source of protein," at least 12 % of its energy value must come from protein (European Commission, 2010; European Parliament and Council of the European Union, 2006). In this regard, the recipes with the lowest protein content are *ratatouille* and *couscous with broad beans and olive oil*. The former, with primarily vegetable ingredients, provides only 1.8 g/portion (1.1/1.4 % DRI) (male/female), while the latter, despite including legumes, still falls short in protein (3.2 g/portion) (2/2.5 % DRI). Neither of these recipes meets the criteria to be considered a source of protein.

On the other hand, the *Valencian paella* stands out for its high protein content, providing 40.3 g of protein per serving (360 g), which represents a significant percentage of the DRI (25.1 % for men and 31 % for women). Thanks to the combination of meat and vegetable ingredients, this dish meets the requirements to be classified as a source of protein.

3.1.6. Salt

Excessive salt intake can raise blood pressure and increase the risk of CVD. The WHO recommends not exceeding 5 g of salt daily (WHO, 2013). Among the compared recipes, Luxembourg's has the lowest salt content, with only 0.1 g per serving (160 g) (1.7 % DRI, both). Meanwhile, *pizza margherita* has a high salt content, with 3.5 g per 250 g (60.3 %), due to the processed ingredients. The Algerian recipe has the highest salt content (28.8 g per 360 g, 496.6 %). These data demonstrate how ingredients and cooking techniques can affect the salt content of dishes.

3.1.7. Calcium

Contributes to the maintenance of normal bones and teeth, and plays a key role in blood clotting, energy metabolism, muscle function, and neurotransmission, according to the Commission Regulation (EU) N° 432/2012 (Commision Regulation, 2012). France and Luxembourg have the recipes with the lowest calcium content, 28.2 (2.8 % DRI, both) and 25.8 mg (2.6 %), respectively. In the case of France, *ratatouille*, while a healthy dish, provides a limited amount of calcium, whereas the *judd with broad beans* from Luxembourg shows a similar trend since their ingredients are poor dietary sources of this mineral. On the other hand, the German *königsberger meatballs* recipe, reaches a much higher amount of calcium for cream, 745.2 mg (74.5 % DRI) and reflecting a different approach in the selection of ingredients that naturally contribute more of this nutrient.

3.1.8. Iron

According to the Commission Regulation (EU) N° 432/2012, iron contributes to the formation of red blood cells and hemoglobin, supports oxygen transport, and helps reduce tiredness and fatigue (Commision Regulation, 2012). *Ratatouille* from France and *judd with broad beans* from Luxembourg have the lowest iron contents, with 1.2 mg (15/6.6 %, DRI) and 1.1 mg (13.2/5.9 %) (male/female), respectively, due to the lack of significant sources of this mineral in their ingredients. In contrast, the *Moroccan chicken tagine with olives and preserved lemons* provides 6.1 mg (76.7/33.8 %), and the *Tunisian couscous with meat and vegetables* reaches 6.8 mg (85.7/38.2 %). These dishes have higher iron levels due to the combination of animal and plant sources, such as chicken, beef brain meat, and chickpeas. Thus, the difference in iron content is since the French and Luxembourg recipes primarily use vegetables, while those from Morocco and Tunisia include meats and legumes, which enhance their iron content.

3.1.9. Antioxidants

In this section, antioxidant compounds are considered as micronutrients with antioxidant activity, specifically vitamins (C, E, A, folates, B_{12}) and minerals (zinc). These components contribute to cellular protection against oxidative stress while also supporting metabolic and physiological functions. The levels of antioxidants and nutrients in the selected dishes show significant variability, reflecting the differences in ingredients used in each recipe.

3.1.9.1. Zinc. For instance, zinc content varies considerably across dishes, from 0.3 mg in *ratatouille* to 6.8 mg in *Tunisian couscous with meat and vegetables*. This variability is due to the presence of legumes, meat, and vegetables, which contribute varying the amounts of this mineral. Contributes to normal metabolism, immune function, the maintenance of tissues (bones, skin, hair, nails, vision), and protection against oxidative damage (Commision Regulation, 2012).

3.1.9.2. Folates. The recipes for *Königsberger meatballs* and *Moroccan couscous with beans and olive oil* (82.4 and 81.6 μg, respectively) stand out for having the highest levels of folates, due to the inclusion and combination of ingredients such as eggs, stale bread, beans, and couscous. Approximately 20 % in both cases of the DRI. However, all the other recipes, except for Morocco, exceed the threshold to be considered a significant source (15 % of the daily value per portion). Folates contribute to blood cell formation, normal metabolism (homocysteine, amino acids), immune function, psychological function, and cell division … (Commision Regulation, 2012).

3.1.9.3. Vitamin B_{12}. Spain and Tunisia stand out for their vitamin B_{12} content (7.9 and 11.2 μg; 330.1 and 465.1 % DRI, respectively). Both dishes contain beef or chicken, which are rich sources of this vitamin, giving them higher nutritional composition. Notably, the high values in the Tunisian recipe are primarily due to the use of beef brains. Contributes to energy and homocysteine metabolism, nervous and immune system function, red blood cell formation, psychological function, cell division, and helps reduce tiredness and fatigue (Commision Regulation, 2012).

3.1.9.4. Vitamin C. Vitamin C levels fluctuate between 11.4 mg in *judd with broad beans* and 61.2 mg in *Moroccan chicken tagine with olives and preserved lemons* (12.6/15.2 and 68/81.7 % DRI) (male/female), with dishes that include a higher proportion of fresh vegetables (being good dietary sources) generally showing higher values. Supports immune function, energy metabolism, nervous and psychological function, collagen formation, antioxidant protection, fatigue reduction, and iron absorption (Commision Regulation, 2012).

3.1.9.5. Vitamin A. Vitamin A varies significantly between Algeria and Morocco, with values of 49 and 757.8 μg, respectively (5.4/6.8 and 84.2/108.4 % DRI) (male/female). The *Moroccan chicken tagine*, with its blend of spices and meat, is a much richer source compared to the *Algerian couscous with broad beans*. In line with this, carotenoids are found in higher concentrations in France and Morocco, with values of 2658.5 and 4546.4 μmol/portion in *ratatouille* and *chicken tagine with olives and preserved lemons*, respectively, due to ingredients like carrots, peppers, and spices that provide carotenoids. Supports iron metabolism, maintenance of mucous membranes, skin and vision, immune function, and cellular differentiation (Commision Regulation, 2012).

3.1.9.6. Vitamin E. Finally, Vitamin E levels also vary, ranging from 0.6 mg (4.1 % DRI) in Luxembourg to 4.7 mg in Morocco and Tunisia (31.3 %). In these latter dishes, the higher content is partly due to the use of healthy fats like EVOO, common in North African cuisine. This vitamin helps protect cells against oxidative damage (Commision Regulation, 2012).

3.2. Antioxidant properties in complete dishes

Several studies showed inconsistencies in the reported data. The variability in the methodologies applied to assess antioxidant capacity, particularly the use of different methods (ORAC and TEAC) and TP, led to substantial discrepancies in the reported values, hindering direct comparisons across studies. Moreover, a considerable proportion of the included works relied on secondary sources or on analyses performed with small, non-representative samples, which further limits the robustness of the findings. Overall, these limitations suggest that the current body of evidence does not allow for a fully reliable comparison of antioxidant capacity among recipes, highlighting the need for standardized methodologies and larger, well-designed primary studies.

There is a paucity of antioxidant properties data on complete dishes and only a small number of studies have addressed this information for Italian (Durazzo et al., 2017, 2019) and Spanish (González et al., 2019; Martínez-Zamora et al., 2021; Cuenca-Ortolá et al., 2023) traditional and popular recipes (see supplementary material SM1). In addition, not all the studies provide values of total antioxidants considering extractable and non-extractable values. For instance, considering TP and comparing only value of the extractable fraction, *Valencian paella* shows values of 28.0 mg GAE/100 g FW (Cuenca-Ortolá et al., 2023), lower than similar Spanish dishes like *rice with vegetables and cod* with 355.4 mg GAE/100 g FW (González et al., 2019). Italian dishes have higher values than *Valencian paella*, such as *carciofi alla romana* with 6643.4 *vs.* 292.4 mg GAE/100 g FW (Durazzo et al., 2017, 2019). Regarding the TAC, among the Italian dishes, *carciofi alla romana* stands out with a higher antioxidant potential with respect to the set analysed, measuring 82,668 μmol/100 g dry weight (DW) determined by the Ferric Reducing Antioxidant Power (FRAP) method (Durazzo et al., 2017, 2019), which is higher than *Valencian paella* with 1286.8 μmol Trolox/100 g DW determined by the TEAC method. For other Spanish dishes, only extractable values are available and the *rice with vegetables and cod* stands out as the dish with the highest TAC, measuring 4455.1 μmol Trolox/100 g DW using the ORAC method (González et al., 2019), compared to 3556.3 μmol Trolox/100 g DW in *paella* (Cuenca-Ortolá et al., 2023). However, another study (Martínez-Zamora et al., 2021) quantified the TAC of a *vegetable paella* that showed an ORAC value of 24,470 μmol Trolox/100 g FW, slightly lower than *Valencian paella* with 27,153.4 μmol Trolox/100 g FW.

In the present study, values of TAC (TEAC and ORAC) and TP are shown in Tables 4–6 are presented based on estimations derived from the ingredients of each recipe. These three tests encompass the three main mechanisms by which antioxidants act, enclosing the direct reaction with radicals and the chelation of free metals: H atom transfer, single electron transfer and metal chelation. However, it should be noted that TEAC, ORAC, and TP mainly assess radical scavenging and do not directly measure metal chelation. Methods such as FRAP assess iron-reducing capacity, which can reflect metal-chelating potential. Therefore, the chelating activity cannot be directly inferred from the TPC, TEAC, or ORAC values reported here. For an evaluation of antioxidant properties, the use of at least two or three assays for standardization is recommended, and only the first two mechanisms were assessed in this study (Durazzo et al., 2019).

TAC of the selected recipes was compiled by, TEAC, ORAC and TP. It is important to mention that the results collected reflect only the extractable antioxidant fraction (aqueous-organic extract) of the foods in each recipe. Additionally, antioxidant values are not available for all the ingredients used. As a result, the values may be underestimated due to the lack of complete data on the antioxidant capacity of all the components.

3.2.1. TEAC

By the TEAC method, Spain stands out with the *torrijas with horchata* recipe, which shows the highest antioxidant capacity, with 1825.9 μmol Trolox/100 g FW (Table 4). This high value is mainly due to the tiger nut, an ingredient known for its richness in phenolic compounds and other antioxidants. It contains tannins, flavonoids and other polyphenols, which are highly effective in neutralizing free radicals (Zhang and Sun, 2023). Additionally, although to a lesser extent, other ingredients like eggs, bread and sunflower oil also contribute to the TAC of this recipe (Pellegrini et al., 2003; Nimalaratne and Wu, 2015; Meral and Erim Köse, 2019).

Table 4
Total polyphenols and antioxidant capacity of recipes from Mediterranean European Countries using the TEAC and ORAC methods.

Mediterranean European Countries		TEAC (μmol Trolox/ 100g FW)	ORAC (μmol Trolox/ 100g FW)	Total Polyphenols (mg GAE/100g FW)
FRANCE	Ratatouille	364.5	1735.3	91.4
	Fish stew	311.7	2433.9	73.2
	Cassoulet	91.7	2583.1	303.4
	Basque pepper stew	597.0	1471.1	169.9
	Meatballs with sauce	225.4	5027.0	410.1
	French beef stew	109.8	6283.4	173.7
	Tielle sétoise	226.5	2703.3	91.5
	Basque cake	71.5	4443.1	50.4
ITALY	Stewed dolphinfish	209.3	2198.0	92.4
	Sardine meatballs	219.1	6697.2	139.0
	Green olives pate	949.0	5104.3	251.3
	Raw of sea bream and croaker fish with mango and green olives	553.0	1447.3	136.9
	Sicilian caponata	145.0	683.5	205.8
	Bread and chickpea flour fritters	217.5	1159.7	90.1
	Margherita pizza	95.6	248.5	70.1
	Tiramisu	544.2	15,074.7	119.8
SPAIN	Garlic rabbit	213.2	2239.3	55.4
	Valencian hake	119.0	546.1	31.1
	Potato omelette	66.0	6113.2	43.3
	Fish suquet	99.6	947.3	10.4
	Valencian titaina	158.0	672.5	76.9
	Zarangollo	183.7	3643.1	43.0
	Valencian paella	373.3	12,898.1	84.1
	Torrija with horchata	1825.9	2826.7	45.2

TEAC: Trolox Equivalent Antioxidant Capacity; ORAC: Oxygen Radical Absorbance Capacity; GAE: Gallic Acid Equivalent; FW: Fresh Weight.

Other recipes, such as *olive tajine, Moroccan chicken vermicelli* and *Tunisian lentil soup* have similar antioxidant values (1271.9, 1107.0 and 1101.2 μmol Trolox/100 g FW, respectively) to *torrijas with horchata*. In the case of *olive tajine* and *Moroccan chicken vermicelli* animal proteins like chicken predominate, along with other ingredients with a low antioxidant contribution, such as butter (Echegaray et al., 2021). Although ingredients like garlic, cinnamon and almonds have high antioxidant properties, their contribution in these recipes is small, limiting their impact on the total value (Ninfali et al., 2005). On the other hand, *Tunisian lentil soup* has lentils, which are rich in antioxidants like phenolic compounds and flavonoids (Xu et al., 2007). Additionally, other ingredients like olive oil and tomato contribute with antioxidants but in limited amounts in the recipe.

Recipes with the lowest antioxidant capacity according to this method include the Tunisian dessert *assidat zgougou* with 35.9 μmol Trolox/100 g FW, a finding that is also confirmed by the ORAC and TP methods. This is followed by Spanish *potato omelette,* French *basque cake* and Italian *margherita pizza* with values of 66.0, 71.5 and 95.6 μmol Trolox/100g FW, respectively. In *assidat zgougou* most of the recipe is composed of water, flour, and sugar, which contribute with minimal antioxidants and although it contains almonds, their low proportion (10 %) does not significantly impact the TAC. *Potato omelette* is primarily made of potatoes which are not particularly rich in antioxidants, and

Table 5
Total polyphenols and antioxidant capacity of recipes from Mediterranean African Countries using the TEAC and ORAC methods.

Mediterranean African Countries		TEAC (μmol Trolox/ 100g FW)	ORAC (μmol Trolox/ 100g FW)	Total Polyphenols (mg GAE/100g FW)
ALGERIA	Rechta	271.6	3188.4	321.7
	White Chorba	376.0	13,797.9	410.6
	Mtewem	188.0	6162.0	95.2
	Dobara	292.8	8649.1	327.7
	Olive tajine	1271.9	2924.9	118.6
	Couscous with beans and olive oil	148.1	335.2	469.4
	Sweet lamb	138.8	3528.5	207.2
	Ej Jaouzina	249.9	2566.3	82.5
MOROCCO	Bissara	77.5	653.1	93.3
	Harira	255.4	1516.4	291.2
	Moroccan chicken vermicelli	1107.0	28,803.0	1620.6
	Chicken tagine with olives and preserved lemons	199.1	4723.1	315.3
	Moroccan lamb or beef tagine with peas and artichokes	111.6	4034.0	31.8
	Moroccan tagine with frances and honey	242.4	5373.3	384.8
	Beef tagine with apricots. prunes and almonds	369.0	9463.2	504.2
	Minichicken bastilla	318.4	8908.4	396.3
TUNISIA	Djerbian rice	303.5	5530.3	139.1
	Tunisian lentill soup	1101.2	5567.5	2646.5
	Ojja with merguez	901.5	2763.1	94.3
	Kafteji	221.9	3146.1	185.8
	Tunisian couscous with meat and vegetables	177.7	3308.1	96.4
	Mloukhia	236.5	3840.5	554.0
	Tunisian-kamounia	158.1	4331.8	66.1
	Assidat zgougou	35.9	1490.9	31.2

TEAC: Trolox Equivalent Antioxidant Capacity; ORAC: Oxygen Radical Absorbance Capacity; GAE: Gallic Acid Equivalent; FW: Fresh Weight.

Table 6
Total polyphenols and antioxidant capacity of recipes from Non-Mediterranean European Countries using the TEAC and ORAC methods.

Non-Mediterranean European Countries		TEAC (μmol Trolox/ 100g FW)	ORAC (μmol Trolox/ 100g FW)	Total Polyphenols (mg GAE/100g FW)
GERMANY	Gulasch	403.7	4633.8	118.1
	Königsberger meatballs	150.7	9823.2	358.3
	Pea Soup	144.5	4078.7	68.5
	Rice pudding with sugar and cinnamon	193.8	7597.9	212.0
LUXEMBOURG	Judd with broad beans	101.2	1037.5	378.0
	Green bean soup	97.5	792.2	282.1
	Plum tart	258.8	4031.4	255.7
	Tarte tatin with vainilla ice cream	960.0	6105.8	748.4

TEAC: Trolox Equivalent Antioxidant Capacity; ORAC: Oxygen Radical Absorbance Capacity; GAE: Gallic Acid Equivalent; FW: Fresh Weight.

although it includes EVOO and onion, their quantities are insufficient to have a notable effect. *Basque cake* is made of flour, sugar, butter and eggs, all with low antioxidant content and without additional ingredients like fruits or spices that could enhance this value. Finally, *margherita pizza* includes tomato sauce and EVOO, which do contain antioxidants, but their proportion is very low compared to the amount of dough and mozzarella cheese, reducing their overall impact on antioxidant capacity (Ninfali et al., 2005).

3.2.2. ORAC

The antioxidant capacity values (ORAC) of the analysed recipes show significant variations between different cultures and dishes. According to the data obtained, the recipe with the highest ORAC value is *Moroccan chicken vermicelli,* with 28,803.0 μmol TE/100 g FW, while the lowest value is found in *margherita pizza* (Italy), with 248.5 μmol TE/100 g FW. Moroccan recipes, along with those from other African Mediterranean countries, stand out for their intensive use of spices and fresh herbs rich in antioxidants (Ninfali et al., 2005), such as cinnamon, cumin, ginger, turmeric, coriander, and mint. Additionally, the inclusion of dried fruits like dates, figs, and nuts, along with olive oil, contributes to the high antioxidant values recorded in these recipes.

European Mediterranean countries, such as Spain and Italy, exhibit slightly lower antioxidant values compared to African Mediterranean countries. Nevertheless, their antioxidant content remains substantial, owing to the frequent use of ingredients such as EVOO, fresh fruits, and vegetables, albeit with a somewhat lower diversity of spices and herbs. For example, *Spanish paella*, with a value of 12,898.1 μmol TE/100 g FW, shows a high concentration of antioxidant ingredients such as tomatoes, peppers, and EVOO, but its values are lower than those of Moroccan recipes. Compared to the *rice and vegetables with cod* recipe reported by González et al. (2019), which has 4455.1 μmol TE/100 g FW, the *paella* shows a significantly higher value. Other recipes, like *zarangollo*, show a value of 844.5 μmol TE/100 g FW (González et al., 2019), while in our study (Table 4), a higher value of 3643.1 μmol TE/100 g FW is reported. This difference may be attributed to variations in ingredients, such as the types of fresh vegetables and oils used. Similarly, for *Murcian ratatouille*, the value of 1048.6 μmol TE/100 g FW obtained in their study (González et al., 2019) is considerably lower compared to recipes like the *Sicilian caponata* and the *Valencian titaina* (683.5 and 672.5 μmol TE/100 g FW, respectively) reported in the present work.

Regarding the omelettes, the *potato omelette* shows a value of 6113.2 μmol TE/100 g FW, significantly higher than the value of 682.6 μmol TE/100 g FW recorded for the *country omelette* in the work by González et al. (2019) and 13,700.0 μmol TE/100 g FW by Martínez-Zamora et al. (2021). The difference appears to be explained by the inclusion of onion in the *potato omelette* recipe, an ingredient rich in phenolic compounds that contributes to its antioxidant content.

Finally, for the fish recipes, *sardine meatballs* (Italy) show a value of 6697.2 μmol TE/100 g FW, significantly higher than the value of 1446.7 μmol TE/100 g FW for *cod meatball stew* (González et al., 2019). This difference can be explained by the high concentration of antioxidants in sardines, which are an excellent source (Nartea et al., 2023).

3.2.3. Total polyphenols

Regarding TP, recipes from Mediterranean African countries stand out for their high polyphenol content, with dishes such as *Tunisian lentil soup*, *Algerian couscous with beans and olive oil*, and *Moroccan chicken vermicelli* (2646.5, 1915.7 and 1620.6 mg GAE/100 g FW, respectively), reflecting the richness of these compounds, mainly due to the plant ingredients and spices. In comparison, European Mediterranean recipes generally show lower polyphenol levels, such as the Spanish *fish suquet* and *Valencian paella* (10.4 and 84.1 mg GAE/100 g FW). This is due to the greater reliance on animal-based ingredients, such as seafood and fish, and fewer antioxidant-rich ingredients like EVOO and vegetables in the proportion of the recipe. However, the comparative analysis by González et al. (2019) shows that in some recipes, such as *zarangollo*, the

differences between the experimental values (175.1 mg GAE/100 g FW) and those from bibliographic databases in our study (43 mg GAE/100 g FW) can be explained by variations in the ingredients used, such as the amount of EVOO and vegetables. Similarly, the *country omelette* shows a significant difference between the experimental value (277.9 mg GAE/100 g FW) and the bibliographic value for *potato omelette* in our study (43.3 mg GAE/100 g FW), suggesting that the quantities and types of ingredients, such as spices and vegetables, greatly influence polyphenol levels.

At the same time, some recipes, such as France's *meatballs with sauce*, which includes sauces rich in vegetables and spices, present a higher value of 410.1 mg GAE/100 g FW, demonstrating how the use of vegetables increases the antioxidant content. In comparison, dishes like *Murcian Ratatouille* and *Valencian titaina* (121.7 and 76.9 mg GAE/100 g FW), which are somewhat like Italian recipes like *Sicilian caponata* and *cod meatball stew* (205.8 and 203.6 mg GAE/100 g FW), show different polyphenol contents (González et al., 2019).

The studies conducted by Durazzo et al. (2017, 2019) provide a more comprehensive evaluation of antioxidant capacity, considering both the extractable and non-extractable fractions. In this regard, the *Italian torta di mele* presents a value of 490.1 mg GAE/100 g FW, which is lower than that of the Luxembourgish *tarte tatin*, with a value of 748.4 mg GAE/100 g FW. This discrepancy is mainly due to the composition of fresh ingredients, such as apples and plums, which in the Italian cake contain antioxidant compounds in non-easily extractable fractions. In contrast, the *tarte tatin*, whose evaluation is limited to a more accessible fraction of antioxidants, may reflect a higher concentration of easily extractable compounds or those more available for absorption, resulting in a higher overall value. This phenomenon highlights the importance of considering both the accessibility of antioxidants in ingredients and the evaluation method used when comparing the antioxidant capacity of different preparations.

According to Arruda et al. (2024), the average polyphenol contents in Brazilian lunches and dinners are 312.0 and 337.1 mg GAE/100 g FW, respectively, figures that some traditional Mediterranean recipes exceed. Dishes such as *couscous with beans and olive oil* in Algeria, *chicken vermicelli* in Morocco, and *lentil soup* in Tunisia (469.5, 1620.6 and 2646.5 mg GAE/100 g FW, respectively) contain significantly higher levels. In Mediterranean European countries, *green olive paté* in Italy and *cassoulet* in France provide 251.3 and 303.4 mg GAE/100 g FW, while in Spain, *Valencian paella* contains a lower level (84.1 mg GAE/100 g FW). In other European regions, dishes like *königsberger meatballs* from Germany and *judd with broad beans* in Luxembourg (358.3 and 378.0 mg GAE/100 g FW) are also notable sources. Thus, Mediterranean dishes generally offer higher and more diverse polyphenol content than the average Brazilian diet.

4. Limitations of the study

This work provides a comprehensive analysis of the nutritional composition and antioxidants present in various dishes from the traditional cuisine of different countries. However, it has some limitations: (i) only a selection of specific traditional MD recipes in 6 countries were included and may not be illustrative of the global MD gastronomy across the Mediterranean area; (ii) our study is a selection of dishes and not a complete menu, as the variety and combination of foods in a menu can influence antioxidant determination and nutritional composition; (iii) the recipes were not evaluated analytically in the lab and values were calculated using raw ingredients (not the whole dish), and may not capture the expected synergistic effect of the complete dish; (iv) it was not possible to differentiate between extractable and non-extractable antioxidants and polyphenols, thus underestimating the real antioxidant properties of the recipes; (v) the variability of the same dish's recipes across regions, preparation methods, or ingredient availability was not considered, which could influence the nutritional and antioxidant profile obtained; (vi) a single software (EasyDiet with the CESNID table) was applied for all analyses; and (vii) recipe selection was based on bibliographic sources and the research team's prior gastronomic knowledge, without experimental evaluation or focus group methods.

5. Conclusion and outlook

This study presents, for the first time, a compilation of the antioxidant properties in a selection of representative and popular dishes from the MD, which can serve as a basis for promoting a diet rich in antioxidants, associated with health benefits.

There is notable energy diversity among recipes from different regions, with dishes from Tunisia and Algeria offering higher caloric content compared to those from France and Luxembourg, which are lower in calories. Additionally, the predominance of EVOO in the dishes, common in the MD, is highlighted. In terms of vitamins and minerals, non-European Mediterranean recipes show higher levels of calcium, iron, and vitamin A, due to the combination of meats, legumes, and vegetables, while non-Mediterranean European dishes exhibit less variability. It is also important to consider limiting salt in certain recipes, such as Algerian *couscous*, and to promote higher plant protein consumption in dishes from countries like Tunisia and Germany.

The study also emphasizes that traditional MD recipes are rich in antioxidants and polyphenols, compiled using methods such as ORAC, TEAC, and TP. Morocco and Tunisia stand out for their high polyphenol content due to the abundant use of spices, herbs, and EVOO, while Spain is recognized for its dishes with high antioxidant capacity, like *Valencian paella*. African Mediterranean recipes stand out for their use of these antioxidant-rich ingredients, enhancing their antioxidant capacity compared to recipes from non-Mediterranean European countries, which show in general lower values.

Further research is needed in this field to expand the information on antioxidant properties in more MD recipes and to provide a quantitative analytical basis on TAC and TP. In fact, research is being conducted in this area as part of the MEDIET4ALL project, where selected traditional MD recipes are being cooked and analytically evaluated to measure antioxidants, to compare these data with the bibliographical values provided in this study. This will offer a more realistic view of the contribution of antioxidants in whole dishes, as the available research does not include enough information on this matter.

In conclusion, the study highlights the importance of the diversity of antioxidant properties in MD dishes, as well as the need to consider multiple factors to promote their adoption, as higher dietary TAC is associated with a lower risk of non-communicable chronic diseases.

CRediT authorship contribution statement

Marta Cuenca-Ortolá: Writing – original draft, Data curation. **Mónica Gandía:** Writing – review & editing, Supervision, Conceptualization. **Stefania Filice:** Writing – review & editing, Conceptualization. **Amparo Gamero:** Writing – review & editing, Project administration, Funding acquisition, Conceptualization. **Amparo Alegría:** Writing – review & editing, Supervision, Conceptualization. **Antonio Cilla:** Writing – review & editing, Supervision, Conceptualization.

Implications for gastronomy

Research on the content of total antioxidant capacity (TAC) and total polyphenols (TP) in traditional Mediterranean diet (MD) recipes have important implications for the field of gastronomy. For example, this study highlights the relevance of evaluating the antioxidant properties of complete dishes to better understand their nutritional value and impact on health. A holistic approach to identifying antioxidant properties of complex matrices such as ready-to-eat dishes can be more appropriate than analysing single ingredients since it may supply synergistic interactions. Furthermore, this approach can provide real nutritional and antioxidant properties of foods as are taken, often mixed

and heat treated. This information may also facilitate further nutrition-related studies and can be used to encourage the consumption of MD recipes from different regions that, for the first time, have been compiled in terms of nutritional values and antioxidant properties. Additionally, the importance of ingredient diversity and cooking techniques in the antioxidant content of dishes is emphasized, suggesting that the variety and freshness of ingredients play a significant role in the antioxidant activity of recipes. This research also underscores the influence of limiting factors such as the cost and availability of fresh foods, the time required to prepare recipes, and psychological and cultural factors in adherence to the MD. In summary, this research provides valuable insights for gastronomy by highlighting the importance of ingredient selection, preparation techniques, and dish diversity to promote a balanced and healthy diet plenty of antioxidants with potential association with lower risk of non-communicable chronic diseases.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijgfs.2025.101375.

Data availability

Data will be made available upon reasonable request to the corresponding author.

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