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An antioxidant 'database' for local food products from the Serres region in Greece

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Abstract. The consumption of local food products provides health benefits, supports local economies, fosters environmental sustainability and preserves cultural heritage. Indeed, consumers can have a positive impact on the economic activity of their communities and, overall, on the broader food system by purchasing local foods. Based on the above, the purpose of the present study was to evaluate the antioxidant capacity of various food products produced in the Serres region, in Greece. Towards this purpose, the free radical scavenging capacity of wines, grains, legumes, potatoes and cured meats was examined and compared with those of other food products from the Greek market that belong to the same general categories. According to the findings obtained, food products from Serres were effective in neutralizing the corresponding free radicals. The results that were exported contribute to creating an antioxidant 'database', that may be used to further assess experimental data on local food products. Collectively, the present study demonstrates the unique qualitative characteristics and the nutritional benefits of food products from the Serres region, thus providing added value and allowing them to compete with other local or trademark food products both nationally and globally.

Introduction

Nowadays, global food systems produce unprecedented quantities of food products at historically low prices; however, they rely on unsustainable agricultural practices. Nutritional quality and safety issues are regularly at the center of social interest, whereas the ever-growing environmental and public health awareness has resulted in increased consumer demands for better food origin orientation, food chain transparency and more regulatory audits in food production systems (1-3).

The quality of food products is associated with specific characteristics, such as the production method, the geographical location, the raw materials and the organoleptic properties. All these attributes motivate consumers to purchase local food products, that appear to have a more reliable production method. The local food market has become a necessity, and an increasing number of individuals prefer to consume fresh, locally-grown food for ensuring their health and wellness (4). This global phenomenon has attracted ample attention, particularly in developed countries (5), although the majority of the research has been carried out in the USA (3). Nevertheless, there is no single definition to describe local food (6). In broad terms, local food is food grown, sold and consumed within a limited geographical region (7,8). Additionally, this term refers to food products that embody the distinctive qualities of a specific location or have a special cultural significance in that area (9).

As regards the consumers criteria for the selection of local food products, the nutritional value, affected by crop variety, growing process, ripeness at harvest, storage, processing and packaging play a fundamental role. Furthermore, previous research has indicated that there are also other parameters, such as societal or personal motivations, that affect the perception of consumers towards local food products. For instance, self-beneficial motivations for local food purchasing is tastiness, freshness, underlying health issues (10-13) and security over conventional trademark food products due to traceability (14). Another key factor for establishing the decision of consumers is that locally-grown foods are environmental-friendly and support sustainable farming practices (10,15,16). In particular, they require less transportation, resulting in lower greenhouse gas emissions and in a reduced dependence on fossil fuels (17). Additionally, local farmers often use sustainable farming practices, which promote biodiversity, conserve water and minimize the use of pesticides and fertilizers (18). The promotion of biodiversity prevents genetic erosion, hence ensuring the availability of diverse food options for future generations (19).

From an economic point of view, the consumption of local food products boosts regional economy by creating local jobs and by assisting small-scale farmers (20,21). Hence, it has the potential to aid in the growth of regional and national economy

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and, for this reason, it is critical for governments to prioritize the superiority and distinctiveness of local foods (21,22). It is worth mentioning that consumers are willing to pay more for locally produced foods when they are aware of their benefits (23). In addition, the scientific community is aware of the potential health advantages of local foods and can contribute to the enhancement of their market value. This is in line with the increased interest of consumers in local foods (24-26).

The city of Serres is the capital of the Regional Unit of Serres, the first inland under cultivation among the seven regional units of Central Macedonia. The Municipality of Serres has a number of comparative advantages, including a well-preserved natural environment of significant ecological value, rich biodiversity, mild climatic conditions, a unique combination of mountainous and plain regions, fertile soil and productive land offering almost all types of primary sector foodstuffs (https://www.serres.gr/greencrew/municipality-of-serres/). These particular characteristics render Serres one of the administrative and economic centers of Northern Greece, becoming a primary agricultural district and an important trade center for grain and livestock and contributing to the national Gross Domestic Product (GDP) at a rate exceeding 1.54% and to the regional GDP at 6.62%. Furthermore, Serres ranks first in beef production and second in grain production at the national level (https://www.serres.gr/greencrew/municipality-of-serres/; https://www.statistics.gr/en/statistics/agr).

The objective of the present study was two-fold; first, to investigate the antioxidant properties of wines, grains, legumes, potatoes and cured meat products, produced in the Serres region by evaluating their free radical scavenging capacity; and second, to compare their antioxidant activities with those of food products from the Greek market that belong to the same general categories. Towards this purpose, representative food products were randomly selected and purchased from a local market in Larissa, Greece. As regards starchy foods, the authors randomly selected Carolina rice, pasta screws from chickpea flour, traditional Greek noodles and potatoes. Concerning legumes, the authors randomly selected fine lentils, white beans, large chickpeas and peanuts. As regards cured meat products, the authors randomly selected boiled pork shoulder, boiled turkey, smoked turkey and sausage. Finally, with respect to wines, 4 red and 4 white wines were randomly selected, produced from various regions across Greece and bottled in 750-ml wine bottles.

Materials and methods

Sample preparation

Homogenization of cured meat products. The homogenization of cured meat products was performed using a Minilys personal homogenizer (Bertin Technologies). In brief, each sample was weighed and 200 mg were mixed with 600 μl deionized water (diH_2O), and homogenized for 30 sec at the highest available speed. The homogenate was centrifuged (15,000 x g, 5 min, 4˚C) and the supernatant was collected, stored in aliquots, and maintained at -20˚C until analysis.

Preparation of extracts from legumes, pasta, pasta with vegetables and rice. Each sample was weighted and 2 g were added to 15-ml conical centrifuge tubes and mixed with diH_2O until reaching a volume of 15 ml. The samples were incubated overnight at room temperature (RT). Following incubation, the volume of diH_2O absorbed per sample was estimated and a specific volume of diH_2O was added to achieve a 1:4 dilution ratio. The samples were then homogenized and centrifuged (5,000 x g, 10 min, 10˚C). Finally, the supernatant was collected, stored in aliquots and maintained at -20˚C for further analysis.

Preparation of extracts from potatoes. Each sample was weighed, 2 g were cut into slices, and a specific volume of diH_2O was added to achieve a 1:4 dilution ratio. The samples were then homogenized and centrifuged (5,000 x g, 10 min, 10˚C). The supernatant was collected, stored in aliquots, and maintained at -20˚C for further analysis.

Preparation of wines. A total of 26 wines, including 12 red wines and 14 white wines, produced in the Serres region, were opened, and each wine was stored into aliquots and maintained at 4˚C until analysis.

2,2-Diphenyl-1-picrylhydrazyl radical (DPPH·) scavenging assay. The DPPH· radical scavenging capacity was examined using the method of Brand-Williams *et al* (27) with minor modifications, as previously described (28). Briefly, 50 μl of each sample, diluted at various concentrations in diH_2O, were mixed with 900 μl methanol (MeOH) (PanReac AppliChem, ITW Reagents) and 50 μl of a methanolic DPPH· solution (2 mM) (Alfa Aesar). Furthermore, 1 ml MeOH was used as a blank and 950 μl of MeOH mixed with 50 μl of DPPH· solution was used as a negative control. The samples were vortexed and incubated for 20 min in the dark at RT. Finally, the optical density (OD) was monitored at 517 nm using a UV/Visible spectrophotometer (U-1500, Hitachi, Ltd.). The radical scavenging capacity percentage (% RSC) was determined using the following equation:

$$\% RSC = \frac{(ODcontrol - ODsample)}{ODcontrol} x\ 100$$

To compare the free radical scavenging capacity of the different samples, the half maximal inhibitory concentration (IC50) was calculated, representing the concentration of the sample required for the neutralization of 50% of free radicals. Therefore, the lower the IC50 value, the greater the antioxidant capacity.

Statistical analysis. As aforementioned, for the comparison of the antiradical activities between different samples, the IC50 value of each food product was calculated by plotting the % RSC vs. the respective sample concentration. All analyses were carried out in triplicate and on least in two separate occasions. The IC50 values of the food products belonging to the same general category were then pooled together to calculate the mean IC50 value. Welch's t-test was performed to compare the mean IC50 value between local products from the Serres and food products from the Greek market. All results are expressed as the mean ± standard deviation (SD) and a value of $P<0.05$ was considered to indicate a statistically significant difference. All statistical analyses were performed using GraphPad Prism version 8.0.1 software for Windows (GraphPad Software, Inc.).

Table I. DPPH· scavenging capacity of local food products from Serres and other food products from the Greek market.

Local food products from Serres	IC50 (mg/ml) of Serres products	Mean IC50 (mg/ml) of Serres products	Mean IC50 (mg/ml) of other products from Greek market	t-test P-value
Cured meat products				
Kavourmas	19.6±1.2	15.43±6.75	32.4±4.3	0.0078[a]
Smoked sausage	6.9±0.3			
Buffalo meat	21.9±2.4			
Iraklias sausage	13.3±0.8			
Legumes				
Lentils	3.3±0.2	13.80±12.31	24.3±5.4	0.1906
Beans	31.5±2.2			
Chickpeas	11.8±0.9			
Peanuts	8.6±0.5			
Starchy foods				
Pasta with vegetables	25.7±0.2	46.20±28.67	52.1±28.0	0.7774
Pasta	47.5±2.3			
Potatoes	25.3±0.6			
Rice	86.3±0.4			

All results are expressed as the mean ± SD of two independent experiments. [a]$P<0.05$, indicates a statistically significant difference.

Results

The antioxidant capacity of the different food products from the Serres region was assessed using the DPPH· scavenging assay. According to the results obtained, all local food products were effective in scavenging the corresponding free radicals, supported by their low IC50 values. Furthermore, the food products from the Serres region exhibited either more potent or comparable antioxidant activities to other food products from the Greek market. More specifically, the IC50 values of the cured meat products from Serres ranged from 6.9 to 21.9 mg/ml, whereas the mean IC50 value of other Greek cured meat products was 32.4±4.3 mg/ml. Among these, the most potent DPPH· radical scavenging activity was exhibited by the smoked sausage. Additionally, a statistically significant difference was observed between the mean IC50 value of the cured meat products from Serres and the Greek market (Table I).

As regards legumes from Serres, the IC50 values ranged from 3.3 to 31.5 mg/ml, while lentils exhibited the most potent efficacy to neutralize the corresponding free radicals. Contrariwise, the mean IC50 value of the Greek legumes was 24.3±5.4 mg/ml, indicating that most legumes from Serres had lower IC50 values. However, no statistically significant difference was observed between the mean IC50 value of legumes from Serres and the Greek market (Table I).

Concerning starchy foods, the IC50 values of food products from Serres ranged from 25.3 to 86.3 mg/ml, whereas the mean IC50 value of starchy food from the Greek market was 52.1±28.0 mg/ml. In particular, potatoes exhibited the most potent scavenging activity among the starchy foods, which however, was comparable with that of pasta with vegetables. Overall, starchy food products from Serres demonstrated a greater antioxidant activity than the other products from the Greek market, apart from rice. However, when all the data were pooled together, no statistically significant difference was observed in the mean IC50 value of starchy foods from Serres and the Greek market (Table I).

With respect to wines produced in the Serres region, the results demonstrated that the red wines exerted more potent antiradical activities than the white wines. It is worth mentioning that the IC50 values of the white wines exhibited a marked variation (Table II). In addition, all red wines from Serres exhibited greater free radical scavenging capacity than the other red wines from the Greek market. The same applied in most cases to the white wines produced in the Serres region as compared to the white wines from the Greek market. Nevertheless, no statistically significant differences were observed between the mean IC50 values of wines from Serres and the Greek market.

Discussion

The global food system is under immense pressure, as a result of the growing population, rising income levels and urbanization (29). Therefore, the production and consumption of local food products poses an attempt at counteracting the negative impact of globalization on regional economies (17). Consumers are becoming increasingly concerned about the safety and health benefits of their foods (30-32). The firm convictions that locally grown food is healthier, more tenable and environmentally friendly have been the driving forces behind the increased interest in local food products over the past decade among consumers, social movements and the media (33). At the same time, governments have focused on local foods to boost economic growth, while the research community has concentrated on the evaluation of their potential health benefits (17,34,35). Therefore, a large number of individuals select

Table II. DPPH· scavenging capacity of wines from Serres and other wines from the Greek market.

Local wines from Serres	IC50 (μl/ml) of Serres wines	Mean IC50 (μl/ml) of Serres wines	Mean IC50 (μl/ml) of other Greek wines	t-test P-value
Red wines (code nos.)				
1	3.3±0.2	2.39±0.57	3.5±2.9	0.4813
2	3.2±0.2			
3	3.1±0.2			
4	2.8±0.1			
5	2.3±0.2			
6	2.2±0.2			
7	2.2±0.1			
8	2.1±0.1			
9	2.0±0.1			
10	1.9±0.1			
11	1.9±0.04			
12	1.6±0.1			
White wines (code nos.)				
1	79.8±3.3	31.44±20.98	49.1±20.9	0.1976
2	65.0±1.0			
3	39.0±1.0			
4	39.0±2.5			
5	38.1±0.9			
6	36.9±0.3			
7	29.2±1.3			
8	27.9±0.7			
9	28.1±0.7			
10	15.4±1.0			
11	12.3±0.4			
12	11.1±0.4			
13	11.0±0.9			
14	7.3±0.7			

All results are expressed as the mean ± SD of two independent experiments.

to consume local foods (3,8,33). However, the assumptions of the health advantages of local food products are mainly based on perceptions rather than on evidence, given the fact that thorough experimental data are generally lacking.

In this context, the authors created a 'database' for the antioxidant capacity of different local foods produced in Serres, one of the executive and economic centers of Northern Greece. Antioxidants, free radicals and their associations with oxidative stress are concepts regularly used to explain the molecular mechanisms of various chronic diseases (36). It has been hypothesized that dietary antioxidants represent the 'cure' for the high levels of oxidative modifications by preventing from excessive generation of free radicals, rendering them potent protective agents for the treatment and prevention of diseases triggered by oxidative stress (37).

In the present study, the antioxidant properties of legumes, starchy foods, cured meat products and wines from the Serres region in Greece were investigated on the basis of their antiradical activities. Although the high nutritional value of legumes is indisputable, they also contain significant quantities of polyphenolic compounds and vitamins that enhance food quality, and exert beneficial effects on human health by preventing from diseases, such as diabetes, obesity and cardiovascular diseases (38,39). Starchy foods are the main source of energy in the human diet as they rapidly provide glucose (40-42). As regards cured meat products, they contain several minerals and vitamins, as well as essential amino acids, rendering them an excellent source of proteins (43-46). Finally, wine, an alcoholic beverage derived from the fermentation of ripe and fresh grapes and consumed in the Mediterranean diet, improves human health and longevity (47-49).

Geographical and climatic conditions are major factors affecting the growth, phytochemical composition and bioactivity of foods. The region of Serres is flat and semi-mountainous with a humid subtropical climate, which borders on a cold semi-arid climate. In particular, the summers are hot and dry, while the winters are cold, though rarely frigid and snowy. There is no discernible dry season and the rainfall is low throughout the year with an erratic pattern.

Herein, the potential antioxidant activity of local food products from Serres was assessed using DPPH· scavenging assay. DPPH· is a synthetic free radical commonly used for the immediate estimation of antioxidant activity (50). The results of the present study demonstrated that local food products were effective scavengers of DPPH· radicals. Among the food categories, smoked sausage, lentils and potatoes were the most effective, as indicated by the lower IC50 values. Concerning lentils and pasta with vegetables, they are not only excellent sources of micronutrients, but they are also rich in polyphenols (51,52). Previous studies have demonstrated that their high antioxidant activity is strongly associated with their phenolic content (53,54).

Winemaking has increased considerably in Serres over the past few years. Indigenous and international grape varietals are cultivated for the production of a wide range of wines, renowned for their distinction, elegance and refinement. The soil types, grape varietals and procedures used by winemakers determine the signature style of local wines. In the present study, as regards their antioxidant properties, the red wines exhibited more potent antiradical activities than the white wines. Furthermore, the red wines produced in Serres were more effective in scavenging the corresponding free radicals than the other red wines from the Greek market, as evidenced by the lower IC50 values. The same phenomenon was observed in the majority of the white wines from Serres.

Several research studies have attempted to investigate the potential health benefits of local food products towards the creation of experimental data on their inherent properties, thus enabling consumers and producers to monitor food quality. In this case, the assessment of their biological activities could enhance product quality and provide added value in global market. Researchers worldwide have investigated and established experimental protocols for examining the possible health benefits of local food products (55-61). Furthermore, several studies have focused on various Greek products, such as dairy products (62,63), honey (64-67), olives and olive oil (28,68-70), and wines (71,72) for exporting experimental data on their biological effects *in vitro* and *in vivo*.

Based on the results of the present study, food products from Serres exhibited potent antioxidant activities, as they were particularly efficacious in scavenging the corresponding free radicals. These results indicate that local foods can compete with other food products from national and international market. More specifically, wines from Serres had comparable or even higher antioxidant activities than other wines from the Greek market (72). Moreover, legumes from Serres exhibited lower IC50 values than other Greek legumes from a previous study (73), showcasing their high antioxidant potential. Finally, rice from Serres exhibited a greater antioxidant capacity than other similar food products from abroad (74).

In conclusion, the consumer demands for safer and healthier food products has motivated the scientific community to investigate the possible health benefits of local foods. The present study evaluated the antioxidant properties of food products from Serres, on the basis of their antiradical activities and compared them with those of other food products from the Greek market. According to the results obtained, food products from Serres were effective scavengers of DPPH· radicals and their free radical scavenging capacity was either comparable or even higher than that of the other examined products from the Greek market. The findings presented herein unravel their unique qualitative characteristics. In this manner, local food products gain additional value, identity and the ability to compete with other local or trademark products both nationally and globally.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

DK conceptualized and supervised the study, and was also involved in project administration. TK, FT, PV and ZS were involved in the study methodology. TK, PV and ZS were involved in data validation, formal analysis and data curation. TK, FT and ZS were involved in the writing and preparation of the original draft. PV was involved in the writing, reviewing and editing of the manuscript. All authors have read and approved the final manuscript. ZS and DK confirm the authenticity of all the raw data.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

DK is an Editor of the journal, but had no personal involvement in the reviewing process, or any influence in terms of adjudicating on the final decision, for this article. The other authors declare that they have no competing interests.

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