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# Concentrations of resveratrol and derivatives in foods and estimation of dietary intake in a Spanish population: European Prospective Investigation into Cancer and Nutrition (EPIC)-Spain cohort

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Resveratrol has been shown to have beneficial effects on diseases related to oxidant and/or inflammatory processes and extends the lifespan of simple organisms including rodents. The objective of the present study was to estimate the dietary intake of resveratrol and piceid (R&P) present in foods, and to identify the principal dietary sources of these compounds in the Spanish adult population. For this purpose, a food composition database (FCDB) of R&P in Spanish foods was compiled. The study included 40 685 subjects aged 35–64 years from northern and southern regions of Spain who were included in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Spain cohort. Usual food intake was assessed by personal interviews using a computerised version of a validated diet history method. An FCDB with 160 items was compiled. The estimated median and mean of R&P intake were 100 and 933 μg/d respectively. Approximately, 32 % of the population did not consume R&P. The most abundant of the four stilbenes studied was *trans*-piceid (53·6 %), followed by *trans*-resveratrol (20·9 %), *cis*-piceid (19·3 %) and *cis*-resveratrol (6·2 %). The most important source of R&P was wines (98·4 %) and grape and grape juices (1·6 %), whereas peanuts, pistachios and berries contributed to less than 0·01 %. For this reason the pattern of intake of R&P was similar to the wine pattern. This is the first time that R&P intake has been estimated in a Mediterranean country.

**Resveratrol: Food composition databases: Intake: Wine: European Prospective Investigation into Cancer and Nutrition (EPIC)-Spain**

Resveratrol (3,5,4′-trihydroxystilbene) is the parent compound of a family of molecules, including glycosides (piceid) and polymers (viniferins), existing in *cis* and *trans* configurations classified as stilbenes[1]. The essential structural skeleton comprises two aromatic rings linked by a methylene bridge (Fig. 1).

Resveratrol and piceid (R&P) are mainly present in grape and wine derivatives and their composition is affected by grape cultivar, degree of maturity at harvest, fungal pressure, climate and wine-making technology[2,3]. Secondary food sources of stilbenes are peanuts, pistachios and berries[4–7]. Recently R&P were also detected in the skin of tomatoes, although the concentrations are 3000 times lower than those found in red table grapes, and R&P have not been found in all kinds of tomato[8]. The importance of R&P food sources depends on food composition and the amount of consumption of them (standard serving size: grapes, 150 g; wine, 125 ml; berries and peanuts, 30 g). The total qualitative and quantitative R&P profile is also affected by the source: *trans*-piceid is mainly present in red and white wines and grape juice; *cis*-piceid in rosé and sparkling wines and *trans*-resveratrol in grapes, berries, peanuts and pistachios[4–7,9–11]. Until now, viniferins have only been described in grape derivatives[12,13].

Resveratrol is of great interest in nutrition and medicine due to its potential health benefits, such as anti-carcinogenic[14,15], neuroprotector[16] and antioxidant effects[17], as a modulator

**Abbreviations:** EPIC, European Prospective Investigation into Cancer and Nutrition; FCDB, food composition database; R&P, resveratrol and piceid.
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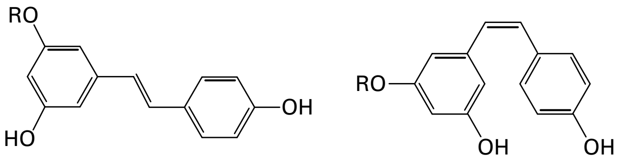

(a) R = OH (b) R = OH
(c) R = glucose (d) R = glucose

**Fig. 1.** Structures of resveratrol and derivatives: (a) *trans*-resveratrol; (b) *cis*-resveratrol; (c) *trans*-piceid; (d) *cis*-piceid.

of lipid and lipoprotein metabolism, as an antiplatelet aggregator[18] and its oestrogenic activity[19]. Indeed, it has been hypothesised that resveratrol uses the same pathways activated by energy restriction[20–22]. The biological effects have been studied mainly *in vitro*, although there is also growing *in vivo* evidence[20]. Some effects required a high concentration of resveratrol in tissues, although chemopreventive and chemotherapeutic anticancer effects are an exception[14,15]. In this case, resveratrol, at micromolar concentrations, affects the activity of transcriptional factors involved in proliferation and stress responses and leads to the modulation of survival and apoptotic factors in carcinogenesis[14,15]. In atherosclerotic and neurodegenerative diseases, the effects of resveratrol are not only due to its antioxidant and scavenging activities, but also to its participation in the modulation of signal transduction pathways and in the activation of several enzymes at micromolar concentrations[14,23,24].

The pharmacological effects are consistent with the resveratrol concentration in plasma, LDL and urine after oral administration in human subjects[25–32]. The biological effect of resveratrol will ultimately depend on the cellular effects of the circulating metabolites that are effectively absorbed (glucuronides and sulfates)[30] and not on the native forms in food[33,34]. However, other authors have speculated that resveratrol metabolites may become deconjugated at the target sites of action, thereby releasing aglycone to elicit biological activity[15,35].

Intake values of *trans*- and *cis*-resveratrol and piceids are not available either since there is no complete food composition database (FCDB) of R&P. The aim of the present study was to compile composition data of R&P in common Spanish foods and to evaluate major food sources and their daily intake in the Spanish adult population.

## Materials and methods

### *Population*

Dietary data and other lifestyle factors from 41 440 subjects, aged 29–69 years, who participated in the European Prospective Investigation into Cancer and Nutrition (EPIC) in Spain, were studied. Participants were healthy volunteers, blood donors principally, recruited between October 1992 and July 1996 in five Spanish regions: three from the North (Asturias, Navarra and Gipuzkoa) and two from the South (Murcia and Granada)[36]. After the exclusion of 755 subjects because of implausible dietary information, the final population studied consisted of 40 885 subjects (15 448 men and 25 237 women) aged 35–64 years. The mean ages at recruitment were 50·8 and 48·4 years for men and women, respectively.

### *Dietary information*

Usual food intake during the preceding year, taking into account seasonal variations, was estimated by personal interview using a computerised diet history questionnaire. This was developed and validated specifically for the EPIC study in Spain[37,38]. The questionnaire was structured according to occasion of food intake (breakfast, lunch, dinner). Trained interviewers gathered data on preparation method, average frequency of consumption per week, and usual portion size for each food consumed at least twice per month (or once per month for seasonal foods). Portion sizes were reported in natural units, household measures or with the aid of a manual of thirty-five sets of photographs prepared specifically for the study. The questionnaire included a list of more than 600 foods and beverages and about 150 regional recipes. For each food described, the final amount consumed was calculated, taking into account the cooking method used and the edible part consumed.

### *Food composition database*

A literature search was conducted in MEDLINE (United States National Library of Medicine, 2006) and in the Food Science and Technology Abstracts (International Food Information Service, 2006) to identify sources of resveratrol compounds in Spanish foods in published food composition data. The search terms included resveratrol, piceid, food composition, food, wine, berry, peanuts, pistachios and tomato. Review papers that did not contain new primary data were excluded. However, the citations used in these reviews were cross-checked with initial literature searching to identify any additional references.

The following information was extracted from each publication: (1) food information: name, food description, scientific name and country of the study; (2) measurement information: value, type of value (mean, median, range, other), number of samples, sampling method and analytical method; (3) bibliographic reference. With this information we assessed the data quality for inclusion in the Database following the key points originally developed in the EU-AIR NETTOX Project[39].

The appropriate methods of analysis were HPLC diode array or GC/MS. When *cis*- and *trans*-piceid were quantified by spectrophotometric method and were expressed as resveratrol, conversion factors were applied: × 1·57 and × 1·75 for *trans*- and *cis*-piceid, respectively. These factors were calculated using the relationship between the molar absorptivities of *trans*-resveratrol (UV λ (10 % ethanol) nm (ε) 306 (31 800/M/cm))[40] and *trans*-piceid (UV λ (10 % ethanol) nm (ε) 306 (20 100/M/cm)) (R Zamora-Ros *et al.*, unpublished results), and the relationship between *cis*-resveratrol (UV λ (10 % ethanol) nm (ε) 286 (13 100/M/cm))[40] and *cis*-piceid (UV λ (10 % ethanol) nm (ε) 286 (7500/M/cm)) (R Zamora-Ros *et al.*, unpublished results), respectively.

Units of measurements and modes of expression varied across the studies. To standardise, values were converted into mg/100 g fresh weight. Data for similar foods were aggregated as weighted means, taking into account the number of samples, sampling plan and frequency of consumption of Spanish foods[41].

When we did not find Spanish food values for important sources of resveratrol such as peanuts, pistachios or berries we selected foreign food values. Other unknown values were estimated using a biologically similar food or calculating recipes. Despite the use of other countries' and estimated values, data were still not available for some foods.

### *Statistical analyses*

Distributions were expressed as means, standard deviations, medians, and as 25th and 75th percentiles, and were measured separately for men and women. Because R&P intakes were skewed toward higher values, we used median values to compare results. The average estimates of dietary intakes were standardised by sex and age of the Spanish population aged 35–64 years[42]. The contribution of each food to the total intake of individual and total R&P was calculated as a percentage.

To assess the differences in R&P intake with respect to the categories of age, region, educational level, tobacco smoking, BMI and energy intake, estimations of the proportion of consumers and R&P median intake among consumers were calculated using linear regression analysis, respectively. All these models were adjusted by sex, age, region, BMI and energy intake (kJ/d). To perform the linear regression analysis, a Box–Cox transformation of the response variable was necessary to observe the assumptions of the model, and the inverse transformation was applied to the resulting estimates to interpret them as medians[43]. Data were analysed with the R language and environment for statistical computing and graphics[44].

## Results

### *Food composition database*

Resveratrol values from fifty-four studies were used to compile the final food database. The compilation included 160 food items with information on the concentrations of *trans*- and *cis*-resveratrol, *trans*- and *cis*-piceid and sum of R&P. Table 1 summarises the resveratrol content from all references compiled for all the common Spanish foods considered. Red wine (0·847 mg/100 g) and itadori tea (0·974 mg/100 g) were the highest sources of R&P, but itadori tea is not consumed in Spain. Intermediate sources of R&P (0·08–0·547 mg/100 g) corresponded to other kinds of wine, grapes, grape juice and peanut butter. Lowest sources of R&P (< 0·01 mg/100 g) were peanuts, pistachios and berries.

### *Estimated resveratrol intake*

Table 2 shows the mean and median values and percentiles of *trans*- and *cis*-resveratrol, *trans*- and *cis*-piceid and total reveratrol intake by sex in the studied population. Average intake of R&P was 933 μg/d, with a median of 100 μg/d. As indicated by the median and percentiles, the distribution was skewed to higher values. A total of 13 175 participants (39·0 and 20·0 % of total women and men standardised by sex and age of the Spanish population respectively) had a total resveratrol intake of 0 μg/d (non-consumers). *trans*-Piceid contributed 53·7 % of total resveratrol intake, *trans*-resveratrol 20·8 %, *cis*-piceid 19·3 % and *cis*-resveratrol 6·2 %.

Table 3 shows the differences in R&P intake according to sex, age, geographic area, energy intake, BMI, education and tobacco smoking. Medians and percentages of consumers were adjusted by sex, age, BMI, region and energy consumption. R&P consumption was lower in quantity and percentage of women consumers (137 μg/d and 61·0 %) than in men (686 μg/d and 80·0 %). Mean of R&P and percentage of

**Table 1.** Food composition data sources for resveratrol content (mg/100 g fresh weight)

| Food item | *trans*-resveratrol | *cis*-resveratrol | *trans*-piceid | *cis*-piceid | Total resveratrol | References |
|---|---|---|---|---|---|---|
| Wine, not specified | 0·114 | 0·037 | 0·303 | 0·105 | 0·558 | Calculated* |
| Red wine | 0·181 | 0·044 | 0·495 | 0·127 | 0·847 | Lamuela-Raventós *et al.* [10], Moreno-Labanda *et al.* [46], Goldberg *et al.* [60], Rodriguez-Delgado *et al.* [61] |
| Rosé wine | 0·041 | 0·041 | 0·071 | 0·154 | 0·307 | Romero Perez *et al.* [11] |
| White wine | 0·010 | 0·016 | 0·26 | 0·022 | 0·074 | Romero Perez *et al.* [11], Rodriguez-Delgado *et al.* [61], Álvarez-Sala *et al.* [62], Martinez-Ortega *et al.* [63] |
| Sparkling wine | 0·005 | 0·014 | 0·018 | 0·055 | 0·092 | Andres-Lacueva *et al.* [64], Pozo-Bayon *et al.* [65] |
| Fortified wine | 0·110 | 0·095 | 0·141 | 0·040 | 0·386 | de Lima *et al.* [66], Goldberg *et al.* [67] |
| Grapes, not specified | 0·156 | – | 0·067 | – | 0·223 | Cantos *et al.* [9,68,69] |
| Red grapes | 0·250 | tr | 0·060 | – | 0·310 | Cantos *et al.* [9,68,69] |
| White grapes | 0·068 | tr | 0·025 | – | 0·093 | Cantos *et al.* [9,68] |
| Must | 0·070 | 0·012 | 0·465 | – | 0·547 | Vinas *et al.* [70] |
| Grape juice | 0·010 | tr | 0·036 | 0·043 | 0·088 | Martinez-Ortega *et al.* [63], Roldan *et al.* [71], Romero-Perez *et al.* [72] |
| Sangria† | 0·091 | 0·022 | 0·248 | 0·063 | 0·424 | Recipe |
| Peanuts, toasted | 0·006 | – | – | – | 0·006 | Sobolev & Cole[6], Lee *et al.* [47] |
| Pistachios, toasted | 0·007 | – | – | – | 0·007 | Tokusoglu *et al.* [7] |
| Peanut butter | 0·065 | nd | 0·014 | nd | 0·080 | Ibern-Gomez *et al.* [73] |
| Cranberry juice | tr | – | – | – | tr | Zhang & Zuo[74] |
| Berries‡ | 0·008 | – | – | – | 0·008 | Rimando *et al.* [5], Lyons *et al.* [75] |
| Itadori tea (infusion) | 0·068 | nd | 0·906 | nd | 0·974 | Burns *et al.* [4] |

tr, Traces; nd, not detected.
* Calculated from consumption of Spanish population: 57 % red wine, 25 % white wine and 18 % rosé wine.
† Recipe of sangria (typical Spanish beverage): 50 % of red wine and 50 % of orange juice, fruit mix (peaches, oranges, lemons, etc.) and sugar.
‡ Berries included: blueberry, bilberry, sparkleberry, deerberry, cranberry, lingonberry and partridgeberry.

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**Table 2.** Estimated resveratrol intake (µg/d) in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Spain by sex

| | *trans*-resveratrol* | *cis*-resveratrol* | *trans*-piceid* | *cis*-piceid* | Total resveratrol* |
|---|---|---|---|---|---|
| Men (*n* 15 448) | | | | | |
| Mean | 337 | 101 | 878 | 313 | 1629 |
| SD | 442 | 121 | 1213 | 380 | 2076 |
| Median | 165 | 61 | 356 | 181 | 902 |
| Percentiles, 25th–75th | 14–502 | 0–162 | 14–1309 | 4–497 | 48–2504 |
| Women (*n* 25 237) | | | | | |
| Mean | 51 | 15 | 123 | 46 | 235 |
| SD | 121 | 35 | 325 | 111 | 571 |
| Median | 0 | 0 | 0 | 0 | 0 |
| Percentiles, 25th–75th | 0–42 | 0–9 | 0–56 | 0–27 | 0–148 |
| Total (*n* 40 685) | | | | | |
| Mean | 194 | 58 | 501 | 180 | 933 |
| SD | 354 | 99 | 965 | 310 | 1675 |
| Median | 31 | 5 | 36 | 16 | 100 |
| Percentiles, 25th–75th | 0–228 | 0–81 | 0–545 | 0–246 | 0–1219 |

* Adjusted by sex and age of Spanish population aged 35–64 years.

consumers tended to increase in the older age categories. Individuals from the northern regions consumed more resveratrol than from the southern regions (513 *v.* 125 µg/d), although the percentage of consumers was approximately the same (88·3 *v.* 69·4 %). Increasing intake of R&P and percentage of consumers seemed to be correlated with higher energy intake. Individuals with a BMI between 25 and 30 $kg/m^2$ had the highest intake of total resveratrol (333 µg/d) and the obese group had the smallest percentage of consumers (66·3 %). Individuals with a high level of education (technical and professional, secondary school or university degree) had a higher intake of R&P than those with only primary education or no education (340–346 *v.* 298–308 µg/d), and the proportion of consumers was also higher in this group (69·8–72·4 % *v.* 68·0–68·6 %). There was a decrease in R&P intake and percentage of consumers in non-smokers (259 µg/d and 67·1 %) when compared with current (369 µg/d and 71·0 %) and former smokers (342 µg/d and 69·4 %).

*Sources of resveratrol*

Table 4 shows the major contributors to R&P intake. The richest source was red wine (82·6 %). As grouped foods, the main contributors were wines (98·4 %), grapes (1·1 %), must and juices (0·5 %) and, finally, peanuts and pistachios (<0·01 %). For *trans*-piceid, the major contributors were wines (98·7 %), must and juices (0·7 %) and grapes (0·6 %). For *trans*-resveratrol, we identified the following food items: wines (95·9 %), grapes (3·8 %), must and juices (0·3 %) and peanuts, pistachios and berries (0·03 %). For *cis*-isomers, we observed the next ranking: wines (99·9 and 99·7 %) and must and juices (0·1 and 0·3 %) for *cis*-resveratrol and *cis*-piceid, respectively.

## Discussion

The present study represents the first attempt to compile the available literature for R&P in common Spanish foods. After developing an FCDB, we estimated dietary intakes and food sources of R&P in Spanish adults.

Previous papers have compared results of the *trans*-resveratrol content but have not compiled data from *trans*- and *cis*-piceid and *cis*-resveratrol[4,20]. R&P are characteristic components of *Vitis vinifera* L. and are present in grape derivatives. R&P is not unique to *Vitis* because it is also present in at least seventy-two other plant species[45], but only berries, peanuts and pistachios are components of the human diet. The high variability in R&P food composition, red wines ranged between 2·86[10] and 32·33 mg R&P per 100 ml[46], was solved with weighted means, adjusted according to Spanish food consumption[41]. Another consideration in the FCDB was the potential losses in R&P from foods during cooking. The data available from the study by Lee *et al.*[47] suggest that average losses during toasting peanuts are approximately 30 %. The most common method for the measurement of R&P is HPLC coupled to a UV detector. Until 2004–5, due to the non-availability of a commercial standard, the piceid results were expressed as equivalents of resveratrol, underestimating 1·57- and 1·75-fold for *trans*- and *cis*-piceid, respectively. We, therefore, applied a correction factor to minimise this error. FCDB also reported a quality index for each value to guarantee the individual quality data and the global control of FCDB. However, further investigation is required to analyse new sources of R&P, because to date many foods have not yet been studied. In a recent study, R&P were found in the tomato skin, but in very small concentrations (0–18·4 parts per million of dried tomato skin)[8]. This value was not used in this FCDB because not all kinds of tomato contain R&P, the concentration is very low (3000 times lower than in red table grape skin) and, at this moment, only one paper reported this compound in American varieties of tomato[8] and not in European varieties[48].

The median and the mean of the estimated daily intake of R&P were 100 and 933 µg/d respectively, and were standardised according to the age and sex structure of the Spanish population aged 35–64 years. The median of intake was significantly higher in males, in oldest age, current smokers, highest educational levels, Northern region and highest energy intake. The large discrepancies between the mean and median values were due to the fact that more than 32 % of the participants did not consume R&P, and there was a

**Table 3.** Estimated intake (μg/d) and percentage of consumers of total resveratrol in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Spain cohort by age and selected demographic and lifestyle factors*

| | Subjects (*n*) | Consumers (%) | Adjusted (%) | Percentage lower 95 % | Percentage upper 95 % | Median adjusted | Lower 95 % | Upper 95 % |
|---|---|---|---|---|---|---|---|---|
| Sex | | | | | | | | |
| Female | 25 237 | 57·1 | 61·0 | 60·3 | 61·8 | 137 | 131 | 144 |
| Male | 15 448 | 84·7 | 80·0 | 79·0 | 88·9 | 686 | 664 | 709 |
| Age (years) | | | | | | | | |
| 35–44 | 13 877 | 65·7 | 67·3 | 66·3 | 68·3 | 271 | 259 | 283 |
| 45–54 | 16 107 | 68·8 | 69·5 | 68·7 | 70·4 | 324 | 312 | 336 |
| 55–64 | 10 701 | 68·2 | 70·8 | 69·8 | 71·9 | 365 | 349 | 382 |
| Region | | | | | | | | |
| North Spain | 24 752 | 69·5 | 68·3 | 67·5 | 69·0 | 513 | 498 | 528 |
| South Spain | 15 933 | 64·8 | 69·4 | 68·5 | 70·3 | 125 | 119 | 131 |
| Energy intake (kJ/d) | | | | | | | | |
| Q1 (1350–6900) | 8137 | 45·6 | 53·2 | 51·4 | 55·0 | 130 | 115 | 146 |
| Q2 (6900–8410) | 8137 | 59·2 | 63·7 | 62·4 | 65·0 | 202 | 189 | 217 |
| Q3 (8410–9960) | 8137 | 69·1 | 70·6 | 69·5 | 71·7 | 266 | 253 | 280 |
| Q4 (9960–12050) | 8137 | 77·4 | 74·9 | 73·9 | 76·0 | 375 | 357 | 392 |
| Q5 (12050–42680) | 8137 | 86·8 | 79·8 | 78·5 | 81·0 | 520 | 492 | 550 |
| BMI (kg/m$^2$)† | | | | | | | | |
| < 25 | 8965 | 67·7 | 70·5 | 69·2 | 71·7 | 298 | 281 | 317 |
| 25–30 | 19 390 | 70·5 | 70·2 | 69·4 | 71·0 | 333 | 321 | 346 |
| > 30 | 12 219 | 63·0 | 66·3 | 65·2 | 67·3 | 296 | 281 | 311 |
| Highest school level† | | | | | | | | |
| None | 13 936 | 64·0 | 68·0 | 66·9 | 69·0 | 298 | 283 | 313 |
| Primary completed | 15 846 | 67·2 | 68·6 | 67·6 | 69·5 | 308 | 296 | 321 |
| Technical/professional | 3344 | 77·2 | 72·4 | 70·4 | 74·3 | 345 | 314 | 378 |
| Secondary school | 2611 | 70·1 | 69·8 | 67·8 | 71·8 | 346 | 313 | 381 |
| University degree | 4674 | 72·3 | 72·0 | 70·5 | 73·6 | 340 | 315 | 365 |
| Smoking status† | | | | | | | | |
| Former smoker | 7180 | 75·7 | 69·4 | 68·1 | 70·8 | 342 | 324 | 360 |
| Current smoker | 9951 | 74·2 | 71·0 | 69·9 | 72·1 | 369 | 352 | 387 |
| Never a smoker | 22 558 | 61·2 | 67·1 | 66·3 | 67·9 | 259 | 249 | 269 |

* Adjusted by age and sex of Spanish population aged 35–64 years; differences between categories for all variables $P < 0·001$.

† The values reported are calculated by the number of subjects with valid information. The number of subjects with missing information was as follows: BMI, *n* 111; highest school level, *n* 274; smoking status, *n* 996.

**Table 4.** Consumption of total resveratrol in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Spain cohort by food items

| Food item | Proportion of intake (%) | Cumulative percentage |
|---|---|---|
| Red wine | 82·63 | 82·63 |
| Rosé wine | 12·19 | 94·83 |
| Wine, not specified | 2·92 | 97·75 |
| Grapes, not specified | 1·13 | 98·88 |
| Must | 0·39 | 99·27 |
| White wine | 0·29 | 99·56 |
| Vermouth | 0·21 | 99·77 |
| Fruit juice | 0·11 | 99·88 |
| Sparkling wine | 0·05 | 99·93 |
| Fortified wine | 0·04 | 99·97 |
| Txacoli (typical Basque wine) | 0·02 | 99·99 |
| Sherry wine | $<$0·01 | 99·99 |
| Peanuts, toasted | $<$0·01 | 99·99 |
| Pistachio, toasted | $<$0·01 | 100 |

skewed distribution toward higher values in the consumers. This distribution of R&P intake was similar to that of wine, because more than 98 % of R&P intake was due to wine. The pattern of wine consumption in the EPIC European cohort was described by Sieri *et al.* [49]. A typical high wine consumer, and consequently high R&P consumer, was an older man, a resident of northern Spain, with a high educational level, smoker, with excess weight but not obese and a high energy intake[49,50]. In Spain, as in Portugal, the pattern of alcohol consumption is changing: the prevalence of wine drinkers is decreasing, and younger generations are shifting from wine to beer and spirits[51].

To our knowledge, only one case–control study estimated *trans*-resveratrol intake for women in the Swiss Canton of Vaud[52]. One limitation to comparison of the results is that Levi *et al.* [52] did not include a complete description, only reporting tertiles. On the other hand, they only used grapes and white and red wine, without taking into account other sources of *trans*-resveratrol such as grape juice, other kinds of wine, peanuts, berries, etc. Taking into account that *trans*-resveratrol only corresponded to 21 % of the four stilbenes investigated in the present study, the median of intake of total individuals was 31 μg/d (0 μg/d for women), and the sources of R&P were 29 μg/d for wine (98·3 %) and 0·5 μg/d for grapes (1·2 %). However, in the study by Levi *et al.* the distribution in food sources was very different, because the second tertiles for wine and grapes were 0·1–176·8 μg/d and 72·3–126·4 μg/d, respectively[52]. This great difference in resveratrol intake from grapes can be due to using other food composition data. Furthermore, in populations with other dietary patterns, the contribution of berries and peanut butter may be different.

In human subjects, the proportion of nutritional resveratrol absorbed ranged from 16 to 25 % of intake, measured in urine by MS techniques[25,27]. Piceid may be absorbed directly, as reported for the rat small intestine[53], and/or hydrolysed by glycosidases before absorption[54], contributing to the biologically available resveratrol dose. Biomarkers of resveratrol intake, such as urinary resveratrol metabolites, can be used as an alternative to evaluate resveratrol status and to assess relationships between resveratrol and disease[32]. The use of biomarkers avoids problems associated with an FCDB[55]. In a recent study, resveratrol metabolites in urine were used as a biomarker of moderate wine consumption in intervention and epidemiological studies[32]. However, not all epidemiological studies are able to undertake the measurement of biomarkers due to a lack of resources or expertise. For this reason, estimation of resveratrol intake from dietary questionnaires and records using adequate food composition data is also required[56].

R&P have been shown to have health benefits in *in vitro* studies, and against cancer, cardiovascular and neurodegenerative diseases. Levi *et al.* found a significant inverse association between *trans*-resveratrol and breast cancer from grapes (OR 0·64 and 0·55) but not from wine[52]. Polyphenols in wine may play an active role in limiting the initiation and progression of atherosclerosis[57]. Localised accumulation of resveratrol in epithelial cells along the aerodigestive tract, and potentially active resveratrol metabolites, may also produce cardiovascular effects. Moreover, resveratrol has been considered to be a energy restriction mimetic *in vitro* and in lower organisms and mice, because it interacts with a variety of enzymes, such as sirtuin, involved in regulating stress responses and longevity[20–23]. So, long-term consumption of a low concentration of polyphenol, such as resveratrol, or a synergic effect with other phenolic compounds or other micronutrients in the Mediterranean diet could be sufficient to cause beneficial effects against these alterations and could constitute a potential arm for prevention of chronic diseases and new therapeutic strategies[23]. It is, therefore, of interest to study the relationship between R&P intake and the risk of chronic diseases in an epidemiological context. However, wine polyphenols are a complex mixture of flavonoids and non-flavonoids (where resveratrol would be included) and the relative contribution of each single one or synergistic contribution of them is still unclear and further investigation should be considered.

One limitation of the present study was that the EPIC-Spain cohort is based on a non-representative sample of the general population. However, the number of volunteers was very large, the participation rate was relatively high, and the subjects came from different social backgrounds and different geographical areas. In addition, the pattern of dietary intake was very similar to that observed in population-based surveys carried out in the Spanish regions included in the present study[58,59].

We conclude that R&P and especially *trans*-piceid are common components of the Mediterranean diet. Clearly, wine is the major contributor of R&P in this population ($>$98 %); the contribution of non-grape derivatives is lower than 0·01 %. This is the first attempt to compile the existing published scientific data on the R&P content of foods. This database allowed the quantification of intakes that can be used to investigate the role of R&P in health benefits to increase lifespan.

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