Evaluating product demographics, composition and health claims of commercial polyphenol supplements: a review of dosage, bioactive compounds and efficacy

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Abstract

This study evaluated the product demographics of commercial polyphenol supplements, including the identities of polyphenolic compounds, recommended daily dosages and claimed health benefits. Only oral supplement products that specified their polyphenol compositions on their labels were included. Data were collected from three major pharmaceutical retail outlets (Guardians, Watson, Unity) and two e-commerce platforms (iHerbs, Amazon). Trained personnel documented product delivery forms, polyphenol compositions, health claims, and dosages. A total of 196 products met the inclusion criteria, predominantly delivered as capsules (79.3%), followed by tablets (9.3%), soft gels (6.2%), liquids (3.1%), and powders (1.0%). Nearly half (49.5%) declared health claims, categorized into 16 domains. Weight management claims were the most common (33%), followed by antioxidant (25%), cardiovascular, and immunity-related claims. Digestion, hormonal, joint, respiratory, skin, and stress-related claims were least frequent. Epigallocatechin gallate was the most often listed polyphenol, followed by catechins, quercetin, and trans-resveratrol. Recommended daily doses of these compounds (5 mg – 1260 mg) significantly exceeded typical dietary intakes from fruits and vegetables. While polyphenol supplementation shows promise for enhancing health, the lack of statistically significant dosage variation and long-term clinical data underscores the need for further research to confirm efficacy, safety, and best dosing strategies for diverse populations.

Keywords: Polyphenol supplement, quercetin, catechins, epigallo-catechin gallate, trans-resveratrol

Introduction

Polyphenols (PP) are natural compounds found in plants, including fruits, vegetables, tea, wine and cocoa [1]. These compounds function as potent antioxidants and effective anti-inflammatory agents, helping to protect cells from oxidative damage caused by free radicals and modulating inflammatory responses [1]. PPs have been associated with several health benefits, including improved cardiovascular health through reductions in blood pressure and cholesterol levels [2], support for weight management [3] and a reduced risk of type 2 diabetes by enhancing blood sugar control [4]. They also exhibit potential anti-cancer properties, inhibiting tumour growth and providing possible protection against certain cancers, likely due to their anti-inflammatory and antioxidant effects [1]. Nutritionally, PPs are an integral component of the human diet, as they are omnipresent in fruits and vegetables [1].

A health supplement is a product intended to complement the diet and to support, maintain, enhance or improve healthy bodily functions [5]. The Singapore Health Science Authority stipulates that health supplements cannot be in injectable form or require sterility [5]. Additionally, health supplements are not considered to be part of a standard meal or diet. Typically, health supplements are available in the form of tablets, powders, gels, capsules and liquids and may contain ingredients such as vitamins, minerals, amino acids, enzymes, herbs or other botanical compounds [5]. They are commonly used to support overall health, enhance physical performance or address specific nutritional deficiencies [6]. PP supplements, specifically, are concentrated forms of PPs available as capsules, tablets, gels, powders or liquids and provide higher doses than is found in regular food sources [7]. These supplements often contain extracts from PP-rich foods, such as green tea, grape seeds, pomegranate or berries [7]. They are marketed for their antioxidant properties and potential health benefits, including cardiovascular support, anti-inflammatory effects and improved cognitive function [7]. The popularity of PP supplements has increased due to their potential health benefits, especially among individuals seeking dietary improvements or targeting specific health concerns [7]. These products are commonly available in health stores and through online markets.

Current research reveals significant knowledge gaps regarding the specific PP compounds present in commercial PP supplements, their optimal daily dosages and the precise health benefits these supplements claim to offer. While PP supplements often include extracts from sources like green tea, grape seeds and berries, the composition and concentration of individual PP compounds, such as flavonoids, phenolic acids or lignans, remains poorly defined across different products. Additionally, standardized recommendations for daily intake are lacking, leading to variability in suggested dosages that may not align with clinically effective or safe levels. Finally, although commercial supplements frequently advertise benefits, such as improved cardiovascular health, enhanced cognitive function and anti-inflammatory effects, the evidence supporting these claims is often inconclusive or based on studies of PP-rich foods rather than isolated supplement formulations. Addressing these gaps is essential to ensure accurate consumer guidance and safe, evidence-based use of PP supplements. The current study evaluated the product demographics of commercial PP supplements, specifically the identities of the PPs, their recommended daily supplement dosage and their claimed health benefits. The merit of PP supplements is also discussed.

Materials and methods

Data collection

Only oral supplement products that specify the PP compositions on their product labels were included in this study. These products were found on the shelves of three major pharmaceutical retail outlets (Guardians, Watson, and Unity) and two major e-commerce platforms (iHerbs and Amazon). The product information, such as claims, delivery form, PP composition, health-related claims and recommended daily dosages found on the product labels were recorded by trained research personnel.

The compositions of the top four specific PPs in fruits and vegetables were obtained from the web-based database, Phenol-Explorer (version 3.6) [8,9]. Their dietary contributions from the recommended intake of two servings each of fruits and vegetables were computed using the data from Phenol-Explorer (version 3.6) [8,9]. The recommended daily supplement dosages of these four PPs were compared with their recommended intakes from fruits and vegetables.

Data analyses

Data were statistically described and analyzed using Microsoft Excel (version 2103, April 2021). Statistical differences between two or more groups were analyzed using a two-sample independent t-test or ANOVA with post-hoc Bonferroni test, respectively.

Results

Delivery forms and health-related claims

The selection criteria were fulfilled by 196 products and these were included for the study. The supplements were administered as capsule (79.3%), tablet (9.3%), soft gel (6.2%), liquid (3.1%) and powder (1.0%).

Of the studied PP supplements, 49.5% declared health claims on their labels. These claims were categorized into 16 distinct health domains (**Fig. 1**). Weight management was declared by 33.3% of the studied products and was the most prevalent health claim category (**Fig. 1**) followed by antioxidant health claims (25%) (**Fig. 1**). Cardiovascular (14.6%) and immunity (12.5%) rounded up the top four health claims (**Fig. 1**). Less prevalent health claims belonged to the domains of digestion, hormonal, joint and mobility, respiratory, skin and stress management (**Fig. 1**).

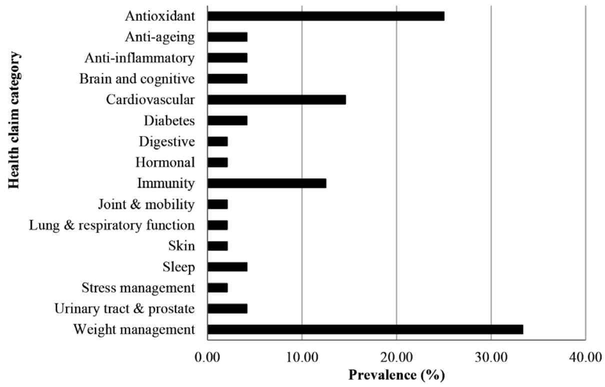

Figure 1 Prevalence of polyphenol supplements with declared health claims on their product labels categorized into specific heath domains (n=196)

Polyphenol composition

Ten PP compounds were specifically listed on the product labels of the studied supplements (**Fig. 2**). The three most abundant PP compounds in commercial PP supplements were epigallocatechin gallate, followed by catechins and quercetin (**Fig. 2**). Trans-resveratrol was also popular, following closely behind quercetin (**Fig. 2**).

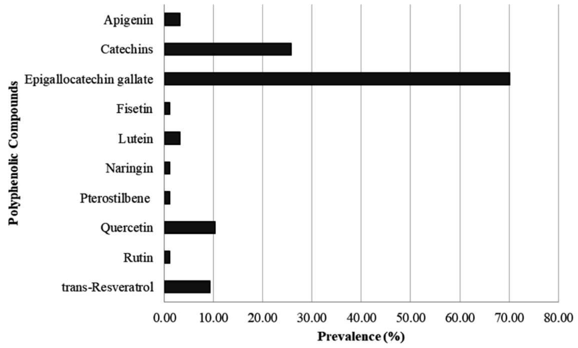

Figure 2 Prevalence of total and specific polyphenolic compounds in commercial polyphenol supplements (n=196)

Polyphenols dosage

The recommended daily dose of the four most prevalent commercial PPs (epigallocatechin gallate, catechins, quercetin and trans-resveratrol) among the studied PP supplements ranged from 5 mg to 1260 mg. The mean (with SD) recommended daily dosage of each supplement is presented in **Fig. 3**. Catechins (393±339 mg/day), quercetin (365±431 mg/day) and trans-resveratrol (265±311 g/day) took the top three spots in the recommended daily amounts (**Fig. 3**).
However, differences in the daily recommended dosages between the four PPs did not reach statistical significance (**Fig. 3**).

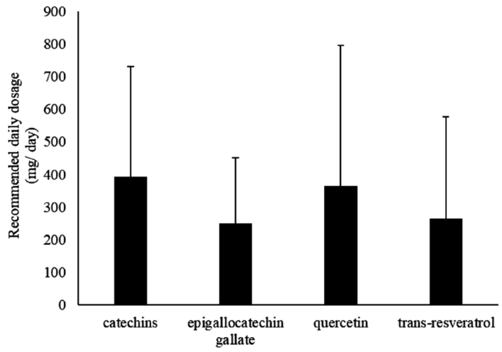

Figure 3 Recommended daily dosage (mg, mean ± SD) of the four most prevalent commercial specific polyphenol supplements (quercetin n=20, catechins n=50, epigallocatechin gallate n=136, trans-resveratrol n=18)

Polyphenols from fruits and vegetables

Fruits supplied significantly greater amounts of catechins and trans-resveratrol than vegetables per 100 mg fresh weight (**Fig. 4**). The opposite was found for epigallocatechin gallate (**Fig. 4**). Fruits and vegetables did not differ significantly in their supplies of quercetin (**Fig. 4**).

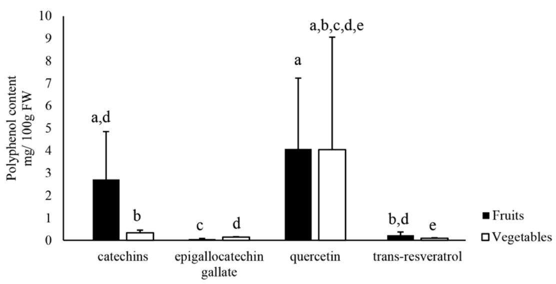

Figure 4 Amounts (mg/100 g fresh weight) of the four most prevalent commercial polyphenols present in fruits and vegetables (n=5). a,b,c,d,e represents $p<0.05$ using ANOVA with post-hoc Bonferroni adjustment

The total daily dietary intakes of catechins, epigallocatechin gallate, quercetin and resveratrol from two servings each of fruits and vegetables are presented in **Fig. 5**. The recommended two servings each of fruits and vegetables provided significantly greater amounts of catechin and quercetin than those of epigallocatechin gallate and resveratrol (**Fig. 5**). The recommended daily doses of catechins, epigallocatechin gallate, quercetin and trans-resveratrol from PP supplements were significantly greater than their corresponding dietary intakes from two servings each of fruits and vegetables (**Table 1**).

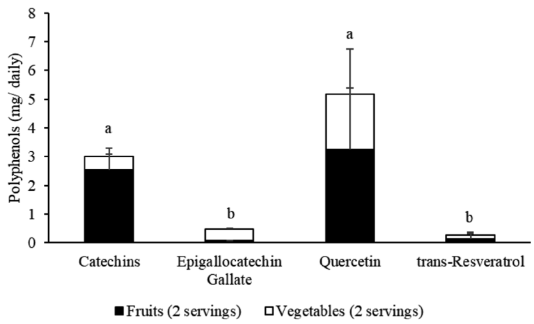

Figure 5 Amounts of catechins, epigallocatechin gallate, quercetin and trans-resveratrol that can be obtained from an intake of two servings each of fruits and vegetables (fruits n=5 and vegetables n=5). a,b represents $p<0.05$ using ANOVA with post-hoc Bonferroni adjustment

Table 1 Estimated daily intake of catechins, epigallocatechin gallate, quercetin and trans-resveratrol from two standard dietary servings of fruits and vegetables compared with recommended daily dosages of polyphenols supplements

	Catechins	Epigallocatechin Gallate	Quercetin	trans-Resveratrol
Dietary	3.01±0.74	0.47±0.02	5.18±3.63	0.28±0.23
Supplements	392.2±339.1*	248.8±202.7*	365.0±431.2*	265.6±311.9*

*$p<0.05$ compared with the dietary intake of the same PP using two-sample independent *t*-test

Discussion

PP supplements are predominantly used for weight management, as evidenced by the prevalence of weight-related claims. Daily PP supplementation has been shown to induce weight loss in overweight individuals, even without dietary changes, while not significantly affecting other parameters within the normal range [10]. Emerging research shows that PP supplementation may facilitate weight management through several mechanisms. PPs can inhibit fat synthesis in adipose tissue by modulating obesity-associated transcription factors [11]. Green tea PPs have been reported to enhance energy expenditure via AMP-activated protein kinase (AMPK) activation [12]. Additionally, PPs may inhibit pancreatic lipase activity, reducing dietary fat absorption [13]. Certain PPs are also believed to influence appetite-regulating hormones, such as leptin and ghrelin, promoting satiety and lowering caloric intake [14,15]. PPs have been shown to support the growth of beneficial gut microbiota while suppressing pathogenic strains [16], potentially influencing energy homeostasis, systemic inflammation, lipid metabolism and insulin sensitivity [17]. Studies suggest that supplementation with catechin-rich green tea extracts can decrease body weight, body mass index (BMI) and waist circumference, with more pronounced effects when combined with exercise and calorie restriction [17]. The thermogenic properties of green tea catechins may further increase resting energy expenditure by approximately 4–5% [18]. A systematic review demonstrated that catechin supplementation combined with caffeine modestly enhanced thermogenesis and fat metabolism, with effects that were dosage dependent [19]. Resveratrol supplementation has been associated with improved insulin sensitivity and the upregulation of genes involved in mitochondrial function and fat oxidation [20]. Similarly, anthocyanin supplementation has shown reductions in body weight and waist circumference in obese adults [21]. Collectively, these findings provide strong evidence for the role of PP supplementation in weight management.

Antioxidant health claims are among the most common for dietary supplements, and PPs have long been celebrated for their significant antioxidant activity. This activity primarily stems from their ability to scavenge free radicals and chelate metal ions [22]. PPs neutralize reactive oxygen species (ROS) through electron donation, thereby preventing cellular damage [22]. Oxidative damage has been implicated in the pathogenesis of cardiovascular diseases [23], diabetes [24] and cancer [25]. Reducing oxidative stress through antioxidant mechanisms may prevent or delay the progression of these diseases [26]. Despite their potential, the efficacy of PPs as *in vivo* antioxidants is often questioned due to their low bioavailability in unconjugated forms [27]. PPs are extensively metabolized *in vivo* into their respective metabolites, some of which exhibit comparable *in vitro* antioxidant activities to their parent compounds [28,29]. However, many of these studies were conducted at concentrations not physiologically relevant, necessitating a cautious interpretation of the results. At physiological levels, PPs are more likely to exert their antioxidant effects by activating enzymes such as glutathione peroxidase, catalase and superoxide dismutase, as well as by modulating the expression of antioxidant and pro-oxidant genes [30,31]. While *in vitro* and animal studies consistently demonstrate strong antioxidant properties of PPs at high concentrations, clinical studies in humans have produced mixed results, particularly regarding high-dose supplementation [32,33].

Cardiovascular health refers to the proper functioning of the heart and blood vessels, ensuring efficient circulation of oxygen and nutrients while removing metabolic waste [34]. Poor cardiovascular health can lead to conditions such as atherosclerosis, myocardial ischaemia, and stroke [34]. Alleviating oxidative damage and inflammation has been shown to mitigate the development or progression of cardiovascular and cerebrovascular diseases [35,36]. PPs contribute to cardiovascular health by protecting low-density lipoprotein (LDL) particles from oxidation, reducing platelet activation, improving ventricular function, alleviating vascular inflammation, restoring endothelial function and lowering blood pressure [1,2]. These properties underscore the therapeutic potential of PPs in promoting cardiovascular wellbeing.

The impact of PPs on immune health is an area of growing interest, primarily due to their anti-inflammatory and antioxidant properties. PPs can modulate immune function by acting on key immune cells, such as macrophages, T-cells, and dendritic cells. They help to balance pro- and anti-inflammatory cytokines and reduce oxidative stress, thereby modulating immune responses [37]. Catechins, quercetin and resveratrol have demonstrated the ability to suppress pro-inflammatory cytokines (e.g. tumour necrosis factor-α, interleukin-6) and enhance anti-inflammatory cytokines (e.g. interleukin-10) [37]. A recent study showed that PP-rich supplementation positively influenced markers of immune ageing, suggesting potential benefits in delaying immunosenescence [38]. However, these findings require further validation in larger, longer-term studies to confirm effectiveness and establish optimal dosing protocols. Clinical trials have shown inconsistent effects of PPs on inflammatory markers, especially in healthy individuals or during short-term interventions [39].

When compared with the four most prevalent commercial PPs, fruits were found to be a superior dietary source to vegetables. Quercetin is the most abundant PP in both fruits and vegetables, followed catechins, epigallocatechin gallate and trans-resveratrol. Two daily servings each of fruits and vegetables provide significantly higher amounts of quercetin compared with catechin and trans-resveratrol. However, fresh dietary sources deliver considerably lower amounts of PPs than the dosages commonly found in supplements, which can be hundreds of times higher. Quercetin, for example, is considered safe at moderate dietary levels and well-tolerated at short-term supplemental doses up to 1,000 mg daily [40]. However, long-term safety data for high-dose quercetin (>12 weeks) are limited [40]. Quercetin inhibits cytochrome P450 enzymes, potentially leading to drug interactions with medications like anticoagulants or statins [41]. Its bioactivity is also influenced by extensive first-pass metabolism, with metabolites likely contributing to its physiological effects [28,29]. Catechins, particularly epigallocatechin gallate, have been linked to hepatotoxicity at high doses, prompting regulatory agencies to set a safe upper limit of 800 mg/day from supplements [42,43]. Moderate doses (200–400 mg/day) are generally well-tolerated, but long-term safety remains under evaluation. Consuming catechins from natural sources like green tea may offer additional nutrients and reduce the risk of adverse effects compared with high-dose supplements.

Among the four most prevalent commercial PPs, our results indicate that fruits serve as superior dietary sources of these specific molecules compared with vegetables. Furthermore, quercetin is found in higher concentrations in both fruits and vegetables than catechin, which in turn exceeds the levels of epicatechin gallate and trans-resveratrol. Consistent with this trend, the recommended two servings each of fruits and vegetables daily provide significantly greater quantities of quercetin than catechin and trans-resveratrol. However, the recommended daily dosages of quercetin, catechins, epigallocatechin gallate and trans-resveratrol supplements are approximately 100 times higher than the amounts derived from consuming the recommended servings of fruits and vegetables. Safety concerns are particularly pertinent for therapeutic doses that exceed typical dietary intake. Quercetin is widely regarded as safe when consumed in moderate amounts through dietary sources. Studies have shown that quercetin is well-tolerated at daily doses up to 1,000 mg for short-term use [40]. However, adequate scientific data regarding the safety of long-term use (>12 weeks) of high supplemental doses of quercetin (1000 mg) are currently lacking [41]. These findings support quercetin's safety in short-term interventions at relatively high daily doses up to 1,000 mg. It has been shown that quercetin inhibits cytochrome P450 enzymes, which play key roles in drug metabolism [41]. This inhibition could elevate the plasma concentrations of drugs metabolized by these enzymes, potentially increasing the risk of drug interactions, particularly with anticoagulants, statins or other medications with narrow therapeutic indices. Therefore, caution is recommended when quercetin is taken alongside medications and further research is necessary to better understand its impact on drug metabolism. Determining the effective dose of quercetin is complicated by its limited oral bioavailability and extensive first-pass metabolism. The metabolites, rather than free quercetin, are believed to circulate in the bloodstream and may exhibit biological activity, although their efficacy relative to the parent compound remains a topic of ongoing research [28,29]. Effective doses of quercetin, as with other PPs, vary depending on the intended therapeutic effect. Oral supplementation of 200 mg of quercetin has been shown to increase nitric oxide expression and decrease vasoconstrictive endothelin-1 levels acutely in healthy men [44]. A systematic review and meta-analysis of 17 randomized controlled trials involving 896 participants found that daily quercetin intakes ranging from 30 to 1000 mg for 8 weeks or more significantly reduced blood pressure and blood triglycerides [20]. Chronic consumption of 1 g/day of quercetin for 2 weeks was associated with a reduction in erythrocyte oxidative damage in human subjects [45]. Another meta-analysis of seven randomized controlled trials indicated that quercetin supplementation of ≥500 mg/day significantly reduced circulating C-reactive protein levels in humans [46].

High doses of catechins, particularly epigallocatechin gallate, have been associated with hepatotoxicity in some cases. Liver damage has been reported in individuals consuming green tea extract supplements, with proposed mechanisms including oxidative stress and mitochondrial dysfunction at supraphysiological doses [42]. To mitigate risks, regulatory agencies such as the European Food Safety Authority have set an upper limit for epigallocatechin gallate intake from supplements at 800 mg/day [43]. Like quercetin, catechins may interact with medications such as anticoagulants and chemotherapeutic agents, potentially altering their efficacy or increasing the risk of adverse effects [47]. High doses of catechins may also cause gastrointestinal discomfort, including nausea and bloating, particularly with concentrated extracts rather than tea consumption. Moderate doses of catechins (e.g. 200–400 mg/day of epigallocatechin gallate) appear to be well-tolerated and effective for most individuals, although long-term safety remains under investigation. Limited data are available to justify the much higher daily intake of catechins and epigallocatechin gallate from supplements for therapeutic purposes. Consuming catechins and epigallocatechin gallate through natural sources, such as green tea, offers additional nutrients and may pose a lower risk of adverse effects compared with high-dose supplements.

The use of PP supplements raises several concerns. First, PP supplementation is believed to be necessary to achieve the effective therapeutic doses, as the amounts obtained from diet may not be sufficient for the desired therapeutic effects. However, the optimal dosage and type of PPs for specific therapeutic health benefits remain undefined and individual responses may vary. Second, while short-term studies show promising results, the long-term effects of PP supplementation on health require further investigation. Third, whole plant foods containing PPs, such as berries, green tea, and spices, are preferred over supplements due to the presence of additional beneficial compounds, such as fibres. However, standardized supplements may be useful for individuals seeking specific PPs at therapeutic doses. Finally, combining PP supplementation with lifestyle modifications, such as a healthy diet and regular physical activity, may offer greater health benefits than supplementation alone.

Conclusions

PP supplementation holds promise as a complementary approach to enhanced health management. However, further clinical studies are required to confirm its long-term efficacy and safety, as well as to identify optimal supplementation strategies for various populations. Current clinical evidence highlights the potential of PPs as beneficial phytochemicals within a balanced diet that is rich in fruits and vegetables, rather than recommending high-dose supplements [48].

Conflict of interest

The authors declare that they have no conflict of interest.

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