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Moderate beer consumption and metabolic health: A comprehensive review from the lipoprotein perspective

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ABSTRACT

Beer intake is part of our society lifestyle but still a controversial topic due to the lack of consensus regarding its effects on our health. Regarding cardiovascular disease, research needs to consider the amount consumed but also drinking thresholds, frequency of drinking, age and gender of consumers, lifestyle, or non-alcoholic components of beers. Nevertheless, epidemiological evidence points to healthy effects of low or moderate beer consumption and even a protective action for cardiovascular risk and diabetes, discouraging heavy intakes without any exception. Beer components include alcohol and phenolics, both of which alter high- or low-density-lipoprotein levels and their oxidation status in blood. This review aims to highlight the importance of the metabolic mechanism by which beer components may influence lipid profile in terms of quantity and functionality, modulating cardiovascular risk. This is a major challenge for our society in light of the remarkable impact of cardiovascular diseases in all-cause mortality.

1. Introduction

In light of recent evidence, beer consumption and its impact in our health is one of the greatest challenges for our society (de Gaetano et al., 2016; Marcos et al., 2021; Spaggiari, Cignarelli, Sansone, Baldi, & Santi, 2020). Extensive research has shown that beer intake, as well as other popular alcoholic drinks consumption, influence cardiovascular health. Indeed, cardiovascular risk appears to diminish after low to moderate intake of fermented beverages wine or beer, in comparison to distilled beverages, such as liquors or spirits (Chiva-blanch & Badimon, 2020; Maugeri et al., 2020; Padro et al., 2018; Spaggiari et al., 2020). The evidence from these studies should be interpreted with caution, avoiding over-generalization and highlighting the need of more research to clarify the plethora of consequences of alcohol and beer consuming customs nowadays.

Cardiovascular disease (CVD) is a priority worldwide as the main cause of global mortality and then focusing on cardiovascular health appears to be a requirement in order to diminish its impact in our society. Cardiovascular health is not only related to the absence of cardiovascular disease, but it also involves advantageous health parameters or behaviors. Among them, blood pressure, fasting plasma glucose, cholesterol count, body mass index (BMI) or physical activity, and smoking status are considered. Additionally, healthy diet influences our cardiovascular health. Therefore, focusing on prevention, promoting beneficial patterns may improve the cardiovascular balance health/disease (Knapper et al., 2015).

Cardiovascular health depends on several risk factors, including popular alcoholic drinks consumption. As previously stated, some evidence suggests that moderate beer intake might be associated to an improvement on the impact of diverse cardiovascular risk factors (Chiva-Blanch et al., 2015; de Jong, de Goede, Oude Griep, & Geleijnse, 2008; Martínez, Luft, de Faria, & Molina, 2019; Padro et al., 2018), highlighting the importance of research concerning the unanswered questions related to the molecular profile of the foods or beverages included in our diet. Our study aims to introduce a novel perspective for beer consumption and cardiovascular health from the alcoholic and non-alcoholic content of this drink, which may influence our molecular lipid profile modifying cardiovascular risk parameters, placing emphasis on the biochemical view to clearly discourage from alcohol or beer consuming.

As a result of the brewing process, beer composition includes many nutrients such as B vitamins, minerals, fibers, proteins, carbohydrates,

Abbreviations: **BMI**, body mass index; **CEC**, cholesterol efflux capacity; **CVD**, cardiovascular disease; **HDL-C**, high-density-lipoprotein-cholesterol; **LDL-C**, low-density-lipoprotein-cholesterol; **TG**, triglycerides; **VLDL**, very-low-density lipoprotein.

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probiotics or polyphenols (Garcia-Moreno, Calvo, & Maldonado, 2013; Marcos et al., 2021; Sohrabvandi, Mortazavian, & Rezaei, 2012). Alcohol, protein, compounds produced by yeasts, and melanoidins phenolic content of beers have been pointed to confer the beneficial effects of moderate beer intake (Maldonado & Calvo, 2010; Martinez-gomez, Caballero, & Blanco, 2020; Spaggiari et al., 2020). The low alcohol content in beers has demonstrated to exert physiological activities in glucose homeostasis and cardio protection, increasing HDL-C, diminishing platelet activation or aggregation, as well as reducing inflammation markers or oxidative stress (Humia et al., 2019; Maldonado, Moreno, & Calvo, 2009; Marcos et al., 2021; Nishiwaki, Kora, & Matsumoto, 2017). What is more, some studies propose that healthy benefits of low-moderate beer intake is due to a synergic result of both alcohol and polyphenol content in this heterogeneous beverage (Arranz et al., 2012; de Gaetano et al., 2016; Spaggiari et al., 2020). This controversial role of beer components as beneficial for cardiovascular health indicates that research is needed to clarify the balance benefits/risks of beer intake.

2. Influence of lower alcohol intake on cardiovascular health

As explained in the previous section, alcohol consumption is a questionable topic; strong evidence supports a J-shaped association between alcohol consumption and cardiovascular risk (Costanzo et al., 2011). In contrast, combined analysis of recent studies report that the lower the alcohol intake, the better for any disease risk (Wood et al., 2018).

On the other hand, reducing the impact of cardiovascular diseases is a priority of our society regarding the data of all-cause mortality. Considering the risk factors for cardiovascular disease and the inflammatory and oxidative microenvironments in cardiovascular illness in a prevention strategy, the lipid content in the blood has been attracting a

Table 1
Comparative studies regarding alcoholic beverages intake.

Study	Population	Beverages	Former drinkers	Comparator	Outcomes
de Jong et al. 2008 (de Jong et al., 2008)	1,052 women and men 60–80 years old Myocardial infarction	Beer, wine and liquor	No	Between beverages and gender Ethanol intake	Ethanol increased HDL-C in men Wine and beer increased HDL-C in men and women
Chiva-Blanch et al. 2015 (Chiva-Blanch et al., 2015)	33 men 55–75 years old High cardiovascular risk	Beer, non-alcoholic beer and gin	NS	Between beverages	Ethanol increased HDL-C, ApoAI and ApoAII levels
Sluik et al. 2016 (Sluik et al., 2016)	1,653 women and men 20–77 years old	Beer, wine and spirits	No	Between beverages and abstainers	Wine increased HDL-C level
Martínez et al. 2019 (Martínez et al., 2019)	12,179 women and men 35–74 years old Healthy	Beer, wine and spirits	Yes	Between beverages Ethanol intake	Ethanol increased HDL-C level
Nova et al. 2019 (Nova et al., 2019)	143 women and men 55–85 years old Healthy	Beer and mixed	NS	Between beverages and abstainers Ethanol intake	Ethanol increased HDL-C level
Du et al. 2020 (Du et al., 2020)	1,785 women and men 25–36 years old	Beer and wine	No	Between beverages Ethanol intake	Ethanol increased small LDL number and decreased ApoB, VLDL-C and ILD-C levels Ethanol increased HDL-C, apoAI levels and HDL lipid content
Padro et al. 2018 (Padro et al., 2018)	36 women and men 40–60 years old Overweight	Beer and non-alcoholic beer	NS	Between beverages Pre-/post- beverage intake	Beer and non-alcoholic beer increased HDL capacity to prevent LDL oxidation Beer increased HDL CEC and HDL-C in subjects with elevated LDL-C
Maugeri et al. 2020 (Maugeri et al., 2020)	2,160 women and men 25–64 years old	Beer, wine and spirits	Yes	Between beverages Ethanol intake	Heavy drinking increased HLD-C Wine decreased LDL-C and total cholesterol /HDL-C ratio compared to beer drinkers and abstainers
Vidot et al. 2016 (Vidot et al., 2016)	15,905 women and men 18–74 years old	Beer, wine and liquors	Yes	Ethanol intake	Heavy drinking decreased HDL level
De Oliveira et al. 2000 (De Oliveira e Silva et al., 2000)	14 women and men 21–70 years old	Vodka	NS	Ethanol intake	Ethanol increased HDL-C, apoAI and apoAII levels
Vu et al. 2016 (Vu et al., 2016)	10,893 women and men 54.3 years old	Beer, wine and liquors	Yes	Ethanol intake	Ethanol increased HDL-C, HDL-2 and HDL-3 levels Ethanol reduced total cholesterol and LDL-C and apoB levels.
Mori et al. 2015 (Mori et al., 2015)	24 women 25–49 years old Healthy	Questionnaire with any kind of beverage Intervention with wine		Ethanol intake Pre-/post- wine intake	High volume of wine increased HDL-C
Hansen et al. 2005 (Hansen et al., 2005)	69 women and men 38–75 years old Healthy	Wine, non-alcoholic wine and alcohol equivalent to wine	NS	Between beverages	All beverages increased HDL-C
Beulens et al. 2004 (Beulens et al., 2004)	23 men 45–65 years old Healthy	Whisky	NS	Pre-/post- beverage intake	Ethanol increased HDL CEC, HDL-C and HDL-PL, preB-HDL and apoA1 levels.

Apo, Apolipoprotein; CEC, cholesterol efflux capacity; HDL-C, high-density lipoprotein cholesterol; HDL-PL, high-density lipoprotein phospholipids; IDL-C, intermediate-density lipoprotein; LDL-C, low-density lipoprotein cholesterol; NS, not shown; VLDL, very low-density lipoprotein.

lot of interest (Grao-Cruces, Lopez-Enriquez, Martin, & Montserrat-de la Paz, 2022; Vu et al., 2016). It is already demonstrated that elevated levels of LDL-C may initiate the vessel atheromatous plaque whereas HDL-C is considered a protective factor of cardiovascular disease (Wilson et al., 1998). In line with this, some evidence suggests that alcohol protects against CVD risk, because moderate alcohol intake increased serum HDL-C and reduced LDL-C levels (Beulens et al., 2004; Chiva-Blanch et al., 2015; de Jong et al., 2008; De Oliveira e Silva et al., 2000; Du et al., 2020; Hansen et al., 2005; Maugeri et al., 2020; Nova, San Mauro-Martín, Díaz-Prieto, & Marcos, 2019; Vu et al., 2016).

On the other hand, our lipid profile is likely to be modulated by our daily food and drink intake (Grao-Cruces, Millan-Linares, et al., 2021; Grao-Cruces, Varela, Martin, Bermudez, & Montserrat-de la Paz, 2021). Thus, many studies report higher lipid content in all HDLs, more specifically, HDL2 and apolipoprotein A1, after alcohol intake in a dose-dependent manner (Chiva-blanch & Badimon, 2020; De Oliveira e Silva et al., 2000; Mori, Burke, Beilin, & Puddey, 2015; Piano, 2017). As HDL facilitates the transport and excretion of cholesterol, avoiding its accumulation in arterial walls and then the atherosclerosis progression, HDLs appear to have a protective role in cardiovascular disease. Some data point to increased concentrations of phosphoglycerides and phosphatidylcholine and lower values of LDL, apolipoprotein B, total cholesterol, VLDL (very-low-density lipoprotein)-cholesterol or triglycerides (TGs) after low-to-moderate alcohol consumption (Du et al., 2020; Vu et al., 2016). Nevertheless, it is still under debate both the HDL cardioprotective role and LDL lipoproteins or TGs behavior after alcohol intake (Chiva-blanch & Badimon, 2020; Piano, 2017).

In recent years, more information has become available for the purpose of stablishing a potential relationship between the consumption of several alcoholic beverages and the levels of lipoproteins. This challenging approach requires many factors to be considered, including age, gender and health status of participants, kind of beverage tested and parameters to be compared (Table 1). In view of several studies regarding fermented beer or wine in comparison to distilled beverages intake, HDL-C levels are increased in 25–85-aged healthy volunteers and the same result when 60–80-aged participants with previous cardiovascular disease.

3. Moderate beer consumption impact on cardiovascular health

In this review, beer consumption has already been considered as a controversial topic when trying to adjust scarce or excessive intake impact in cardiovascular disease. Low or moderate beer consumption is documented to exert metabolic effects related to cardiovascular system, glucose homeostasis and all-cause mortality (Marcos et al., 2021). Beer is a fermented beverage composed of water (90 %), malt, hops to achieve the bitter flavor and yeast for fermentation, with an alcohol content between 3 and 10 % v/v in most cases (Abiko, Paudel, & Uehara, 2022; de Gaetano et al., 2016; Spaggiari et al., 2020; Tasdemir & Sanlier, 2020). Consumption of beer modulates blood lipid profile and this may be influenced by both alcoholic and non-alcoholic components of this beverage, but there is still uncertainly regarding the mechanisms that underlie the effects in cardiovascular health of this popular drink.

3.1. Beer and lipoprotein blood levels

The effects of beer consumption on lipoprotein blood levels are not completely clear (Table 2). Several observational studies report that moderate beer consumption increases HDL-C level and even reduces LDL-C level, on the contrary, recent evidence reports that there is no difference in lipoprotein levels among abstainers and beer consumers. In the general population, the studies showed different outcomes: In the NQplus study no differences were found between beer consumers and abstainers (Sluik, Brolsma, Vries, Geelen, & Feskens, 2016); neither did Nova et al. (Nova et al., 2019). On the other hand, Martinez et al., with a large study population, found that moderate beer consumption increased HDL-C and decreased LDL-C levels (Martínez et al., 2019). Furthermore, beer consumption showed different effects between genders in an older population, an increase in HDL-C level was found in women but no effect was found in men (de Jong et al., 2008). In an interventional study conducted in the middle-aged population, after the two periods of beer consumption (alcohol-free and traditional beer), participants showed a higher HDL-C level. Probably, the increase in HDL-C was due to an increase in the lipoprotein itself, because the main constituent proteins of HDLs, apoAI, and apoAII also increased (Chiva-Blanch et al., 2015). In line with these results, in a younger population, beer consumption was associated with higher levels of HDLs of all sizes and increased HDL lipid content (Du et al., 2020). In contrast, another interventional study, conducted in a middle-aged obese population, did not find differences in the lipid profile after any intervention with beer, HDL-C only increased after beer consumption in those who had a higher LDL-C level (Padro et al., 2018).

The alcohol content in beer is also important when considering this beverage impact in lipid profiles as a cardiovascular risk. For example, after traditional beer intake, an increase of HDL main proteins was found, but when the beer was alcohol free, apoAI and apoAII levels were reduced (Chiva-Blanch et al., 2015).

3.2. Beer and lipoprotein functionality

Recent evidence suggests that not only lipoprotein levels and distribution are important in assessing cardiovascular risk, but also lipoprotein quality is essential. Traditionally, lipoproteins have been reduced to cholesterol transport; however, it has been demonstrated that lipoprotein composition determines lipoprotein functionality and, therefore, quality (Grao-Cruces, Millan-Linares, et al., 2021; Ronsein & Heinecke, 2017; K. Wang, Li, Luo, & Chen, 2020). Regarding the effect of alcohol in the quality of lipoproteins, it is important to highlight that

Table 2
Lipoproteins levels associated to beer consumption.

Study	Year	Type of trial	N	Subjects	Country	Gender	Age	HDL-C	LDL-C
de Jong et al., 2008 (de Jong et al., 2008)	2002–2003	Observational	1,052	History of myocardial infarction	Netherlands	Both	60–80	Increased in men	ND
Chiva-Blanch et al., 2015 (Chiva-Blanch et al., 2015)	NS	Interventional	33	High cardiovascular risk	Spain	Male	55–75	Increased	NS
Sluik et al., 2016 (Sluik et al., 2016)	2011–2013	Observational	1,653	No restriction	Netherlands	Both	20–77	ND	ND
Martínez et al., 2019 (Martínez et al., 2019)	2008–2010	Observational	12,179	No restriction	Brazil	Both	35–74	Increased	Decreased
Nova et al., 2019 (Nova et al., 2019)	2012–2013	Observational	143	Healthy	Spain	Both	55–85	ND	ND
Du et al., 2020 (Du et al., 2020)	2002–2004	Observational	1,785	No restriction	Australia	Both	25–36	NS	NS
Padro et al., 2018 (Padro et al., 2018)	NS	Interventional	36	Overweight	Spain	Both	40–60	Increased when elevated LDL-C	ND

HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; ND, no difference; NS, not shown.

alcohol is a pro-oxidant factor that could increase lipoprotein oxidation.

Several reports have shown that the quality of lipoproteins improved after beer consumption; specifically, with both alcohol-free and traditional beer, the susceptibility of LDL to oxidation was lower. What is more, HDL functionality improved with beer consumption, showing a higher antioxidant capacity by preventing LDL oxidation and inducing cholesterol efflux from macrophages a higher cholesterol efflux capacity (CEC). However, CEC did not increase after alcohol-free beer consumption (Padro et al., 2018). Recent clinical approaches point to bioactive phenolic compounds as the antioxidant agents of beers, in specific, the intake of beer-similar polyphenolic-rich beverages decreased LDL-oxidation when testing in mouse cancer models (Tedesco et al., 2021). Nevertheless, anti-atherogenic effect after beer consumption with animal models remains to be elucidated, because no difference was found after the beer intake on atherosclerotic lesions, despite the reduction of non-HDL-C (Escolà-Gil, Calpe-Berdiel, Ribas, & Blanco-Vaca, 2004). Beer hops have also exerted biological activity in mice reducing both liver cholesterol and TG whereas HDL-C increased after dietary administration (Miura et al., 2005). In a clinical assay with LDLR knockout mice, levels of HDL-C and VLDL-C were increased after beer and ethanol free beer intake, whereas TGs amount was reduced and no change was measured for LDL-C. Additionally, beer consumption modulated the expression of lipoprotein metabolism-related genes, therefore altering their metabolism and functionality (Degrace, Moindrot, Mohamed, Gresti, & Clouet, 2006). Other trials also demonstrate the improvement of the vascular elasticity and the lipid profile, with higher levels of HDL-C and apolipoprotein A1, without differences in LDL-C or TGs values (Du et al., 2020; Spaggiari et al., 2020).

Turning to the experimental evidence on the role of alcohol in lipoproteins functionality, evidence found that 6 % of ethanol consumption decreased LDL and VLDL susceptibility to oxidation in a hamster model of atherosclerosis (Trevithick et al., 1999). In addition, in rats, beer alcohol content resulted in lipoproteins with less susceptibility to oxidation (Gasbarrini et al., 1998). Two different studies conducted in humans concluded that alcohol-free beer showed lower antioxidant capacity compared to traditional beer (Chiva-Blanch et al., 2015; Ghiselli et al., 2000), which suggest that alcohol could be partly responsible for the antioxidant properties of beers. On the contrary, Vinson et al. measured the tendency to oxidation of LDL and VLDLs after the intake of different beers and concluded that the lower tendency to oxidation was due to the phenol content of beers (Vinson, Mandarano, Hirst, Trevithick, & Bose, 2003). Additionally, other antioxidant component of beers are melanoidins, and it has been reported that melanoidins content of beers reduce lipid peroxidation, which could contribute to reduce lipoprotein oxidation (Tagliazucchi, Verzelloni, & Conte, 2010).

On the other hand, pathological conditions, such as obesity and diabetes, change the composition of lipoproteins and turn HDL into pro-inflammatory lipoproteins (Li, Zhong, & Wang, 2018; Morgantini et al., 2014). Diet modulates lipoprotein composition and the adherence to the Mediterranean Diet is associated with better lipoprotein quality, even counteracting the effects of pathological states (Grao-Cruces, Varela, Martin, Bermudez, & Montserrat-de la Paz, 2021). Moderate consumption of beer is within the pattern of Mediterranean Diet and beer could modulate the composition of the lipoproteins and thus, their functionality (Grao-Cruces, Varela, et al., 2021).

3.3. Beer and its components

The main components of beer are water, malt, hops, and yeast, which would brew the cereal and produce the alcohol present in beers. Moreover, different micronutrients are found in beers: polyphenols, minerals, bitter acids and melanoidins (Martinez-gomez et al., 2020; Osorio-Paz, Brunauer, & Alavez, 2020). Polyphenols are known to modulate the circulating lipid profile. Polyphenols from different sources have demonstrated to increase HDL and reduce LDL and TG quantity (Cicero & Colletti, 2018). Therefore, beer polyphenols could contribute to change the lipid blood profile. There is also vast scientific literature on the biological activity of polyphenols as antioxidants and anti-inflammatory agents of interest in the prevention of atherosclerosis, diabetes, neurodegeneration, aging or cancer (Arruda, Neri-Numa, Kido, Maróstica Júnior, & Pastore, 2020; Chiva-blanch & Badimon, 2020; Fiore et al., 2020; Maugeri et al., 2020; Padro et al., 2018; Spaggiari et al., 2020; Sun, Kang, Li, Sang, & Chang, 2021). Regarding lipoprotein oxidation, as the concentration of polyphenols in the blood is low, protection may not be only due to circulating polyphenols, requiring also the binding of both molecules (Hernáez et al., 2014; Poloni et al., 2019; Tung et al., 2020). On the other hand, the oxidation of LDLs is the onset of atheromatous plaque formation and HDLs have the ability to prevent LDL oxidation, but when HDLs are oxidized, they lose their antioxidant capacity and contribute to atheroma plaque formation. Polyphenols have been shown to reduce LDL susceptibility to oxidation and increase HDL antioxidant capacity (Castañer et al., 2012).

Phenolic compounds in beers include flavonoids and phenolic acids (Table 3) and are strongly affected by the conditions of the cultivars of the raw materials and the brewing process (de Gaetano et al., 2016). Many polyphenols analyzed in beers show simple structures that are extensively metabolized in humans, which suggest that the phenolic content in beer may play a key role in vascular diseases (Humia et al., 2019; Marcos et al., 2021; Sohrabvandi et al., 2012; Spaggiari et al., 2020). What is more, the antioxidant capacity of beer is highly related to polyphenol content. Oliveira Neto et al. (2017) found that ale had higher antioxidant capacity than lager beers, due to the brewing process that allows to higher extraction of phenolic compounds (Oliveira Neto, de Oliveira, Ghedini, Vaz, & Gil, 2017). On the other hand, xanthohumol, the most abundant and beer-specific polyphenol, inhibited LDL oxidation and inhibited inducible nitric oxide synthase and cyclooxygenase 1 activity (Abiko et al., 2022; Hirata et al., 2012; Miranda et al., 2000).

On the other hand, as a result of the beer-making process, melanoidins are present in beers as a product in the reaction of Mailliard. Melanoidins are highly antioxidant compounds, for example, they reduce the oxidative status and have been described to have antihypertensive effects (H. Y. Wang, Qian, & Yao, 2011). Beer melanoidins have been described to contribute to the antioxidant properties of this beverage (Alves, Xavier, Limoeiro, & Perrone, 2020; Pastoriza & Rufián-Henares, 2014; Rivero et al., 2005; Tagliazucchi et al., 2010; Zhao, Li, Sun, Yang, & Zhao, 2013), however, the antioxidant capacity of melanoidins is lower compared to polyphenols (Zhao et al., 2013). Content of melanoidins differs depending on the type of beer, results range between 0.58 and 12.3 g/L (Alves et al., 2020; Rivero et al., 2005; Tagliazucchi et al., 2010), being dark beers the ones with more melanoidins content (Tagliazucchi et al., 2010).

4. Conclusions

The purpose of the current review was to focus on the composition of beers, which are very popular drinks, as the source of metabolites, including alcohol, phenols and melanoidins, which influence our cardiovascular health. Many data demonstrate so far that low to moderate beer intake exerts a beneficial effect in terms of cardiovascular risk. This study provides a new understanding regarding the molecular profile involved in beer components healthy effects. Circulating lipids in blood may alter their levels or oxidation status, anticipating cardioprotective microenvironments. What is more, populations of high-density or low-density lipoproteins may exert different functions in our cardiovascular health after beer intake, in order to diminish cardiovascular risk. Nevertheless, further research is needed to elucidate the complex mechanisms underlying beer components behavior to contribute to reduce cardiovascular disease mortality. However, it is important to highlight that the benefits of beer intake does not outweigh the risks, the WHO discourages of any alcohol consumption.

Table 3
Beer components.

			1 L	Men daily recommendations	Women daily recommendations
Energy (kcal)			330	3,000	2,300
Water (g)			973	2,500	2,000
Alcohol (g)			31		
Macronutrients	Proteins (g)		3	54	41
	Lipids (g)		0	100–117	77–89
	Carbohydrates (g)		24	375–413	288–316
Vitamins	Thiamine (mg)		Traces	1.2	0.9
	Riboflavine (mg)		0.3	1.8	1.4
	Niacin equivalents (mg)		4	20	15
	B6 vitamin (mg)		–	1.8	1.6
	Folates (μg)		41	400	400
	Vitamin B12 (μg)		1.4	2	2
	Vitamin C (mg)		0	60	60
	Vitamin A (μg)		Traces	1,000	800
	Vitamin D (μg)		0	15	15
	Vitamin E (mg)		0	12	12
Minerals	Calcium (mg)		70	1,000	1,000
	Iron (mg)		0.1	10	18
	Iodine (μg)		–	140	110
	Magnesium (mg)		60	350	330
	Zinc (mg)		0.2	15	15
	Sodium (mg)		110	<2,000	2,000
	Potassium (mg)		430	3,500	3,500
	Phosphorus (mg)		200	700	700
	Selenium (μg)		Traces	70	55
Phenols	Simple phenols (mg)	Vinyl-4-phenol Vinyl-4-guayacol ethyl-4-phenol isoeugenol propil-4-siringol 2,3-dihydroxy-guaiacyl 1 propan-2-one	≤ 0.55		
		Tyrosol	≤ 40		
	Acid phenols (mg)	4-hydroxyphenylacetic homovanillic 3,5-dihydroxybenzoic 2,6-dihydroxybenzoic 3-hydroxybenzoic protocatecuic gallic siringico siringic aldehyde m-coumaric 5-caffeoilquinic caffeic sinapic	≤ 1		
		2-hydroxybenzoic vanillic o-vanillin p-coumaric o-coumaric	1–5		
		4-hydroxybenzoic Ferulic	≤ 10		
	Flavonoids (mg)	Isoxanthohumol 8-prenilnaringenin 6-prenilnaringenin 6-geranilnaringenin taxifolin procyanidin *C*2 kanpherol-3-rhamnoside 3,7 dimetilquercitin miricetin Quercetin 3-O-Arabinoside Quercetina 3-O-rutinoside isoquercitrin apigenin	≤ 1		
		Isoxanthohumol (-)-catechin (-)-epicatechin procyanidin B3 Prodelphynidina B3 Prodelphynidina B9	1–5		

(*continued on next page*)

Table 3 (*continued*)

	quercitrin rutin	
	Catechin gallate epicatechin gallate kanpherol quercetin	5–20
Isoflavonoids (mg)	Daidzein Genistein formononetin biochanin A	≤ 0.015
Alkylphenols (mg)	3-methylcatechol 4-ethylcatechol 4-methylcatechol vinil-4-phenol	≤ 0.15
Chalcones (mg)	Xanthohumol	0.002 – 1.2
α-acids (hummulones) (mg)		1.7
Iso-α-acids (isohummulones) (mg)		0.6–100
Others (mg)	Catechol Pirogalol	0.1–0.3

(Arranz et al., 2012; Osorio-Paz et al., 2020; Valero Gaspar -Paula Rodríguez Alonso Emma Ruiz Moreno -José Manuel Ávila Torres Gregorio Varela Moreiras Fotografía Raúl Molinero Hernando, Agricultura, & Alimentación Gobierno De España, 2018).

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.

Data availability

No data was used for the research described in the article.

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