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Makro Bileşenlerle İlişkili Polifenollerin Biyokimyasal Etkileri

Aysel GÜVEN[1]

Öne Çıkanlar:
- Flavonoidler ve içerikleri
- Polifenoller ve Sağlık
- Polifenol biyokimyası

Anahtar Kelimeler:
- Flavonoidler
- Fenolik asitler
- Stilbenler
- Lignanlar
- Sağlık

ÖZET:

Uzun yıllardır ağırlıklı olarak şeker, tuz, doymamış yağlar ve işlenmiş hazır gıdalarla beslenme alışkanlığı giderek artmış bu da beraberinde kronik hastalıklara yakalanma oranını arttırmıştır. Bunun sonucu olarak ortaya çıkan çok çeşitli sağlık sorunlar insanları, daha sağlıklı beslenme arayışlarına götürmüştür. Bu da temel besin bileşenleri olan karbonhidratlar, proteinler ve yağların sekonder metabolitleri olan fenolik bileşenlerce zengin yenilebilir meyvelerin, sebzelerin, baharatlarin, yemişlerin, tohumların ve çiçeklerin önemini artmıştır. Bu derlemede makro bileşenlerle ilişkili polifenollerin polifenol bileşikler olan flavonoidler, fenolik asitler, stilbenler ve lignanların biyokimyasal etkilerine bağlı olarak sağlık üzerine faydaları ortaya konmaya çalışılmıştır.

Biochemical Effects of Polyphenols Associated with Macro Components

Highlights:
- Flavonoids and compaonts
- Pollyphenolics and health
- Biochemistr of pollyphenolics

Keywords:
- Flavonoids
- Phenolic acid
- Stilbenes
- Lignans
- Health

ABSTRACT:

For many years, the habit of eating mainly sugar, salt, unsaturated fats and processed ready-to-eat foods has gradually increased, which has increased the rate of chronic diseases. A wide variety of health problems that have arisen as a result of this have led people to seek healthier nutrition. This has increased the importance of edible fruits, vegetables, spices, nuts, seeds and flowers rich in phenolic components, which are secondary metabolites of carbohydrates, proteins and fats, which are essential nutritional components. In this review, it was tried to reveal the health benefits of polyphenols associated with macro components due to the biochemical effects of polyphenol compounds such as flavonoids, phenolic acids, stilbenes and lignans.

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INTRODUCTION

Polyphenolic substances are nutrients that must be included and consumed in daily eating habits for people of all age groups due to their rich nutritional content and phenolic substances they contain, protecting them from diseases and being anti-aging (Zeriouh et al., 2017; Lorrain et al., 2012; Çimen et al., 2020; Saini et al., 2020; Zhang et al., 2020). In general, foodstuffs contain a different number of phytochemicals between 500-25000, and "phenolic compounds", which make up about 500 of them, are the most popular compound group due to their close relationship with health (Acosta-Estrada et al., 2014). It is estimated that 5–10% of the total dietary polyphenols are absorbed from the small intestine, while 90–95% are fermented by the colon microbiota. Thanks to this mutual interaction between polyphenols and gut bacteria, host health is maintained, the formation of chronic diseases is prevented, and the progression of existing health problems is prevented (Kumar and Baojun, 2017; Saini et al., 2020).

In this study, it was tried to reveal the health benefits of polyphenols associated with macro components depending on their biochemical effects.

Polyphenols

Polyphenols are secondary metabolites synthesized from phenylalanine and tyrosine, which are responsible for the coloring of plants in parts of plants such as flowers, leaves, fruits, stems and roots, and also protect plants against insects, microorganisms, ultraviolet rays and extreme heat. Polyphenols are usually not free, but are formed in ester or glycoside form, structurally by attaching one or more benzene rings and OH groups (Shahidi, and Yeo, 2016). Over 8000 polyphenol compounds have been identified so far, which are subject to main classification within themselves due to differences in their chemical structures. Polyphenols in plants are examined in four classes as flavonoids, phenolic acids, stilbenes and lignans according to the number of phenol rings, the function of the structural elements connecting the rings, the structure of their skeletons and the hydroxylation, oxidation, glycolysis and acylation status of heterocyclic rings (Lagos et al., 2015; Manach et al., 2004).

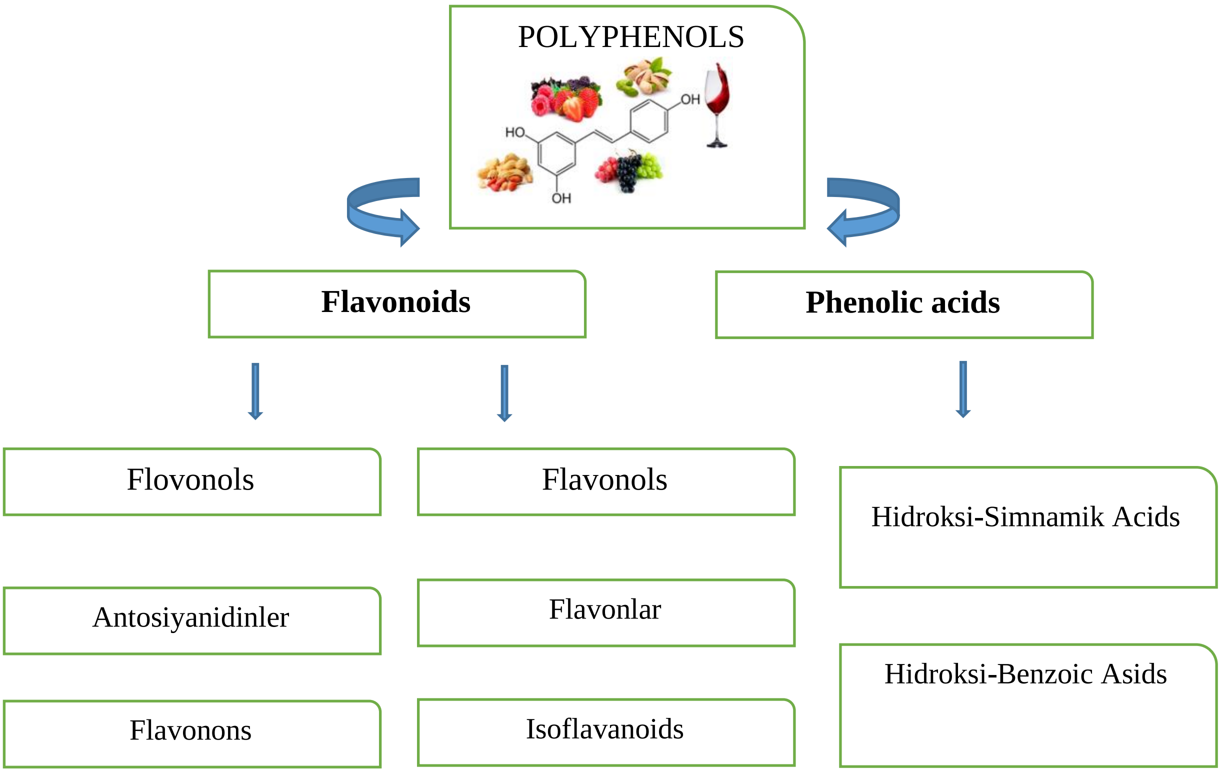

Figure 1. Classification of polyphenols)

While some of the phenolic compounds are involved in the formation of the taste of vegetables and fruits, some of them are involved in the formation of yellow, yellow-brown, red-blue tones. The role of phenolic compounds in this coloring causes problems such as enzymatic browning in the processing of vegetables and fruits (Yalçın et al., 2017). Approximately 60% of dietary polyphenols are flavonoids and 30% are phenolic acids (Spencer et al., 2008).

Polyphenols Assocıated wıth Macro Components

The bioavailability of phenolic compounds in foods is associated with their release from the food matrix in the gastrointestinal tract, their absorption and passage into the bloodstream system. In particular, the binding of polyphenols in some foods to macromolecules such as proteins, carbohydrates and lipids in the cell wall structure greatly affects their bioavailability in the gastrointestinal tract. Dozens of studies have shown that these complex formations have positive effects on the elimination of many health problems (Karabulut and Yemiş, 2019; Zhang et al., 2020, Zhang et al., 2020¸Öztürk and Yılmaz 2024).

Complexes formed by phenolics with macromolecules mostly cause positive changes, but in some studies, they cause a decrease in nutritional values or enzyme activities (Zeriouh et al., 2017; Lorrain et al., 2012; Çimen et al., 2020; Saini et al., 2020; Zhang et al., 2020). Thanks to these macro structures, which act as nanocarriers, the most important benefit in terms of health is that phenolics can be transported to the colon system without changing their antioxidant activity. Similarly, many gastrointestinal diseases, especially colon cancer, can be prevented by supporting the antioxidant and antimicrobial environment in the colon environment (Santos,.et al., 2013). Smaller molecules, such as phenolic acid, are formed by fermenting polyphenols that are resistant to enzymes in the colon. Thus, the formation of active metabolites is ensured. This activity is very important for the biological action of polyphenols. Polyphenol-rich foods such as blackberries, grapes, pomegranates, apples, oranges, legumes, tea, wine, cocoa, and other foods provide great health benefits and regulate the composition of the gut microbiota (Plamada ve Vodnar, 2021; Maniglia et al., 2021).

As a result of enzymatic browning caused by the polyphenol oxidase enzyme, fruits and vegetables are damaged, as well as their colors and tastes are adversely affected, and their nutritional value decreases significantly.

Protein-phenolic Compounds

Phenolic compounds and proteins in the food matrix can be linked to each other by covalent and non-covalent bonds (Le Bourvellec and Renard, 2012). The protein-phenolic relationship is based on fundamentally non-covalent interactions between the aromatic ring (-OH groups) of phenolics and the hydrophobic regions (-COOH groups) of proteins (Le Bourvellec and Renard, 2012; Czubinski et al., 2017). As a result of the complexion of proteins with phenolic compounds, the secondary and tertiary structures of proteins undergo changes with the increase in α-helix and βconformation. The structure of proteins and the composition of amino acids in the structure are also of great importance in the formation of the protein-phenolic complex structure (Friesen, et al., 2015). It is known that proteins rich in proline amino acids, which are especially flexible, have higher affinity against phenolic compounds. Due to its ring structure, the amino acid proline prevents the conversion of hydrogen bonds to the α-helix structure and creates suitable binding sites for phenolic compounds (Acosta-Estrada et al., 2014; Soares et al., 2012). Phenolic compounds such as tannins and flavonols can act together with antibiotics to inhibit the ability of pathogens to cause disease. The interaction between phenolic compounds and protein can reduce the nutritional value of coffee by adversely affecting antimicrobial activity and bioavailability from some amino acids. At the same time, the conditions of the environment in which they are located, such as pH, temperature, type of substances, hydrophilic/hydrophobic properties and ionic force, can be decisive in the interaction between proteins and phenolic compounds. Proteins can form complexes with phenolic compounds thanks to their hydrophobic regions. It is stated that the reason for the feeling of astringency left in the mouth when eating fruits and vegetables with high phenolic content is the protein-phenolic complex and this is due to the precipitation of proanthocyanidins by binding to saliva proteins with high proline content (Czubinski, J., Dwiecki, K. 2017). Variables such as the degree of polymerization of proanthocyanidins, the percentage of esterification with gallic acid, and the number of -OH groups have been found to have effects on their effect on complexing with proteins (Czubinski, J., Dwiecki, K. 2017; Rinaldi et al., 2014; Friesen et al., 2015). It can be said that the increase of these variables triggers the hydrophobicity and multiple bonds forming ability of proanthocyanidins and thus increases the formation of the proanthocyanidin-protein complex. Astringency, especially in products such as tea and wine, occurs as a result of protein-phenolic interaction.

In a study, it was emphasized that the high proline content of casein micelles had an effect on the affinity of casein micelles, especially against catechin in the structure of tea (Hasn et al., 2011), and in a study on soy proteins-phenolic relationship, it was stated that there was a decrease in the amount of some amino acids such as lysine, cysteine and tryptophan in the complex formed (Rawel et al., 2002).

Carbohydrate-phenolic compounds

As one of our body's main sources of nutrients and energy, carbohydrates can interact with phenolic compounds and alter the bio-accessibility/bio-availability of phenolic compounds. The relationship between carbohydrates and phenolic compounds is influenced by hydrogen bonds, hydrophobic interactions, non-covalent hydrogen, van der Waals and hydrophobic bonds formed between the hydroxyl groups of carbohydrate and glycosidic oxygen atoms and proanthocyanidins in the cell wall. The hydrophobic pores of carbohydrates are very effective in forming complexes with carbohydrates by interacting with cellulose and dietary fibers, which are among the cell wall materials (Watrelot et al., 2014; Renard et al., 2017). Polyphenols can form complexes with various carbohydrates such as cyclodextrin, pectin, cellulose and dietary fiber. This complex is known to have many positive effects on health (Jakobek, 2015).

In a study, it was emphasized that curcumin, which is highly unstable in alkaline environments, shows higher stability in alkaline environment when it forms a complex with carbohydrate structures in this interaction where hydrogen bonds are dominant in the establishment of the carbohydrate-curcumin complex structure (Zhou et al., 2016). In another study, the effect of anthocyanins on tannin cell wall interaction in red and white wines was examined, and it was revealed that tannins and anthocyanins compete to bind to cell wall adsorption sites depending on the anthocyanin content and concentration (Bautista-Ortin et al., 2016). Its carbohydrate-phenolic complex structure helps to transport phenolic compounds from the digestive system to the colon system by maintaining its activity. The complex structure has not been shown to have any negative effects on the digestibility of carbohydrates in the body. Similarly, in an in vivo study, mouse subjects were fed only 1 g of procyanidin and 1 g of procyanidin + 2 g of carbohydrate-rich food product and the amount of phenolics in blood plasma samples was analyzed. As a result of the study, higher phenolic metabolites were detected in vitro compared to mouse subjects (Serra et al., 2010).

Lipid-phenolic compounds

Any molecule that may have an effect on the emulsion properties or lipase activity of oils can affect the oil absorption process. Polyphenols are able to change the surface or size of the oil droplets, which in this case are important for lipase activity. By their effect on emulsion properties, polyphenols can lead to a decrease in lipase activity and thus a decrease in oil absorption (Ortega et al., 2009).

In a study examining the effect of lipid-phenolic complexes on digestion, it was emphasized that phenolic compounds in cocoa have higher availability in chocolate products with high fat content (Orlega et al., 2009). In addition, it is known that the complex structure of phenolic compounds with lipids prevents lipid oxidation and provides positive health effects by reducing the absorption of lipids (Lorrain et al., 2012). In addition, it has been revealed that lipids that form complexes with phenolics are absorbed at a lower rate in the gastrointestinal tract compared to blood samples taken from subjects who consume meat products and red wine together (Georelik et al., 2013). With regard to cardiovascular health, flavonoids inhibit low-density lipoprotein (LDL) oxidation by altering lipid metabolism, thereby reducing atherosclerotic lesion formation, inhibiting platelet aggregation, and reducing vascular cell adhesion molecule expression (Georelik et al., 2013; Saini et al., 2020; Zhang et al., 2020).

Digestion of polyphenols associated with macro components

In protein-phenolic complexes, protein digestibility may increase or decrease depending on the structure. In particular, the digestibility of hydrophobic and aromatic amino acids phenyl alanine, proline, tyrosine and tryptophan in the upper gastrointestinal tract decreases, while its digestibility in the small intestine increases with pancreatic enzymes (Petzke et al., 2005). Phenolics change the structure, quality, sensory properties (especially bitter taste) and functionality of proteins. Nutritional losses in complex proteins are associated with the degradation of essential amino acids and the inhibition of proteolytic, glycolytic enzymes (Le et al., 2012).

It is possible to describe the path and changes of phenolic compounds due to macro components in the human body as follows. Protein-phenolic, lipid-phenolic and carbohydrate-phenolic complex components taken orally pass into the stomach from interaction with salivary enzymes. Their bound phenolic structures, which are resistant to acidic conditions, leave the stomach environment unchanged and undergo enzymatic hydrolysis at a rate of approximately 5-10% directly in the small intestine with Phase I modifications (oxidation, reduction). Various metabolites are formed while the polyphenolic structures reaching the blind intestine (appendix) from here are hydrolyzed by Phase II enzymes and microflora in the colon without depolymerization and digested into simple phenols. As the absorbed components are transported to the liver through the blood, sulfated, methylated and glucoronidated conjugates are formed. Some components pass back into the small intestine through the bile duct and are discharged through the urea duct (Bohn, 2014).

Bound phenolic compounds, which cannot be released during digestion, can create a positive antioxidant environment in the colon until they reach the colon from the gastrointestinal tract. Therefore, they can neutralize the free radicals they encounter or react with oxidation by-products such as semi-quinone and quinone (Gorelik et al., 2013).

Consumption of foods containing bound phenolics can promote the growth of beneficial bacteria in the intestine as well as inhibit the growth of pathogenic bacteria. These complex components can be fermented into smaller components or metabolites that have proven positive effects on health, acting as substrates for microbial flora in the colon. It is stated that ellagitannin derivatives (urolithins and pyrosgallol) and chlorogenic acid derivatives (dihydrocaffeic acid, dihydroferulic acid and feruloylglycine), which are metabolites formed in the colon as a result of fermentation of phenolic compounds, can prevent diabetic complications (Verzelloni et al., 2011). In addition to this effect, it is stated that the fermentation of polyphenols reaching the colon provides metabolites with various positive effects on health such as hydroxyphenylacetic, phenylpropionic, phenylvalerolactones, phenylvaleric acids, phenylpropionic acids, phenylacetic acids, hypercuric, benzoic acid and phenylbutyric acid (Saura et al., 2020).

Effects of natural plant polyphenols on the human body

There is a growing body of evidence regarding the beneficial roles of natural plant polyphenols in the human body. These are: inflammations, cancer, cardiovascular diseases, obesity, diabetes, neurological disorders, antioxidative effect on osteoporosis and immune system regulation, antibacterial, anticarcinogenic, anti-inflammatory, anti-diabetic, anti- neurodegenerative, anticholesteremic, anticholesterolemic effects (Saini et al., 2020; López-Oliva et al., 2013; Dewi, 2019; Çimen et al., 2020).

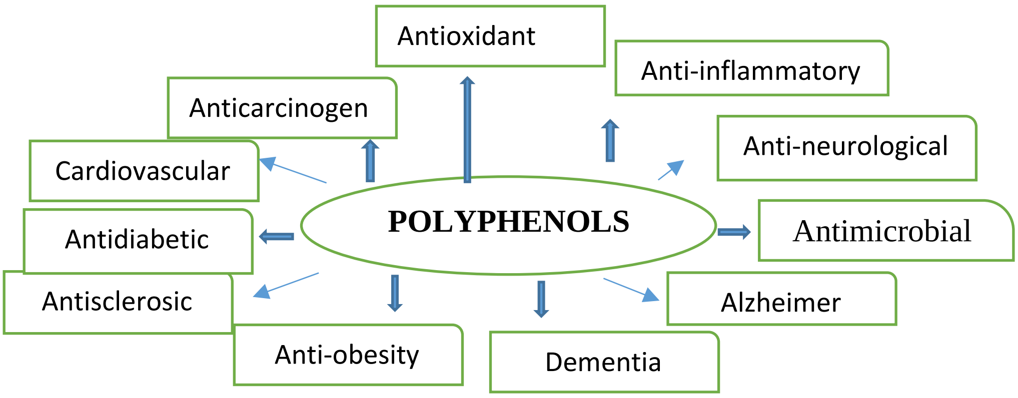

Figure 2. Bioactivities of polyphenols

Phenolic compounds show antioxidant activity due to their ability to be easily oxidized because they have at least one aromatic ring and at least one hydroxyl group attached to this ring. Vitamins A, C and E, which are found in green and red leafy vegetables and fruits, which generally contain phenolic components, show more antioxidant properties. Most of the flavonoids, including flavanols, show their free radical scavenging, inhibiting hydrolytic and oxidative enzymes, and anti-inflammatory activities due to their ability to scavenge or neutralize free radicals due to the location of hydroxyl groups (Alkan and Rakıcıoğlu., 2021; Anantharaju et al., 2016; López-Oliva et al., 2013; Dewi, 2019). Accordingly, it has been reported that there is an inverse correlation between the risk of developing lung, stomach, mouth, pharynx, esophagus, colon and rectum cancers and fruit and vegetable consumption (López-Oliva et al., 2013; Dewi, 2019) The antioxidant capacity of flavonoids depends on their molecular structure, and one of the reasons for these effects has been associated with the pro-oxidant activity of polyphenols. Because high doses of some polyphenolic compounds have been shown to cause DNA damage, apoptosis, and cell death (Zhou et al., 2016). In addition, polyphenols have protective effects against some types of cancer, inhibiting the number and growth of tumors, on the other hand, they also show cytotoxic and apoptosis stimulating effects and initiating the activities of various enzymes in cancer cells (Soyocak and Koç, 2020).

Studies have shown that phenolics protect colon cancer from oxidative and antifertility effects, and phenolics in tea protect DNA in cellular structure from oxidative stress (Zeriouh et al., 2017, Sanchez-Tena et al., 2013). In another study, flavonoids, phenolic acids, stilbenes and lignans-derived components found in polyphenols show their protective effects against cancer with their cancer-reducing effects, and various mechanisms such as inhibiting enzymes that activate carcinogens, regulating cell receptors and other proteins (Alkan and Rakıcıoğlu, 2021; Li et al., 2022).

The anticholesterolemic activities of flavonoids and derivatives obtained from plants are shown by bioactive components such as alkaloids, terpenoids and flavonoids, especially in essential oils. Polyphenols taken from some plant foods such as extra virgin olive oil, dark chocolate, black and green tea, forest fruits, citrus fruits and grapes have been shown to have a protective effect on the cardiovascular system through different mechanisms (inhibiting the oxidation of LDL, increasing HDL, reducing LDL and triglycerides). Luteolin, the favonoid component of artichoke, has been found to play an important role in inhibiting cholesterol biosynthesis and reducing serum cholesterol (Cansey et al., 2024).

Another effect of polyphenol compounds is on the intestinal flora. It has been concluded that polyphenol compounds can also increase the richness of the intestinal flora, reduce the activity of carcinogenic bacteria, stabilize the ratio of the core flora, and maintain the homeostasis of the intestinal microenvironment (Li et al., 2022). Polyphenols show all these effects together with carbohydrates by positively affecting the development of the colon microbiota. In particular, the binding of polyphenols in some foods to macromolecules such as proteins, carbohydrates, and lipids in the cell wall structure greatly affects their bioavailability in the gastrointestinal tract (Zhang et al. 2020). 5-10% of the total polyphenols in the diet are usually absorbed in the small intestine by deglycosylation. The remaining 90-95% of the small intestine that is not absorbed is broken down by colon bacteria in the large intestine. As a result of the activity of the intestinal microbiota, polyphenols are reduced to simpler derivatives by the breakdown of glycosidic bonds in the structure of polyphenols and the deterioration of the heterocyclic structure. Thus, the absorption of polyphenols in the gastrointestinal (GI) tract increases. Short-chain fatty acids, which are produced as a result of carbohydrate metabolism of the gut microbiota, inhibit the development of pathogens by lowering the intraluminal pH level of the gut (López-Oliva et al., 2013; Pérez-Jiménez et al., 2013). In human studies, it is reported that the levels of probiotic bacteria such as Lactobacillus and Bifidobacterium increase in the intestinal microbiota with regular consumption of polyphenol-rich foods, while the levels of pathogenic bacteria such as Clostridium species and Staphylococcus aureus decrease (Shahidi, 2016) In this way, polyphenol-rich foods such as blackberries, grapes, apples, oranges, legumes, tea, cocoa, honey and wine are effective in regulating the composition of the gut microbiota can be said.

Some plant polyphenols also have effects on the immune system and inflammatory cells. Chlorogenic acid found in vegetables and fruits; Phenolic substances formed by the esterification of caffeic acid and quinic acid act on cytokine and cytokine receptors, while some of them affect the secretory process. Olive leaf extract treatment has been reported to reduce inflammation, while Hydroxytyrosol and 3,4-Dihydroxyphenylglycol purified from olive leaf also have the ability to reduce inflammation in vitro through inhibition of pro-inflammatory cytokines (TNF-α, IL-6 and IL-1β). A diet rich in polyphenols; It reduces the risk of developing diabetes. These positively regulate insulin and glucagon-like peptide (GLP-1) pathways and increase insulin sensitivity in peripheral tissues (Dominguez, Avila et al., 2017; Sarı, 2017; Yaman, 2015). It also strongly inhibits the enzymes α-glucosidase and α-amylase and thus contributes to normal glucose balance by regulating the absorption of glucose from the intestines.

Regarding cardiovascular health, flavonoids alter lipid metabolism, inhibit low-density lipoprotein (LDL) oxidation, reduce atherosclerotic lesion formation, inhibit platelet aggregation, reduce vascular cell adhesion molecule expression, improve endothelial function, and may lower blood pressure (Saini et al., 2020).

CONCLUSION

Phenolic compounds have the ability to bind to the cell wall and structures such as proteins, carbohydrates and lipids in the environment with hydrophobic and hydrophilic interactions, hydrogen and covalent bonds due to their aromatic rings and hydroxyl groups. Phenolics, which are found together with the macrocomponents of foods such as edible fruits, vegetables, spices, nuts, seeds and flowers, can be covalently attached to structures such as cellulose, pectin and protein in the cell wall by ester, ether or acetal bonds. There are many effective factors such as molecular weight, degree of polymerization, number of aromatic groups in the interaction of phenolics with macromolecules. And these factors affect the bioavailability of phenolic compounds in foods, their release from the food matrix in the digestive or intestinal tract, their absorption and passage into the blood circulation system. In particular, polyphenols in some foods bind to macromolecules such as proteins, carbohydrates and lipids in the cell wall structure and greatly affect the bioavailability in the gastrointestinal tract.

As a result, more studies need to be conducted on the regular consumption of foods rich in polyphenols to reveal the macro components in different food combinations.

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