

Nature's Superfood: A Review of Apple Nutrients and Health Benefits

Doina Georgeta ANDRONOIU¹, Oana Viorela NISTOR¹, Gabriel – Dănuț MOCANU¹

¹"Dunarea de Jos" University of Galati, Faculty of Food Science and Engineering, 111 Domesca Street, 800201, Galati, Romania

1

ABSTRACT

Apples (*Malus domestica* Borkh.), frequently consumed fruits, are known to be a great source of micronutrients – including vitamins (C, A, and E, thiamin, riboflavin, nicotinic acid, folic acid, and pyridoxine) and minerals (potassium, phosphorus, calcium, magnesium, zinc, and iron) – as well as soluble and insoluble dietary fibers, and various bioactive compounds.

Apple bioactive compounds with beneficial effects on human health include various polyphenols (specifically hydroxycinnamic acids, glycosylated flavonoids, flavan-3-ols, proanthocyanidins, and dihydrochalcones), along with polysaccharides (pectin), phytosterols, and pentacyclic triterpenic acids.

Epidemiological studies demonstrate a correlation between apple consumption and a reduced incidence of several chronic pathologies: cardiovascular disease, asthma, type 2 diabetes, Alzheimer's, and Parkinson's disease. Numerous *in vitro* and *in vivo* studies demonstrate that apples and their bioactive compounds possess high antioxidant activity, facilitate cholesterol reduction, attenuate lipid oxidation, and inhibit the growth of various cancer cells.

This review evaluates the nutraceutical potential of apples and their derivatives (juices, purees, pomace, chips, and isolated bioactive compounds) on human health.

2

INTRODUCTION

Malus domestica (family *Rosaceae*) is among the most economically and culturally important fruit crops cultivated across temperate regions worldwide, valued for its high nutritional content and broad agricultural significance (Oyenihi et al., 2022).

As one of the most widely consumed fruits, apples are highly valued for their nutritional composition and health-promoting properties. They contain a diverse range of bioactive compounds with beneficial effects on human health; however, the composition and concentration of these active constituents vary considerably among apple cultivars grown in different regions of the world (Qin et al., 2017).

In this context, the polyphenols, vitamins, triterpenes, dietary fiber, and other bioactive constituents present in apples have demonstrated potential therapeutic effects against various diseases, as evidenced by numerous *in vitro* and *in vivo* studies, as well as multistage clinical investigations. Although fresh apples remain the most commonly consumed form, processed apple-derived products, including apple juice, apple vinegar, apple powder, apple chips, and apple cider, have also gained increasing consumer acceptance and popularity (Zhang et al., 2023).

3

BIOACTIVE COMPOUNDS IN APPLES

Apples contain essential macroelements, including abundant levels of potassium, nitrogen, phosphorus, calcium, and magnesium, as well as trace elements such as boron, zinc, iron, manganese, and aluminum. These minerals constitute essential components of human tissues and perform important physiological functions, including the activation of various enzymatic processes (Punchay et al., 2020).

Vitamin C in apples contributes to the inhibition of LDL oxidation, stabilization of endothelial function, and reduction of cholesterol levels, thereby potentially aiding in the prevention of diabetes and hypertension (Zhang et al., 2023). Apples also contain several other vitamins, including vitamins A, E, B₁, B₂, B₃, B₆ and B₉ (Islam et al., 2016).

Apple polyphenols exhibit diverse bioactive properties, including anti-inflammatory, antioxidant, antiviral, and neuroprotective effects. Moreover, these polyphenolic compounds may contribute to the prevention of cardiovascular, degenerative, and intestinal inflammatory diseases, while also protecting the gastric mucosa against aspirin-induced damage (Matos et al., 2020).

Triterpenoids present in apple peels exhibit a broad spectrum of bioactivities, including anticancer, anti-inflammatory, antihyperlipidemic, hypoglycemic, analgesic, gastroprotective, hepatoprotective, antiulcer, and antiatherosclerotic effects (Hortas et al., 2018). Apples contain both soluble and insoluble dietary fibers (Gidley & Yakubov, 2019) that promote intestinal health (King et al., 2012).

5

CONCLUSIONS

Several scientific studies have shown that apple consumption is associated with a reduced risk of chronic diseases, including cardiovascular disease, cancer, and asthma. *In vitro* and *in vivo* studies have demonstrated that apples and their derivatives, due to their rich profile of polyphenols, fiber, and vitamins, exhibit strong antioxidant activity, inhibit cancer cell proliferation, reduce lipid oxidation, and lower cholesterol levels, which may help explain their role in reducing the risk of chronic diseases. Further research should focus on the extraction of additional bioactive compounds from apples, which may contribute to the protection of human health and also provide economic benefits. In conclusion, "An apple a day keeps the doctor away".

4

BENEFICIAL HEALTH EFFECTS OF APPLES

4.1. Cardiovascular disease

A balanced equilibrium between reactive oxygen species (ROS) and antioxidants is essential for proper cardiovascular function (Ali et al., 2020). Oxidative stress can lead to protein oxidation, lipid peroxidation, and DNA damage (Kreuzer et al., 2020), thereby contributing to the development of cardiovascular diseases (CVDs). Apples and apple juice contain a wide range of antioxidants that may support the prevention of CVDs. Fresh fruits, particularly apples, are important dietary sources of natural antioxidants, including polyphenols, vitamin C (Anjum et al., 2020), and flavonoids such as quercetin (Molagoda et al., 2021).

4.2. Diabetes

It has been reported that apple consumption, attributed to its high quercetin content, may reduce the risk of diabetes, and that apple peels are also associated with a lower risk of type II diabetes. Phenolic compounds, including flavonoids present in apple juice, have been shown to significantly influence insulin and plasma glucose levels, as well as key hormones such as glucose-dependent insulinotropic polypeptide (GIP) and glucagon-like peptide-1 (GLP-1) (Patocka et al., 2020).

4.3. Cancer

Cancer represents a major global health burden, with approximately 20 million new cases reported in 2022, affecting 10,306,455 men and 9,658,356 women worldwide (Mierczak & Garus-Pakowska, 2024; Bray et al., 2024). Apple consumption has been associated with a reduced risk of several cancers, including head and neck, liver, prostate, colon, and breast cancers (Fabiani et al., 2016). Phloretamide, a compound derived from apples, has demonstrated potential protective effects against the development of hepatocellular carcinoma and related liver damage (Krajka-Kuźniak et al., 2013). Apple phytochemicals exhibit chemopreventive properties against colorectal cancer; apple-derived polysaccharides have been shown to reduce DNA damage and precancerous lesions, such as aberrant crypt foci in the colon and rectum, while also inducing apoptosis in cancer cells. These compounds inhibit specific cellular signaling pathways in human colorectal cancer cell lines, including HT-29 and Caco-2 (Jaganathan et al., 2014; Li et al., 2015). Triterpenoids found in apples may provide protective effects against breast cancer. 3β-trans-cinnamoyloxy-2α-hydroxy-urs-12-en-28-oic acid (CHUA), a representative triterpenoid present in apple peels, has demonstrated anticancer properties (Qiao et al., 2015).

4.4. Obesity

Obesity is a complex, chronic disorder characterized by excessive accumulation of body fat, which promotes inflammation and metabolic dysfunction and significantly increases the risk of serious conditions, including cardiovascular diseases, type 2 diabetes, and various cancers (Omer, 2020). Therefore, dietary choices play an important role, with apples representing a significant component of weight management diets. These fruits are low in saturated fat and cholesterol, making them suitable for individuals managing obesity. Their low caloric content and low glycemic index (GI ≈ 44) result in a gradual and modest increase in postprandial blood glucose levels, thereby supporting weight control strategies (O'Neil et al., 2015; Atkinson et al., 2021). Apple polyphenols play an important role in weight management by modulating metabolic pathways, reducing visceral fat accumulation, and regulating appetite-related hormones such as leptin, particularly in individuals with a high body mass index (BMI). Clinical studies have indicated that daily intake of apple polyphenols can significantly reduce visceral fat area and body weight (Asgary et al., 2018). Bioactive compounds present in apples, particularly polyphenols and dietary fibers such as pectin, contribute to the maintenance of a healthy body weight, promote weight loss, and help prevent complications associated with excess body fat (Cargnin & Gnoatto, 2017; Timm et al., 2023; Raji et al., 2023).

4.5. Other health benefits

Apples contain various bioactive compounds, including polyphenols such as quercetin and tannins, as well as dietary fiber, which inhibit dental plaque formation and reduce acid production by oral bacteria (Zhang et al., 2023). A study investigated whether chewing apples mechanically removes dental plaque or affects the viability of salivary bacteria. The results proved that chewing an apple did not remove dental plaque; however, it did reduce the viability of salivary bacteria, with effects comparable to tooth brushing (Rubido et al., 2018).