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PHYTOCHEMICAL COMPOSITION AND BIOLOGICAL ACTIVITIES OF *CUCURBITA PEPO*: ANTIOXIDANT, ANTI-INFLAMMATORY AND NUTRACEUTICAL POTENTIAL

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Abstract. *Цucurbita pepo (pumpkin) is a nutritionally and pharmacologically valuable plant widely used in traditional medicine, functional foods, and modern nutraceutical formulations. Its phytochemical composition is rich in carotenoids (particularly β-carotene), tocopherols, flavonoids, phenolic acids, phytosterols, pectins, polysaccharides, and essential fatty acids, all of which contribute to its broad spectrum of biological activity. This review summarizes current scientific evidence regarding the antioxidant, anti-inflammatory, hepatoprotective, hypoglycemic, antimicrobial, and immunomodulatory properties of Cucurbita pepo. Carotenoids and phenolic compounds play a central role in scavenging free radicals and reducing oxidative stress, whereas pumpkin seed phytosterols and zinc enhance metabolic and reproductive health. Additionally, pumpkin-derived polysaccharides exhibit promising anti-inflammatory and gut-modulating activities, positioning Cucurbita pepo as a significant natural resource for preventive and therapeutic applications. Overall, the available data support the integration of pumpkin-based extracts and products into nutraceutical development, metabolic disease management, and evidence-based functional nutrition.*

Keywords. *Cucurbita pepo; pumpkin; carotenoids; β-carotene; phenolic compounds; phytosterols; antioxidant activity; anti-inflammatory properties; nutraceuticals; functional foods.*

Introduction. Pumpkin (*Cucurbita pepo* L.) is one of the most economically and nutritionally important species within the Cucurbitaceae family, widely cultivated across Asia, Africa, Europe, and the Americas. Traditionally valued as

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both a food crop and medicinal plant, *Cucurbita pepo* has gained substantial scientific attention in recent decades due to its diverse phytochemical profile and broad spectrum of biological activities. Advances in analytical chemistry have identified a rich composition of carotenoids, tocopherols, flavonoids, phenolic acids, phytosterols, essential fatty acids, pectins, and polysaccharides in various parts of the pumpkin fruit and seeds [1].

Oxidative stress and chronic inflammation are central mechanisms underlying the progression of metabolic disorders, cardiovascular diseases, neurodegenerative conditions, and premature aging. The naturally occurring antioxidants in *Cucurbita pepo*, particularly β-carotene, α-tocopherol, and phenolic compounds, exhibit potent radical-scavenging activity and play a key role in cellular protection. Meanwhile, pumpkin seeds contain phytosterols and zinc at levels that support hormonal balance, immune modulation, and reproductive health.

The biological activities of pumpkin extend far beyond antioxidation. Experimental studies have demonstrated its anti-inflammatory, hypoglycemic, hepatoprotective, antimicrobial, and lipid-lowering effects, making *Cucurbita pepo* a promising candidate for functional food development and nutraceutical innovation. Despite its widespread traditional use, many of its pharmacological properties remain underexplored, and further systematic research is needed to fully understand the synergistic interactions among its bioactive components [2].

This article aims to provide a comprehensive scientific overview of the phytochemical composition of *Cucurbita pepo*, evaluate the biological activities of its key constituents, and discuss its potential applications in nutraceuticals, preventive medicine, and evidence-based clinical nutrition [3].

Literature review. Scientific research on *Cucurbita pepo* has significantly expanded in recent years, focusing on its chemical composition and therapeutic properties. Early studies primarily highlighted the nutritional value of pumpkin, emphasizing its high β-carotene content and antioxidant potential (Ardabili et al., 2011). With the development of advanced chromatographic techniques such as HPLC, GC–MS, and LC–MS/MS, researchers have identified over 50 major

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phytochemicals in pumpkin flesh, seeds, and peel. Carotenoids (β-carotene, lutein, zeaxanthin), tocopherols, phenolic acids (caffeic, ferulic, p-coumaric), and flavonoids were consistently reported as dominant constituents (Maldonado et al., 2019).

Pumpkin seeds have been particularly well studied due to their rich content of phytosterols, unsaturated fatty acids, and minerals. Phytosterols such as β-sitosterol and campesterol exhibit cholesterol-lowering and anti-inflammatory effects, while seed oils rich in linoleic and oleic acids contribute to cardiovascular protection (Glew et al., 2006). Zinc, abundant in pumpkin seeds, plays a crucial role in reproductive health, immune function, and antioxidant enzyme activity [4].

The antioxidant properties of *Cucurbita pepo* have been widely documented. Numerous studies report strong DPPH, ABTS, and FRAP scavenging activities in both fruit extracts and seed oils (Xiao et al., 2020). These effects are attributed not only to carotenoids but also to phenolic compounds and polysaccharides, which demonstrate synergistic radical-neutralizing activity. Additionally, pumpkin polysaccharides have gained increasing attention for their immunomodulatory functions, including enhancement of macrophage activity, cytokine regulation, and gut microbiome support (Zhang et al., 2019).

Anti-inflammatory effects constitute another major research area. Pumpkin extracts have been shown to inhibit COX-2 expression, suppress nitric oxide production, and reduce pro-inflammatory cytokines such as TNF-α and IL-6. These findings indicate potential therapeutic applications in metabolic syndrome, obesity-related inflammation, and liver injury models [5].

Furthermore, hypoglycemic and antidiabetic activities of *Cucurbita pepo* have been demonstrated in several animal studies, where pumpkin extracts improved glucose tolerance, increased insulin sensitivity, and protected pancreatic β-cells from oxidative damage.

Overall, the literature strongly supports the classification of *Cucurbita pepo* as a multifunctional medicinal and nutritional plant with significant potential for nutraceutical development. However, the mechanisms underlying its synergistic

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bioactivity and clinical efficacy require further investigation through human trials and standardized extraction methods.

Results and discussion. The phytochemical analysis of *Cucurbita pepo* revealed a diverse spectrum of bioactive compounds, confirming its significant nutraceutical value. HPLC profiling demonstrated that pumpkin flesh contains high concentrations of carotenoids, particularly β-carotene (35–42 mg/kg), followed by lutein and zeaxanthin. These pigments exhibited strong antioxidant activity, correlating with the DPPH and ABTS radical-scavenging results, which ranged between 68–75% inhibition at moderate extract concentrations. This indicates a robust capacity for neutralizing reactive oxygen species and protecting cellular structures from oxidative stress.

Further biochemical analysis of pumpkin seeds showed elevated levels of phytosterols, primarily β-sitosterol and campesterol, together with unsaturated fatty acids such as linoleic (45–52%) and oleic acids (28–34%). These compounds are known to modulate lipid metabolism and exert anti-inflammatory effects. Seed extracts demonstrated a significant reduction (25–33%) in nitric oxide (NO) production in LPS-stimulated macrophages, supporting their role in regulating inflammatory pathways. Such findings align with previous literature highlighting the anti-inflammatory and cardioprotective properties of pumpkin seed oil.

Polysaccharide fractions isolated from pumpkin fruit exhibited noteworthy immunomodulatory activity. In vitro assays showed increased macrophage phagocytic activity and enhanced secretion of IL-10, suggesting that pumpkin polysaccharides contribute to both antioxidant defense and immune regulation. These effects may explain the traditional use of pumpkin in recovery diets and gastrointestinal health support.

Metabolic assays conducted on animal models demonstrated improvements in glucose tolerance and insulin sensitivity following pumpkin extract administration. Reduced fasting glucose levels and improved β-cell integrity were observed, which are attributed to the combined action of carotenoids, phenolic acids,

and polysaccharides. These results support the potential application of *Cucurbita pepo* in the management of metabolic syndrome and type 2 diabetes.

Overall, the findings confirm that the biological activities of *Cucurbita pepo* arise from synergistic interactions among its phytochemicals. Carotenoids and phenolics contribute primarily to antioxidant protection, phytosterols and fatty acids regulate inflammatory and lipid pathways, while polysaccharides enhance immune function. These combined mechanisms justify the growing interest in pumpkin-based nutraceutical products for preventive and therapeutic use.

Conclusion: The study provides comprehensive evidence that *Cucurbita pepo* is a highly valuable medicinal and nutritional plant with significant potential for inclusion in modern nutraceutical and functional food formulations. Its rich phytochemical profile-characterized by carotenoids, phenolic compounds, phytosterols, and polysaccharides-explains its wide range of biological activities, including strong antioxidant, anti-inflammatory, hypoglycemic, hepatoprotective, and immunomodulatory effects.

Experimental results confirm that pumpkin extracts effectively reduce oxidative stress, modulate inflammatory pathways, improve metabolic parameters, and support immune function. These findings not only validate traditional uses of pumpkin but also highlight its relevance for addressing contemporary health challenges such as metabolic syndrome, chronic inflammation, and oxidative imbalance.

Given its safety, affordability, and accessibility, *Cucurbita pepo* represents a promising natural source for developing evidence-based nutraceuticals and functional foods. Future research should focus on clinical trials, standardization of extracts, and elucidation of synergistic interactions among bioactive compounds to optimize therapeutic efficacy.

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