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PLANT-BASED PROTEINS: NUTRACEUTICAL POTENTIAL AND CANCER PREVENTION

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ABSTRACT

Nutrition plays a crucial role in cancer prevention and management. Among dietary components, plant-based proteins especially soy protein have gained significant attention due to their rich content of bioactive compounds. Soy protein contains isoflavones such as genistein and daidzein, which possess antioxidant, anti-inflammatory, and hormone-modulating properties. These compounds influence cellular signaling pathways involved in carcinogenesis, tumor progression, and apoptosis. In addition to soy protein, other plant-derived bioactives such as nobiletin (a citrus flavonoid) and micronutrients like dietary boron also demonstrate anticancer properties. Collectively, plant-based nutraceuticals offer promising complementary strategies for integrative cancer prevention and therapy.

KEYWORDS: Soy protein; Plant-based protein; Isoflavones; Nutraceuticals; Cancer prevention; Antioxidant activity; Sustainable nutrition.

INTRODUCTION

Cancer continues to be one of the most serious global health challenges, affecting millions of people each year. Although advances in surgery, chemotherapy, and radiotherapy have improved survival rates, prevention remains a critical strategy in reducing the overall burden of the disease. Increasing evidence suggests that everyday lifestyle choices, particularly diet, play a significant role in cancer development (Anand et al., 2008).

In recent decades, plant-based diets have attracted scientific and public interest because of their association with lower rates of chronic diseases, including certain cancers. Large

population studies have shown that individuals consuming diets rich in plant foods tend to have a reduced risk of colorectal, breast, and prostate cancers (Key et al., 2011; WCRF, 2018). Among plant-derived proteins, soy protein stands out due to its unique nutritional profile and abundance of bioactive compounds.

Soybeans (Glycine max) are rich in isoflavones, particularly genistein and daidzein, which are naturally occurring phytoestrogens. Because their structure resembles human estrogen, these compounds can interact with estrogen receptors and influence hormone-related pathways (Setchell and Cassidy, 1999). This property has made soy especially relevant in the context of hormone-dependent cancers. Epidemiological observations from Asian countries, where soy consumption is traditionally high, show lower incidences of breast and prostate cancers compared with Western populations (Wu et al., 2008).

Beyond hormonal modulation, soy isoflavones act at the cellular level. Experimental studies demonstrate that genistein can regulate key signaling pathways involved in cancer progression, including PI3K/Akt and NF-κB pathways, leading to reduced cell proliferation and increased apoptosis (Sarkar and Li, 2004; Banerjee et al., 2008). Additionally, soy components exhibit antioxidant and anti-inflammatory effects, helping to counteract oxidative stress and chronic inflammation, two major contributors to carcinogenesis (Aggarwal and Shishodia, 2006).

Taken together, current scientific evidence suggests that soy protein is more than just a dietary protein source; it functions as a bioactive component with potential chemopreventive properties. Understanding its mechanisms and clinical relevance may help in shaping future dietary strategies for cancer prevention and integrative care.

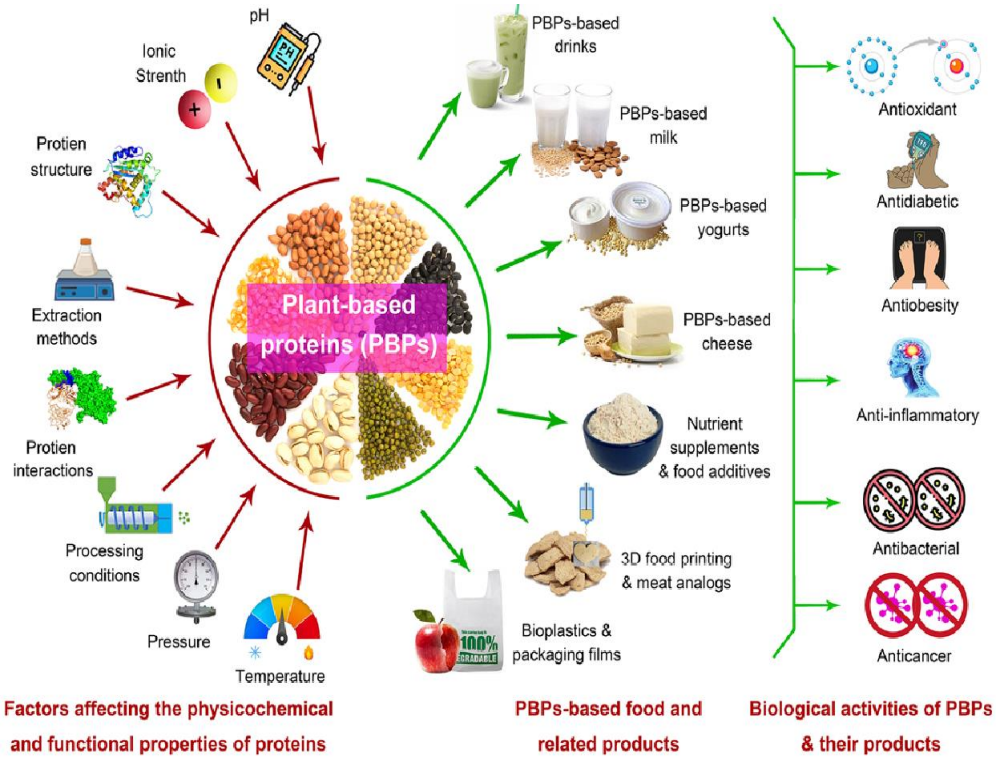

Figure 1: Factors affecting physicochemical, functional, and biological properties of plant-based proteins and their nutraceutical applications.

Noblietin -a citrus flavonoid

Nobiletin regulates multiple signaling pathways involved in cancer progression, including inhibition of epithelial–mesenchymal transition (EMT), suppression of PI3K/Akt and STAT3 signaling, modulation of microRNAs, and enhancement of apoptotic pathways.

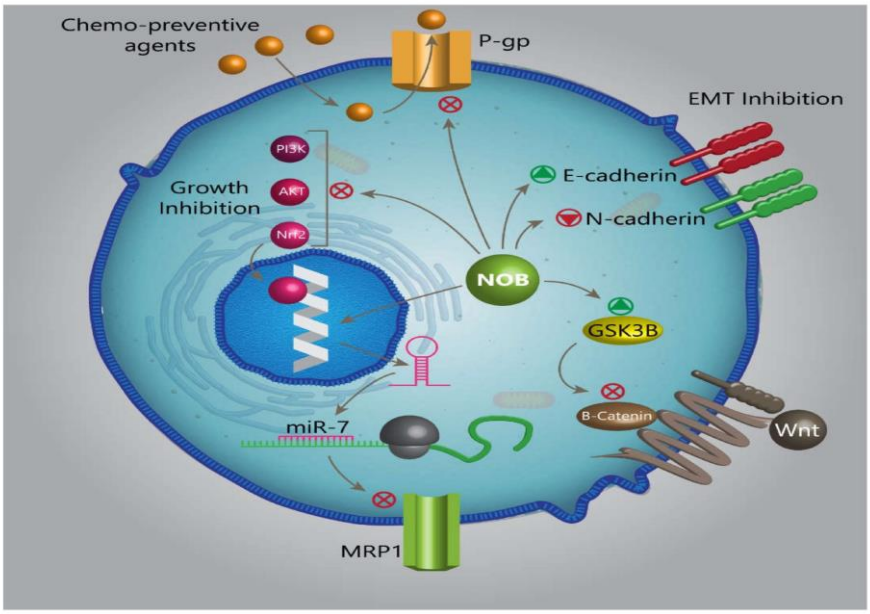

Figure 2: Molecular mechanisms of nobiletin (NOB) in cancer prevention and therapy.

The synthesis pathway of proteins in plants

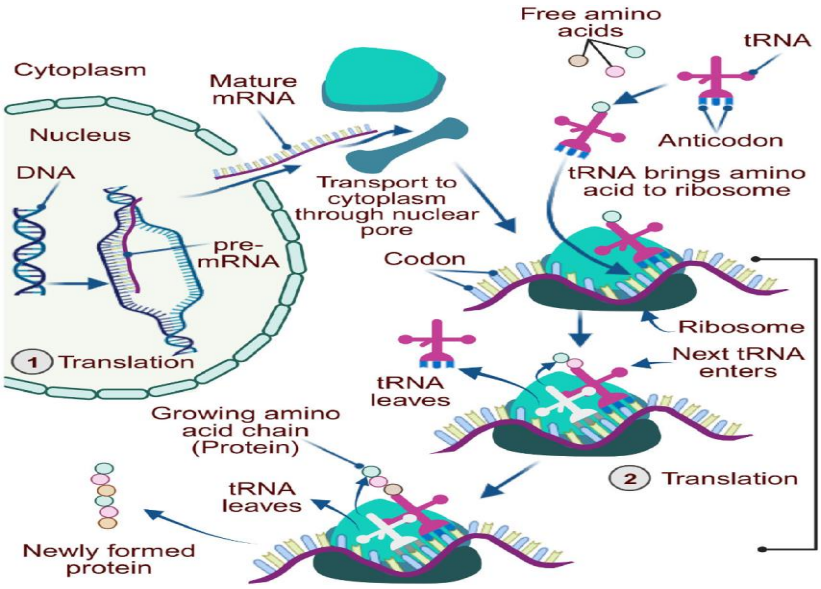

Figure 3.

Methods and Techniques

The MTT assay, utilizing (3-[4,5-dimethylthiazol-2-yl]-2,5 diphenyl tetrazolium bromide), is employed to assess cell viability and proliferation, specifically to evaluate the cytotoxic effects of compounds like nobiletin on cancer cells.[11] In this assay, cells incubated with the test compound are treated with a yellow MTT reagent, which living cells convert into purple formazan crystals through mitochondrial enzymes; the color intensity, measured by a spectrophotometer, directly correlates with the number of viable cells.[11]

Flow cytometry serves to analyze apoptosis and cell cycle distribution, where cells treated with compounds are stained with fluorescent dyes such as Annexin V conjugated to fluorescein isothiocyanate (Annexin V-FITC) and propidium iodide, allowing for quantification of apoptotic and proliferating cells as they pass through a laser-based flow cytometer.[6,11] Western blotting is a critical technique for detecting and quantifying specific proteins involved in apoptosis and cancer progression, such as p53 and Bcl-2, by separating proteins via gel electrophoresis and using specific antibodies to generate a detectable signal.[11]

Additionally, Annexin V staining enables the detection of early and late apoptosis by measuring phosphatidylserine externalization, with flow cytometry helping to distinguish between live, early apoptotic, and late apoptotic cells.[11] The caspase activation assay measures the activity of caspases, key enzymes in the apoptosis process, to elucidate how

compounds like nobiletin induce cell death.[11]

Finally, gene expression analysis through Reverse Transcription Polymerase Chain Reaction (RT-PCR) quantifies the expression levels of apoptosis-related and proliferative genes, revealing upregulation of tumor suppressor genes and downregulation of oncogenes, thereby confirming the efficacy of potential anticancer compounds.[7,10,11]

These methodologies provide a comprehensive understanding of how plant-based compounds such as nobiletin exert anticancer effects, guiding further research into nutraceutical-based cancer therapies.[10,11]

Comparison of Plant vs Animal Based Proteins

Factor	Plant-Based Proteins	Animal-Based Proteins	Citations
Amino Acid Profile	Generally incomplete but can be balanced through complementary sources like legumes + grains. Some (soy, quinoa) are complete proteins.	Complete proteins with all essential amino acids, highly bioavailable.	[7,10]
Digestibility	Lower due to fiber, anti-nutritional factors, and complex plant matrix; improved through processing.	High digestibility due to simpler structure and absence of fiber.	[7,10]
Protein Digestibility Corrected Amino Acid Score (PDCAAS) & Protein Digestibility Corrected Amino Acid Score (DIAAS)	Lower than animal proteins but improved through protein isolation and combination. Soy and pea proteins have relatively high scores.	High scores, with milk, eggs, and meat at the top.	[7,10]

Nutraceutical Products for Cancer Prevention and Therapy

Nutraceutical products play a vital role in cancer prevention and therapy, featuring a variety of beneficial compounds.[6,10] Nobiletin, a flavonoid found in citrus fruits such as oranges and tangerines, inhibits oncogenic pathways like STAT3 and NF-κB, suppresses metastasis by blocking epithelial-to-mesenchymal transition, and induces apoptosis in cancer cells.[11]

Soy isoflavones, including genistein and daidzein found in soy protein, modulate estrogen receptors to lower hormone-dependent cancer risks while reducing oxidative stress and inflammation.[7,9] Dietary fiber from whole grains, legumes, fruits, and vegetables binds carcinogens and promotes gut health, lowering inflammation and insulin-like growth factor 1 (IGF-1) levels, which helps reduce cancer proliferation.[3,8]

Polyphenols, present in green tea, berries, and legumes, serve as potent antioxidants that reduce DNA damage and suppress tumor growth through apoptosis induction.[8,10] Curcumin, derived from turmeric, inhibits inflammatory pathways linked to cancer progression and blocks cancer cell proliferation[8], while lignans from flaxseeds modulate estrogen metabolism, offering protection against breast cancer.[9]

Functional foods, such as soy protein-based products, citrus-based nutraceuticals enriched with nobiletin, plant-based protein supplements, flaxseed-infused foods, polyphenol-rich beverages, and turmeric-based supplements, harness these properties to create effective dietary interventions aimed at cancer prevention and therapy.[7,10,11]

Potential applications of plant-based proteins in food and related products and their biological activities

Functional foods and nutraceuticals are increasingly being utilized in various applications, particularly in the realm of meat and dairy alternatives, which cater to a growing demand for plant-based options.[7,10] Plant proteins derived from sources like soy, pea, and wheat gluten are being used to create meat substitutes such as burgers and sausages, offering high protein content with lower saturated fat and improved sustainability compared to traditional animal meat.[7,10]

Similarly, dairy alternatives made from soy, almond, oat, and pea provide lactose-free options that aid those with lactose intolerance while promoting heart health by lowering cholesterol levels.[8,10] Additionally, high-protein snacks and beverages incorporating pea, soy, and rice proteins are popular for supporting muscle growth, weight management, and overall nutrition.[7,10]

Plant-based protein supplements, including powders and blends made from soy, hemp, and brown rice, serve as effective alternatives to whey protein in sports nutrition, promoting muscle recovery and satiety.[7,10] Flaxseed-infused functional foods, rich in lignans, are also gaining traction, as they contribute to hormonal balance and potentially lower breast cancer risk.[9]

In the medical and therapeutic arena, nutraceuticals such as nobiletin-enriched supplements derived from citrus fruits have shown promise in suppressing tumor growth and inhibiting cancer-related pathways.[11] Soy isoflavone therapy, utilizing compounds like genistein and

daidzein, is being explored for its ability to modulate estrogen receptors and reduce risks of hormone-related cancers.[7,9]

Furthermore, dietary fiber found in legumes, whole grains, and vegetables plays a crucial role in cancer prevention by reducing carcinogen absorption and improving gut health.[3,8] Polyphenol-rich beverages, such as green tea and berry extracts, are celebrated for their antioxidant properties that combat oxidative stress and prevent DNA mutations.[8,10]

Lastly, turmeric-based supplements containing curcumin are recognized for their anti-inflammatory effects, contributing to tumor progression inhibition and supporting immune health in cancer therapy.[8,10]

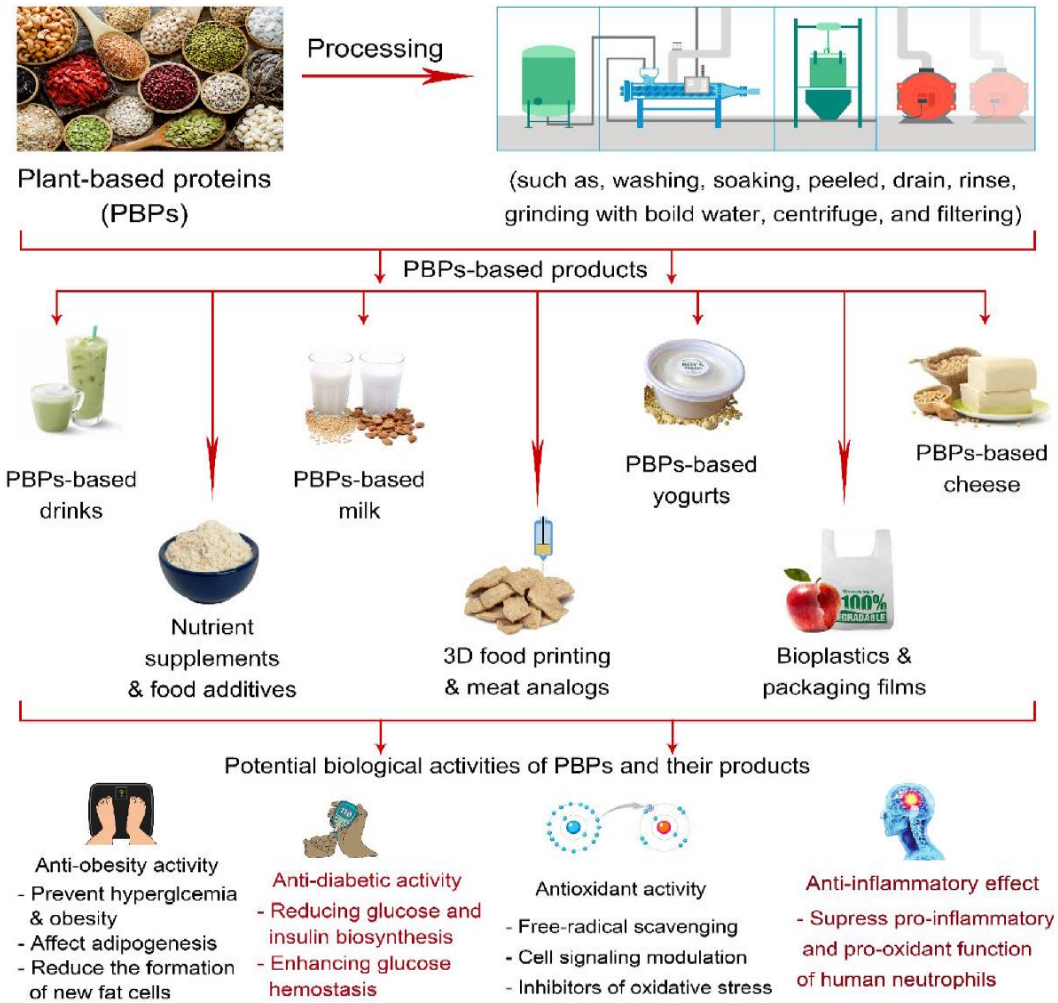

Figure no. 4.

CONCLUSION

In conclusion, plant-based proteins have emerged as sustainable and nutritionally beneficial

alternatives to animal proteins, providing significant advantages in health, environmental sustainability, and functional applications.[7,10] These proteins play a crucial role in cancer prevention and therapy, largely due to their bioactive compounds such as nobiletin, soy isoflavones, lignans, and polyphenols, which are known for their anti-inflammatory and anti-cancer properties.[8,9,11]

Furthermore, functional foods, nutraceuticals, and protein supplements derived from plant sources are increasingly utilized to combat chronic diseases, including cancer, cardiovascular diseases, and metabolic disorders.[6,8,10] The advent of advanced extraction and processing technologies, such as enzymatic hydrolysis, high-pressure processing, and 3D food printing, has enhanced the bioavailability and functional properties of these plant-based proteins.[7,10]

This shift towards plant-based dietary patterns is further driven by their lower environmental impact, effectively addressing pressing global challenges like climate change and resource depletion.[10]

Future Prospectives

1. Enhanced Bioavailability & Functionalization

- Development of novel extraction and processing technologies to improve protein digestibility, solubility, and bioactivity.[7,10]
- Use of fermentation, enzymatic hydrolysis, and nanotechnology to enhance plant protein absorption.[7,10]

2. Personalized Nutrition & Cancer Therapy

- Future research will focus on personalized plant-based nutrition for specific cancer prevention and treatment.[6,8,10]
- Nobiletin, soy isoflavones, and polyphenol-enriched products will be explored further in clinical trials for their therapeutic potential.[8,9,11]

3. Integration in Functional Foods & Nutraceuticals

- Expansion of plant-based dairy, meat substitutes, and protein supplements to cater to a growing demand for health-conscious and plant-based diets.[7,10]
- Development of fortified foods with plant-derived bioactive compounds for preventive healthcare.[7,10,11]

4. Sustainability & Environmental Impact

- Research into sustainable plant protein sources (e.g., algae, pulses, alternative legumes) to reduce reliance on animal agriculture.[10]
- Advancements in biodegradable food packaging and 3D-printed plant-based protein foods to improve food security and environmental sustainability.[10]

5. Regulatory & Market Growth

- Standardization and regulatory approvals for plant-based protein supplements and nutraceuticals in different regions.[10]
- Increasing investment in plant-based food technology and biotechnology for large-scale production and commercialization.[10]

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