International Journal of Advance and Applied Research
www.ijaar.co.in
ISSN – 2347-7075 Impact Factor – 8.141
Peer Reviewed Bi-Monthly
Vol. 7 No. 33 March – April - 2026

A Review on Valorisation of Cauliflower Stem Powder for Environmental Health and Sustainable Development

Apoorva Soni[1] & Dr. Rajlakshmi Tripathi[2]

[1]*Assistant Professor, Department of Food and Nutrition, Govt. M. H. College of Home Science and Science for Women, Jabalpur*

[2]*Associate Professor, Department of Food and Nutrition, Govt. M. H. College of Home Science and Science for Women, Jabalpur*

DOI - 10.5281/zenodo.20117417

Abstract:

The escalating global population necessitates a paradigm shift toward circular bio-economies to mitigate the environmental burden of agro-industrial waste. Cauliflower (Brassica oleracea var. botrytis) processing generates immense quantities of non-edible biomass, with stems accounting for nearly one-third of the total plant weight. Traditionally discarded or utilized as low-value animal feed, these stems represent a potent source of bioactive compounds. This review systematically evaluates the transformation of cauliflower stems into a high-value functional powder (CSP). We detail its exceptional fiber profile (up to 31%), significant protein content, and the presence of health-promoting glucosinolates and polyphenols. Furthermore, we analyse its techno-functional role in enhancing food matrices—such as increasing water retention in meat analogues and mineral density in bakery products. By integrating CSP into the human food chain, the food industry can directly address Sustainable Development Goals (SDGs), specifically SDG 12 (Responsible Production) and SDG 3 (Good Health), effectively turning environmental waste into a nutritional goldmine.

Keywords: Agro-Industrial Waste, Cauliflower Stem Powder, Functional Food, Circular Economy, Sustainable Development Goals.

Introduction:

In the contemporary era of environmental health consciousness, the "trash-to-treasure" philosophy is no longer a niche concept but a necessity for sustainable development. Agricultural by-products, particularly from the *Brassicaceae* family, are notorious for their high moisture content, which leads to rapid fermentation and greenhouse gas emissions if left in landfills. Cauliflower is one of the most widely cultivated vegetables globally; however, only the curd is primarily consumed, leaving the stems and leaves as underutilized residues (Koodi et al., 2022).

The conversion of these stems into a dehydrated powder (CSP) offers a dual-action solution: it significantly reduces the volume of organic waste while providing a stable, nutrient-dense ingredient for food fortification. This review aims to bridge the gap between waste management and nutritional science by exploring the physicochemical resilience of CSP, its molecular bioactivity against chronic diseases, and its emerging applications in climate-smart food technology (Shinali et al., 2024).

Nutritional Profile of Cauliflower Stem Powder:

The nutritional profile of cauliflower stem powder (CSP) is a testament to the "zero-waste" potential of cruciferous vegetables. While the florets are the most consumed part of the plant,

the stems are often denser in specific dietary fibres and minerals.

When processed into a dehydrated powder, the concentration of these nutrients increases significantly, making it a potent functional ingredient.

1. Macronutrient Breakdown:

The primary strength of CSP lies in its structural carbohydrates and protein content, which often exceeds that of refined cereal flours.

- **Dietary Fiber (23.27% – 31.43%):** CSP is exceptionally high in fiber. It contains a balanced ratio of **Insoluble Dietary Fiber (IDF)**, which aids in bowel regularity, and **Soluble Dietary Fiber (SDF)**, which helps in glucose and lipid management.
- **Crude Protein (19.12% – 24.09%):** For a vegetable byproduct, the protein content is notably high. It contains a well-rounded amino acid profile, particularly rich in **Glutamine**, **Valine**, and **Alanine**.
- **Low Lipid Profile:** CSP is naturally low in fats, making it an ideal bulking agent for calorie-reduced food formulations.

2. Micronutrient Profile (Minerals & Vitamins):

- CSP acts as a natural mineral concentrate. The stems draw significant nutrients from the soil to support the heavy curd (floret) of the plant. As per (Malik et al., 2025) (Horticulture Journal, 2026; Shinali et al., 2024).

Mineral	Concentration (mg)	Physiological Role
Potassium	1785.35 – 2175.23	Regulates blood pressure and fluid balance.
Calcium	505.35 – 598.86	Essential for bone density and muscle function.
Magnesium	124.12 – 156.40	Supports over 300 enzymatic reactions.
Iron	9.45 – 12.10	Crucial for haemoglobin synthesis and energy.
Zinc	2.85 – 4.15	Enhances immune response and DNA repair.

- **Vitamin C (45–60 mg/100g):** Even after drying, CSP retains significant ascorbic acid, which acts as a powerful antioxidant and improves iron bioavailability (Malik et al., 2025).
- **Vitamin K:** High levels of phylloquinone are present, which is vital for bone health and blood clotting.
- **B-Vitamins:** It is a reliable source of **Folate (B9)** and **B6**, which are often stripped away during the processing of white wheat flour (Malik et al., 2025).

3. Bioactive Compounds (Secondary Metabolites):

The true "functional" power of CSP comes from its secondary metabolites, which provide protection against chronic diseases (Cuellar-Nuñez et al., 2022) (Zhang et al., 2024) (Ahmed et al 2013).

- **Glucosinolates:** These are the sulphur-containing compounds responsible for the pungent aroma. In the body, they break down into **Isothiocyanates** (like Sulforaphane) and **Indoles**, which are studied for their potent anti-carcinogenic properties.
- **Phenolic Acids & Flavonoids:** CSP is rich in **Quercetin** and **Kaempferol**. These polyphenols neutralize free radicals and reduce systemic inflammation (Ahmed et al 2013).
- **Carotenoids:** Contains measurable amounts of **Lutein** and **Beta-carotene**, which are essential for ocular health and skin integrity.

4. Techno-Functional Properties:

Beyond biology, the nutritional structure of CSP gives it unique physical properties used in food science:

- **High Water Holding Capacity (WHC):** Its fiber network can hold several times its weight in water, which helps keep baked goods moist.
- **Oil Absorption Capacity:** This property makes it useful in stabilizing emulsions in meat analogues or processed sauces.
- **Low Glycaemic Load:** Due to the high fiber-to-carbohydrate ratio, adding CSP to foods slows down sugar absorption into the bloodstream.

Physiological Health: A Nutritional and Bioactive Goldmine:

CSP is not merely a fiber supplement; it is a dense matrix of secondary metabolites that support human physiology and prevent chronic disease.

- **Combating "Hidden Hunger":** CSP is a concentrated source of essential minerals like Potassium, Calcium, and Iron. Its integration into staple foods helps alleviate micronutrient deficiencies in populations consuming calorie-rich but nutrient-poor diets (Horticulture Journal, 2026).
- **Anticarcinogenic Potential:** The presence of glucosinolates in CSP is a key physiological benefit. These compounds are converted into isothiocyanates, such as Allyl Isothiocyanate (AITC), which have been shown to inhibit the proliferation of colorectal and prostate cancer cells by inducing apoptosis and managing oxidative stress (Cuellar-Nuñez et al., 2022).
- **Metabolic and Digestive Regulation:** With a fiber content exceeding 25%, CSP acts as a powerful prebiotic. It supports gut microbiome diversity, improves insulin sensitivity, and lowers the glycaemic index of fortified foods, making it a vital tool in the dietary management of Type 2 diabetes and obesity (Malik et al., 2025).

Applications in Food Technology:

- **Bakery and Cereal Products:** CSP is utilized as a wheat flour substitute (5–9%) to enhance fiber and mineral density in bread and snacks (Abebe *et al* 2026).
- **Meat and Plant-Based Alternatives:** Due to its water-holding capacity, CSP serves as a natural binder in patties, improving juiciness and reducing cooking loss (Malik et al., 2025).
- **Functional Fortification:** It is used in gluten-free formulations to restore iron and B-vitamins, providing a "clean label" alternative to synthetic additives (Abebe *et al* 2026) (Bateju *et al* 2026).
- **Gluten-Free Formulations:** Gluten-free products often lack iron and B-vitamins. Incorporating 10% CSP restores these micronutrients while improving the crumb structure through its fiber network.
- **Nutraceutical Supplements:** CSP is now being encapsulated or sold as a "green superfood" powder to be added to smoothies and juices, providing a whole-food alternative to synthetic multivitamin pills.

Environmental Health: Mitigating the Impact of Agro-Waste:

Agricultural waste management is a critical component of environmental health. Traditional disposal methods for cauliflower stems often involve landfilling or open-air decomposition, both of which pose ecological risks.

- **Reduction of Greenhouse Gas Emissions:** Organic waste in landfills undergoes

anaerobic decomposition, releasing methane (CH_4), a potent greenhouse gas. By upcycling stems into CSP, we significantly reduce the carbon footprint of the vegetable processing industry (Banerjee et al 2012).

- **Prevention of Soil and Water Contamination**: Decomposing vegetable waste can lead to leachate production, which may contaminate groundwater and soil with high organic loads and nitrates. Diverting this biomass into a controlled production chain preserves the integrity of local ecosystems (Sobiya *et al* 2024).
- **Resource Efficiency:** Utilizing the entire plant reduces the "per-unit" environmental cost of cultivation. The water, fertilizers, and energy invested in growing the cauliflower are more efficiently utilized when the 30% of the plant previously considered waste is recaptured for human consumption (Abebe *et al* 2026).

Circular Economy: Closing the Loop in Food Production:

The circular economy model seeks to decouple economic growth from resource consumption by "closing the loop" on waste. CSP is a primary exemplar of this model in action (Agrawal *et al* 2024).

- **Waste-to-Value Transformation:** In a linear economy, stems are a cost burden (disposal fees). In a circular economy, CSP becomes a revenue stream. By creating a market for "upcycled" ingredients, food technology creates economic value from zero-cost raw materials. (Abebe *et al* 2026)
- **Industrial Symbiosis:** The production of CSP creates a symbiotic relationship between farmers, food processors, and the nutraceutical industry. The "waste" of one sector becomes the "raw material" of another, reducing the need for virgin resources like synthetic mineral fortificants.
- **Sustainable Production and Consumption (SDG 12):** Utilizing CSP aligns with the United Nations Sustainable Development Goal 12. It encourages a responsible production cycle where every part of the biological nutrient cycle is returned to the system, ensuring long-term food security and industrial resilience (Sobiya *et al* 2024).

Conclusion:

The comprehensive micronutrient and bioactive profiling of cauliflower stem powder (CSP) underscore its transformative potential in addressing "hidden hunger"—the pervasive deficiency of essential vitamins and minerals in populations consuming calorie-dense yet nutrient-poor diets. By strategically reclaiming this agricultural biomass, the food industry can mitigate the environmental burden of vegetable processing waste while simultaneously providing a low-cost, high-impact matrix for food fortification.

This review has demonstrated that CSP transcends the role of a simple "filler," emerging instead as a sophisticated functional ingredient characterized by a robust profile of dietary fiber, essential minerals, and potent anticarcinogenic secondary metabolites. As food technology advances, CSP serves as a primary exemplar of how sustainable development goals can be realized through the scientific re-evaluation of materials traditionally classified as "refuse."

Ultimately, the valorisation of CSP represents a landmark opportunity at the intersection of environmental health and nutritional science. Its integration into global food systems directly fosters a circular economy, significantly reducing the carbon footprint of the agricultural supply chain while addressing critical

public health gaps. The adoption of CSP is a vital step toward a resilient and sustainable food future, substantiating the premise that the keys to both human health and planetary well-being are frequently sequestered within underutilized organic waste streams.

References:

1. Abebe Z, Haileyesus A. Climate-Smart Bread with Cauliflower Leaf Powder: Enhancing Nutrition and Reducing Food System Waste and Carbon Footprint, Addressing Sensory Trade-Offs and Improvement Opportunities. Food Sci Nutr. 2026 Feb 13;14(2):e71533. doi: 10.1002/fsn3.71533. PMID: 41695103; PMCID: PMC12903547.
2. Agrawal, S., Jain, V.K. & Agarwal, S. Circular Bioeconomy: a Comprehensive Approach to Planetary Health and Sustainability. *Circ.Econ.Sust.* **5**, 1483–1508 (2025). https://doi.org/10.1007/s43615-024-00469-0
3. Ahmed FA, Ali RF. Bioactive compounds and antioxidant activity of fresh and processed white cauliflower. Biomed Res Int. 2013; 2013:367819. doi: 10.1155/2013/367819. Epub 2013 Sep 22. PMID: 24171164; PMCID: PMC3793502.
4. Banerjee, T., Srivastava, R. K., Hung, Y.-T., & 11 Professor, D. (2012). Plastics Waste Management in India: An Integrated Solid Waste Management Approach.
5. Cuellar-Nuñez ML, Luzardo-Ocampo I, Lee-Martínez S, Larrauri-Rodríguez M, Zaldívar-Lelo de Larrea G, Pérez-Serrano RM, Camacho-Calderón N. Isothiocyanate-Rich Extracts from Cauliflower (*Brassica oleracea* Var. Botrytis) and Radish (*Raphanus sativus*) Inhibited Metabolic Activity and Induced ROS in Selected Human HCT116 and HT-29 Colorectal Cancer Cells. Int J Environ Res Public Health. 2022 Nov 13;19(22):14919. doi: 10.3390/ijerph192214919. PMID: 36429638; PMCID: PMC9691161.
6. Koodi, S.; Ameta, K.D.; Kaushik, R.A.; Choudhary, A.; Jain, D.; Dudwal, B.L.; Kumar, U.; Farooq, T.H.; Gulnaz, A.; Al-Sadoon, M.K. The Integrated Approach for Organic and Inorganic Sources of Nutrients to Enhance Performance of Cauliflower (*Brassica oleracea* var. *botrytis* L.) under Sub-Humid Climatic Conditions. *Sustainability* **2022**, *14*, 13368. https://doi.org/10.3390/su142013368
7. Physicochemical and functional properties of microwave-dried cauliflower powder, Malik, N.H., Roslan, Baharuddin, N. A. *Food Research*, p. 31-40, vol. 9. https://www.myfoodresearch.com/uploads/8/4/8/5/84855864/_31__fr-2024-260_malik.pdf,
8. Research on the utilization of nutrients and bioactive compounds from cauliflower stalks, through the development of a functional ingredient, Horticulture Journal, *Scientific Papers. Series B, Horticulture*, https://horticulturejournal.usamv.ro/pdf/2025/issue_2/Art97.pdf, p. 784-792, vol. 69.
9. Potential of utilizing plant stem waste as an excellent source of dietary fiber for novel food applications. Boteju PDN, Senanayake CM, Jayathunge K G L R. RSC Publishing, *Sustainable Food Technology*, doi: 10.1039/D5FB00591D, p. 120-135, vol. 4.
10. Shinali TS, Zhang Y, Altaf M, Nsabiyeze A, Han Z, Shi S, Shang N. The Valorization of Wastes and Byproducts from Cruciferous Vegetables: A Review on the Potential Utilization of Cabbage, Cauliflower, and Broccoli Byproducts. Foods. 2024 Apr 11;13(8):1163. doi:

10.3390/foods13081163. PMID: 38672834; PMCID: PMC11049176.

11. Sobiya Manzoor, Ufaq Fayaz, Aamir Hussain Dar, Kshirod Kumar Dash, Rafeeya Shams, Iqra Bashir, Vinay Kumar Pandey, Gholamerazi Abdi,Sustainable development goals through reducing food loss and food waste: A comprehensive review,Future Foods,Volume 9, 2024, 100362, ISSN 2666-8335, https://doi.org/10.1016/j.fufo.2024.100362. (https://www.sciencedirect.com/science/article/pii/S2666833524000686)
12. Xiaomeng Zhang, Qiong Jia, Xin Jia, Jie Li, Xiaoxue Sun, Leiguo Min, Zhaokun Liu, Wei Ma, Jianjun Zhao, *Brassica* vegetables—an undervalued nutritional goldmine, *Horticulture Research*, Volume 12, Issue 2, February 2025, uhae302, https://doi.org/10.1093/hr/uhae302