ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating (2025): 4.69
IJAN 2025; 7(8): 97-99
www.agriculturejournal.net
Received: 13-06-2025
Accepted: 15-07-2025

Saudagar Aqsa Samrin
Department of Agriculture and Food Science, MIT-CSN, Aurangabad, Maharashtra, India

DT Bornare
Department of Agriculture and Food Science, MIT-CSN, Aurangabad, Maharashtra, India

SG Jaiswal
Department of Agriculture and Food Science, MIT-CSN, Aurangabad, Maharashtra, India

Corresponding Author:
Saudagar Aqsa Samrin
Department of Agriculture and Food Science, MIT-CSN, Aurangabad, Maharashtra, India

Review of nutraceutical integration of astaxanthin extract from shrimp shell and moringa powder as chewable gummies for glycemic control

Saudagar Aqsa Samrin, DT Bornare and SG Jaiswal

DOI: https://www.doi.org/10.33545/26646064.2025.v7.i8b.273

Abstract
This review explores the potential of astaxanthin derived from shrimp shells and *Moringa oleifera* as bioactive components in chewable gummies for glycaemic control. Astaxanthin, a potent antioxidant carotenoid, and Moringa, rich in bioactive compounds, demonstrate promising effects in managing blood glucose levels and mitigating oxidative stress associated with diabetes. The paper examines their extraction, bioactivity, and synergistic potential in a nutraceutical gummy formulation. It also assesses the sustainability of shrimp shell-derived astaxanthin, Moringa's pharmacological benefits, formulation challenges, and future research directions. This integrative approach highlights a novel strategy for developing functional foods to support glycaemic management.

Keywords: Astaxanthin, *Moringa oleifera*, glycaemic control, nutraceuticals, chewable gummies, shrimp shells

Introduction
Diabetes mellitus, a global health challenge, affects over 460 million people, with projections estimating a rise to 700 million by 2045 (International Diabetes Federation, 2019) [12]. Characterized by chronic hyperglycaemia and oxidative stress, diabetes contributes to complications such as cardiovascular diseases, neuropathy, and nephropathy (Xia *et al*., 2020) [25]. The demand for natural, sustainable interventions has driven interest in nutraceuticals food derived compounds offering health benefits beyond basic nutrition. Astaxanthin, a ketocarotenoid from shrimp shells, and *Moringa oleifera*, a nutrient-rich plant, have emerged as promising candidates for glycaemic control due to their antioxidant and hypoglycaemic properties (Ambati *et al*., 2014; Leone *et al*., 2016) [1, 13]. This review explores their integration into chewable gummies, a consumer-friendly delivery system, to enhance glycaemic management.

Astaxanthin: Sources and Bioactivity
Shrimp Shells as a Sustainable Source
Astaxanthin (3,3'-dihydroxy-β, β-carotene-4,4'-dione) is a potent antioxidant carotenoid found in marine organisms like shrimp, krill, and microalgae such as *Haematococcus pluvialis* (Shah *et al*., 2016) [20]. Shrimp shells, a by-product of the crustacean industry, contain astaxanthin at concentrations of 4.79-239.96 µg/g, depending on species and processing methods (Wang *et al*., 2021) [24]. With shrimp waste constituting 50-70% of total shrimp weight, it offers a sustainable and cost-effective source for astaxanthin extraction (Ambati *et al*., 2014) [1]. Advanced extraction techniques, including solvent-based, ultrasound-assisted, and enzymatic methods, achieve high-purity yields (up to 87.34%) (Wang *et al*., 2021; Zhao *et al*., 2019) [24, 29]. These methods reduce environmental impact and enhance the economic viability of utilizing shrimp waste.

Bioactivity Relevant to Glycemic Control
Astaxanthin's antioxidant capacity, 100-500 times greater than α-tocopherol, mitigates oxidative stress, a key contributor to diabetes progression (Sila *et al*., 2015) [21]. In alloxan-induced diabetic rats, shrimp-derived astaxanthin reduced plasma glucose levels, lipid

peroxidation markers (e.g., malondialdehyde), and restored antioxidant enzyme activities such as superoxide dismutase (SOD) and catalase (CAT) (Sila *et al*., 2015) [21]. It also improves insulin sensitivity and reduces inflammation by modulating pathways like NF-KB (Yu *et al*., 2020) [28]. Studies on diabetic models further demonstrate astaxanthin's protective effects against nephropathy and hepatotoxicity (Sila *et al*., 2015; Takemoto *et al*., 2015) [21, 22].

Bioactivity relevant to glycaemic control refers to biological processes, molecules, or compounds that regulate blood glucose levels by influencing insulin secretion, insulin sensitivity, glucose uptake, or glucose metabolism. These bioactivities are critical in managing conditions like type 2 diabetes and maintaining metabolic health. Below is a detailed description of key mechanisms and bioactive agents involved, supported by scientific literature.

Insulin and Glucagon Regulation: Insulin, secreted by pancreatic beta cells, facilitates glucose uptake in tissues via glucose transporter 4 (GLUT4) and suppresses hepatic glucose production (gluconeogenesis) (Saltiel & Kahn, 2001) [19]. Glucagon, released by alpha cells, counteracts insulin by promoting glycogenolysis and gluconeogenesis (Quesada *et al*., 2008) [17]. Bioactive compounds, such as incretin hormones, modulate these hormones to stabilize blood glucose.

Incretin Hormones: Glucagon-like peptide-1 (GLP-1) and glucose-dependent insulinotropic polypeptide (GIP) are gut-derived hormones that enhance glucose-dependent insulin secretion, slow gastric emptying, and reduce appetite (Drucker & Nauck, 2006) [6]. GLP-1 receptor agonists (e.g., exenatide) and dipeptidyl peptidase-4 (DPP-4) inhibitors (e.g., sitagliptin) leverage these bioactivities to improve glycaemic control (Nauck, 2016) [14].

Glucose Transporters

GLUT4 mediates insulin-stimulated glucose uptake in muscle and adipose tissue (Saltiel & Kahn, 2001) [19]. Sodium-glucose cotransporter 2 (SGLT2) in the kidneys reabsorbs glucose; SGLT2 inhibitors (e.g., dapagliflozin) reduce this reabsorption, lowering blood glucose levels (Vallon, 2017) [23].

Enzymes in Glucose Metabolism

AMP-activated protein kinase (AMPK) enhances glucose uptake and fatty acid oxidation, improving insulin sensitivity (Hardie *et al*., 2012) [11]. Metformin, a common antidiabetic drug, activates AMPK to reduce hepatic glucose output (Rena *et al*., 2017). DPP-4 degrades incretins, and its inhibition extends incretin activity, aiding glycaemic control (Nauck, 2016) [14].

Bioactive Compounds

Polyphenols are found in berries and tea, these compounds improve insulin sensitivity and reduce oxidative stress (Hanhineva *et al*., 2010) [10]. Dietary Fiber Slows carbohydrate absorption, stabilizing postprandial glucose (Anderson *et al*., 2009) [3]. Omega-3 Fatty Acids May enhance insulin sensitivity, though evidence is mixed (Flachs *et al*., 2014) [7]. Plant-Derived Compounds are Berberine activates AMPK and inhibits gluconeogenesis, showing promise in glycaemic control (Yin *et al*., 2008) [27].

Inflammation and Oxidative Stress: Chronic inflammation impairs insulin signalling, while antioxidants like alpha-lipoic acid reduce oxidative stress, supporting glycaemic control (Packer *et al*., 2001) [16].

Gut Microbiota: Gut microbiota metabolites, such as short-chain fatty acids, modulate insulin sensitivity (Cani *et al*., 2012) [5]. Prebiotics and probiotics may enhance these effects, contributing to better glucose regulation.

Bioactive compounds and drugs targeting these pathways (e.g., metformin, GLP-1 agonists, SGLT2 inhibitors) are cornerstones of type 2 diabetes management (American Diabetes Association, 2023) [2]. Dietary interventions, including polyphenol-rich foods and fiber, complement pharmacological approaches (Anderson *et al*., 2009) [3]. Ongoing research explores novel bioactive, such as plant alkaloids and microbial metabolites, for their potential in diabetes prevention and treatment (Yin *et al*., 2008; Cani *et al*., 2012) [27, 5].

***Moringa oleifera*: Nutritional and Pharmacological Profile**

Moringa oleifera, known as the "miracle tree," is rich in vitamins (A, C, E), minerals (calcium, potassium), and bioactive compounds such as polyphenols, flavonoids, and glucosinolates (Leone *et al*., 2016) [13]. Its leaves contain high levels of quercetin and chlorogenic acid, contributing to its antioxidant and anti-inflammatory properties (Leone *et al*., 2016) [13].

Moringa leaf extracts exhibit hypoglycaemic effects in both animal and human studies. They reduce fasting blood glucose and improve glucose tolerance by enhancing insulin secretion and sensitivity (Nova *et al*., 2019) [15]. Bioactive compounds like isothiocyanates inhibit hepatic glucose production, while antioxidants reduce oxidative stress, a contributor to insulin resistance (Leone *et al*., 2016) [13]. Clinical trials report significant reductions in HbA1c levels with Moringa supplementation at doses of 2-4 g/day (Nova *et al*., 2019) [15].

Synergistic Potential of Astaxanthin and Moringa

The combination of astaxanthin and Moringa leverages their complementary mechanisms. Astaxanthin's lipid-soluble nature targets cell membranes, neutralizing reactive oxygen species, while Moringa's water-soluble antioxidants enhance systemic oxidative defence (Ambati *et al*., 2014; Leone *et al*., 2016) [1, 13]. Both compounds modulate inflammatory pathways, potentially improving insulin signalling and reducing diabetic complications (Yu *et al*., 2020; Nova *et al*., 2019) [28, 15]. Their synergistic effects could enhance glycaemic control by addressing oxidative stress and glucose metabolism simultaneously.

Astaxanthin Extraction: Green extraction methods, such as supercritical fluid extraction and enzymatic hydrolysis, improve astaxanthin yield from shrimp shells. Neutral protease treatment increases yields by 3.7 times compared to traditional methods (Wang *et al*., 2021) [24]. Ethanol-based extraction achieves high purity (up to 85.1%) suitable for nutraceutical applications (Zhao *et al*., 2019) [29].

Moringa Processing: Moringa leaves are typically dried and powdered to preserve bioactive compounds. Water or ethanol extraction retains polyphenols and flavonoids,

ensuring efficacy for glycaemic control (Leone *et al*., 2016) [13]. Spray drying or freeze-drying maintains stability for incorporation into gummies.

Sustainability and Economic Considerations: Shrimp shells, constituting 50-70% of shrimp weight, offer a sustainable source of astaxanthin, reducing waste in the aquaculture industry (Gómez-Estaca *et al*., 2016) [8]. Moringa, a fast-growing plant, is economically viable for cultivation in tropical regions. Combining these ingredients in gummies aligns with consumer demand for eco-friendly, natural products.

Conclusion

The integration of shrimp shell-derived astaxanthin and *Moringa oleifera* in chewable gummies offers a promising nutraceutical approach for glycaemic control. Their complementary antioxidant and hypoglycaemic properties, combined with sustainable sourcing and a consumer-friendly delivery system, position this formulation as a viable functional food. Continued research will further elucidate its therapeutic potential and market viability.

References

1. Ambati RR, Phang SM, Ravi S, Aswathanarayana RG. Astaxanthin: Sources, extraction, stability, biological activities and its commercial applications A review. Mar Drugs. 2014;12(1):128-52.
2. American Diabetes Association. Standards of medical care in diabetes-2023. Diabetes Care. 2023;46(Suppl. 1):S1-S291.
3. Anderson JW, Baird P, Davis RH, Ferreri S, Knudtson M, Koraym A, *et al*. Health benefits of dietary fiber. Nutr Rev. 2009;67(4):188-205.
4. Bassijeh A, Ansari S, Hosseini SM. Astaxanthin-loaded microcapsules in beverage systems. J Food Sci. 2020;85(10):3332-40.
5. Cani PD, Neyrinck AM, Fava F, Knauf C, Burcelin RG, Tuohy KM, *et al*. Selective increases of bifidobacteria in gut microflora improve high-fat-diet-induced diabetes in mice through a mechanism associated with endotoxaemia. Diabetologia. 2012;50(11):2374-83.
6. Drucker DJ, Nauck MA. The incretin system: Glucagon-like peptide-1 receptor agonists and dipeptidyl peptidase-4 inhibitors in type 2 diabetes. Lancet. 2006;368(9548):1696-705.
7. Flachs P, Rossmeisl M, Kopecky J. The effect of n-3 fatty acids on glucose homeostasis and insulin sensitivity. Physiol Res. 2014;63(Suppl. 1):S93-S118.
8. Gómez-Estaca J, Calvo MM, Álvarez-Acero I. Characterization and storage stability of astaxanthin esters, fatty acid profile and α-tocopherol of lipid extract from shrimp (*L. vannamei*) waste with potential applications as food ingredient. Food Chem. 2016;216:340-8.
9. Gulzar S, Benjakul S. Microencapsulation of shrimp oil with mung bean protein isolate and sodium alginate. Food Chem. 2020;317:126418.
10. Hanhineva K, Törrönen R, Bondia-Pons I, Pekkinen J, Kolehmainen M, Mykkänen H, *et al*. Impact of dietary polyphenols on carbohydrate metabolism. Int J Mol Sci. 2010;11(4):1365-402.
11. Hardie DG, Ross FA, Hawley SA. AMPK: A nutrient and energy sensor that maintains energy homeostasis. Nat Rev Mol Cell Biol. 2012;13(4):251-62.
12. International Diabetes Federation. IDF Diabetes Atlas. 9th ed. International Diabetes Federation; 2019.
13. Leone A, Spada A, Battezzati A, others. *Moringa oleifera* seeds and oil: Characteristics and uses for human health. Int J Mol Sci. 2016;17(12):2141.
14. Nauck MA. Incretin therapies: Highlighting common features and differences in the modes of action of glucagon-like peptide-1 receptor agonists and dipeptidyl peptidase-4 inhibitors. Diabetes Obes Metab. 2016;18(3):203-16.
15. Nova E, Redondo-Useros N, Martínez-García RM. Potential of *Moringa oleifera* to improve glucose control for the prevention of diabetes and related metabolic alterations. Nutrients. 2019;12(1):17.
16. Packer L, Witt EH, Tritschler HJ. Alpha-lipoic acid as a biological antioxidant. Free Radic Biol Med. 2001;19(2):227-50.
17. Quesada I, Tudurí E, Ripoll C, Nadal Á. Physiology of the pancreatic α-cell and glucagon secretion: Role in glucose homeostasis and diabetes. J Endocrinol. 2008;199(1):5-19.
18. Rena G, Hardie DG, Pearson ER. The mechanisms of action of metformin. Diabetologia. 2017;60(9):1577-85.
19. Saltiel AR, Kahn CR. Insulin signalling and the regulation of glucose and lipid metabolism. Nature. 2001;414(6865):799-806.
20. Shah MMR, Liang Y, Cheng JJ, Daroch M. Astaxanthin-producing green microalga *Haematococcus pluvialis*: From single cell to high value commercial products. Front Plant Sci. 2016;7:531.
21. Sila A, Ghlissi Z, Kamoun Z. Astaxanthin from shrimp by-products ameliorates nephropathy in diabetic rats. Eur J Nutr. 2015;54(2):301-7.
22. Takemoto M, Yamaga M, Furuichi Y, Yokote K. Astaxanthin improves non-alcoholic fatty liver disease in Werner Syndrome with diabetes mellitus. J Am Geriatr Soc. 2015;63(6):1271-3.
23. Vallon V. The mechanisms and therapeutic potential of SGLT2 inhibitors in diabetes mellitus. Annu Rev Med. 2017;66:255-70.
24. Wang L, Hu J, Lv W. Optimized extraction of astaxanthin from shrimp shells treated by biological enzyme and its separation and purification using macroporous resin. Food Chem. 2021;363:130369.
25. Xia W, Tang N, Kord-Varkaneh H. The effects of astaxanthin supplementation on obesity, blood pressure, CRP, glycaemic biomarkers, and lipid profile: A meta-analysis of randomized controlled trials. Pharmacol Res. 2020;161:105113.
26. Yamashita E. The effect of a dietary supplement containing astaxanthin on skin condition. Carotenoid Sci. 2006;10:91-5.
27. Yin J, Xing H, Ye J. Efficacy of berberine in patients with type 2 diabetes mellitus. Metabolism. 2008;57(5):712-7.
28. Yu W, Liu X, Zhao J. The marine carotenoid astaxanthin: A potent antioxidant with multiple health benefits. Front Nutr. 2020;7:594013.
29. Zhao X, Zhang X, Liu H. Extraction and purification of astaxanthin from shrimp shells and the effects of different treatments on its content. Food Chem. 2019;274:356-64.