INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

OPEN ACCESS

Review Paper

Anti-Aging Bioactives of Kiwi Fruit (Actinidia deliciosa): A Comprehensive Review

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ARTICLE INFO

Published: 20 May 2026
Keywords:
Actinidia deliciosa; ascorbic acid; anti-aging; antioxidant; polyphenols; collagen; inflammageing; skin aging; nutraceutical
DOI:
10.5281/zenodo.20310736

ABSTRACT

Kiwi fruit (Actinidia deliciosa C. F. Liang & A. R. Ferguson, Actinidiaceae), a commercially significant botanical, has attracted substantial scientific interest for its diverse array of bioactive phytochemicals with established anti-aging properties. This comprehensive review systematically examines the phytochemical composition of A. deliciosa, with particular emphasis on ascorbic acid, tocopherols, polyphenols (quercetin, chlorogenic acid, epicatechin), carotenoids (lutein, zeaxanthin), actinidin, dietary fiber (pectin), serotonin, and folate. The mechanistic pathways underlying their anti-aging efficacy are critically discussed, including reactive oxygen species (ROS) scavenging, collagen biosynthesis, matrix metalloproteinase (MMP) inhibition, suppression of nuclear factor kappa-B (NF-κB)-mediated inflammation, mitochondrial protection, facilitation of DNA repair, and modulation of the gut-skin axis. Clinical and preclinical evidence corroborating these mechanisms is synthesized, with reference to validated study designs and quantified outcomes. Kiwi fruit emerges as a functionally potent dietary agent capable of attenuating multiple hallmarks of biological aging, offering a compelling case for its integration into anti-aging nutritional strategies

INTRODUCTION

Biological aging is a universal, time-dependent process characterized by progressive deterioration of physiological functions, structural integrity, and cellular homeostasis. At the molecular level, aging is driven by well-characterized hallmarks including genomic instability, telomere attrition, epigenetic alterations, loss of proteostasis, mitochondrial dysfunction, cellular senescence, deregulated nutrient sensing, and chronic low-grade systemic inflammation termed "inflammageing." (Li et al., 2022; Rattan, 2006). Oxidative stress, arising from an imbalance between reactive oxygen species (ROS) production and antioxidant defense, is regarded as a central mechanistic axis linking these hallmarks

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

to visible and physiological manifestations of aging, including dermal atrophy, wrinkle formation, neurodegeneration, and cardiovascular decline (Goto, 2015).

Dietary bioactive compounds have garnered increasing scientific and clinical attention as viable modulators of aging trajectories. Fruits and vegetables, as primary dietary sources of antioxidants, polyphenols, vitamins, and enzymes, exert demonstrable anti-aging effects through complementary and synergistic mechanisms (Kawamura et al., 2026). Among these, kiwi fruit (Actinidia deliciosa C. F. Liang & A. R. Ferguson) represents an exceptional candidate, combining a uniquely rich phytochemical matrix with superior nutrient bioavailability and established clinical efficacy.

Originating in China and globally commercialized from New Zealand in the 20th century, A. deliciosa is now cultivated across 30+ countries, with annual production exceeding 4.5 million metric tonnes (Huang & Ferguson, 2001; Rice et al., 2017). The fruit's characteristic green flesh, distinctive flavor, and recognized nutritional profile have made it a focus of nutraceutical and functional food research. Its phytochemical complexity, including the highest ascorbic acid content among commonly consumed fruits, a diverse pool of polyphenols, the unique cysteine protease (actinidin), and multiple micronutrients, positions it as a multidimensional anti-aging dietary agent (Satpal et al., 2021).

Despite a growing body of evidence, comprehensive reviews that integrate phytochemical characterization with mechanistic anti-aging science and clinical corroboration remain limited. This review addresses that gap by providing a critical, evidence-based synthesis of the anti-aging bioactives of A. deliciosa, with emphasis on mechanistic pathways, quantitative phytochemical data, and translational clinical relevance.

Taxonomy and Botanical Profile

Actinidia deliciosa belongs to the family Actinidiaceae, order Ericales, and is classified within the genus Actinidia, which encompasses approximately 76 species. The commercially dominant cultivar 'Hayward' constitutes the majority of global kiwi production and is the primary subject of phytochemical research reviewed herein. The golden kiwi (A. chinensis var. chinensis 'Zesy002') is also acknowledged where evidence extends to this variety. A. deliciosa is a dioecious, deciduous woody vine producing berries characterised by a brown fibrous exocarp, vibrant green mesocarp with a central cream-coloured core, and numerous small black seeds embedded within. The plant thrives in temperate climates, requires substantial chilling hours, and is sensitive to late-spring frosts (Hussain et al., 2021).

The fruit's unique biochemistry reflects its evolutionary ecology in the diverse subtropical forests of the Yangtze River Valley, where phytochemical investment in antioxidant defense, pollinator attraction, and seed dispersal converged to produce a phytochemically concentrated berry. Modern breeding programs have further intensified bioactive concentrations in commercial varieties, contributing to documented varietal differences in antioxidant capacity (Satpal et al., 2021).

Phytochemical Composition and Quantification

The anti-aging efficacy of A. deliciosa is underpinned by its extraordinary phytochemical richness. Table 1 summarises the principal bioactive compounds, their quantified concentrations in the edible portion, primary anti-aging mechanisms, and supporting references. Concentrations are expressed per 100 g fresh weight (FW) or dry weight (DW) as reported in primary literature.

Table 1. Phytochemical Profile and Anti-Aging Properties of Actinidia deliciosa Bioactives

Bioactive Compound	Concentration	Anti-Aging Mechanism	Reference
Vitamin C (Ascorbic acid)	80–154 mg/100 g FW	Antioxidant, collagen synthesis	(Carr & Maggini, 2017)
Vitamin E (Tocopherols)	1.46 mg/100 g FW	Lipid peroxidation inhibitor	(Fiorentino et al., 2009)
Vitamin K	40.3 µg/100 g FW	Anti-inflammatory	(Zehra et al., 2020)
Lutein & Zeaxanthin	122 µg/100 g FW	UV protection, ROS scavenging	(Sommerburg et al., 1998)
Chlorogenic acid	23.6 mg/100 g DW	Antioxidant, anti-inflammatory	(Satpal et al., 2021)
Quercetin	0.56–3.4 mg/100 g FW	Anti-inflammatory, anti-apoptotic	(Wojdyło et al., 2017)
Epicatechin	1.8 mg/100 g FW	Collagen cross-link protection	(Satpal et al., 2021)
Actinidin (protease)	0.4–1.5 mg/g FW	Skin renewal, protein digestion	(Wojdyło et al., 2017)
Pectin (dietary fibre)	1–2 g/100 g FW	Gut microbiome, systemic inflammation	(Wojdyło et al., 2017)
Serotonin	5.8 µg/g FW	Neuroprotective, sleep regulation	(Billows et al., 2022)
Folate	25 µg/100 g FW	DNA repair, methylation	(Billows et al., 2022)
Potassium	312 mg/100 g FW	Cardiovascular health	(Richardson et al., 2018)

FW = fresh weight; DW = dry weight; ROS = reactive oxygen species; MMP = matrix metalloproteinase.

1. Ascorbic Acid (Vitamin C)

Ascorbic acid is unequivocally the predominant antioxidant micronutrient in A. deliciosa, present at concentrations of 80–154 mg per 100 g FW in 'Hayward' cultivars—substantially exceeding concentrations in oranges (53 mg/100 g FW) and strawberries (59 mg/100 g FW) (Carr & Maggini, 2017). This concentration varies with cultivar, ripeness, post-harvest storage conditions, and analytical methodology. Ascorbic acid exerts anti-aging effects through multiple mechanisms: direct ROS scavenging, regeneration of tocopherol from tocopheroxyl radicals, and essential cofactor activity for collagen hydroxylases (prolyl-4-hydroxylase, lysyl hydroxylase) that stabilize the triple-helical structure of procollagen (Richardson et al., 2018; Wojdyło et al., 2017). Additionally, ascorbate modulates hypoxia-inducible factor (HIF) hydroxylases, epigenetic demethylases (TET enzymes), and supports carnitine biosynthesis, critical for mitochondrial fatty acid oxidation (Carr & Maggini, 2017).

2. Polyphenols

Deliciosa contains a structurally diverse polyphenol pool dominated by hydroxycinnamic acids (chlorogenic acid: 23.6 mg/100 g DW), flavonols (quercetin: 0.56–3.4 mg/100 g FW), and flavan-3-ols (epicatechin: 1.8 mg/100 g FW) (Moysidou et al., 2024a). The peel fraction has a 2–3-fold higher total polyphenol content than the mesocarp, a characteristic with implications for whole-fruit consumption and extraction technologies. Quercetin modulates multiple aging-associated signaling cascades: inhibition of xanthine oxidase (ROS source), suppression of NF-κB transcription factor activation, downregulation of pro-inflammatory

cyclooxygenase-2 (COX-2), and activation of sirtuin-1 (SIRT1), a NAD+-dependent deacetylase central to longevity signaling (Moysidou et al., 2024a; Satpal et al., 2021). Chlorogenic acid demonstrates complementary activity through activation of the Nrf2 pathway, upregulating endogenous antioxidant enzymes, including superoxide dismutase (SOD), catalase, and glutathione peroxidase (GPx).

3. Carotenoids

The green color of A. deliciosa mesocarp reflects its chlorophyll content, while carotenoid pigments, principally lutein (122 µg/100 g FW) and zeaxanthin, are also present. These xanthophyll carotenoids accumulate preferentially in the macula lutea of the retina and skin, providing selective UV photoprotection and direct quenching of singlet oxygen and triplet-state photosensitizers (Moysidou et al., 2024b; Richardson et al., 2018). Lutein's anti-aging significance extends beyond ocular protection; dermal accumulation of lutein has been associated with reduced UV-B-induced collagen degradation and inflammatory cytokine release in human skin equivalent models. Provitamin A activity (β-carotene) is minimal in A. deliciosa compared to golden kiwi varieties(Wojdyło et al., 2017).

4. Tocopherols (Vitamin E)

Alpha-tocopherol, the biologically most active tocopherol isoform, is present at approximately 1.46 mg/100 g FW in A. deliciosa. Vitamin E is the primary lipid-phase antioxidant, interrupting lipid peroxidation chain reactions in cellular and mitochondrial membranes, a process directly linked to age-related membrane dysfunction (D'Evoli et al., 2015). The vitamin C–vitamin E recycling system, in which ascorbate regenerates tocopherol from tocopheroxyl radicals, creates a synergistic antioxidant network that is uniquely potent in kiwi owing to its concurrent high ascorbate content. This synergy is documented to exceed the antioxidant capacity of either compound in isolation(Goto, 2015; Satpal et al., 2021).

5. Actinidin

Actinidin (EC 3.4.22.14) is a cysteine protease unique to the genus Actinidia, present at 0.4–1.5 mg/g FW in A. deliciosa 'Hayward', and constituting the major kiwi fruit protein by weight. While primarily investigated for its digestive enzyme activity, actinidin exerts anti-aging relevance through modulation of proteostasis, the maintenance of protein synthesis, folding, and degradation equilibrium that deteriorates with aging (Boland, 2013). By facilitating the breakdown of misfolded and oxidized proteins, actinidin may reduce the accumulation of proteotoxic aggregates implicated in cellular senescence and neurodegenerative pathology. Topical application of actinidin-enriched extracts has been shown to accelerate stratum corneum desquamation, consistent with enhanced skin renewal (Boland, 2013).

6. Dietary Fiber and Serotonin

Deliciosa provides approximately 3 g of dietary fiber per 100 g FW, predominantly as pectin and hemicellulose. Pectin serves as a prebiotic substrate, promoting the proliferation of beneficial intestinal microbiota (Lactobacillus and Bifidobacterium spp.) that produce short-chain fatty acids (SCFAs) with documented anti-inflammatory and anti-aging systemic effects via the gut-skin and gut-brain axes. Kiwi fruit notably contains physiologically significant concentrations of serotonin (5-hydroxytryptamine; 5.8 µg/g FW)—a monoamine neurotransmitter precursor linked to sleep quality, circadian rhythm regulation, and neuroprotection, all of which decline with advancing age (Billows et al., 2022; Boland, 2013; Kawamura et al., 2026).

Molecular and Cellular Anti-Aging Mechanisms

The anti-aging bioactives of A. deliciosa act through interconnected and mutually reinforcing cellular and molecular pathways. Figure 1 provides a mechanistic overview of the primary anti-aging axes. These mechanisms align directly with the recognized hallmarks of aging as defined by (López-Otín et al., 2013), providing a systems-level framework for understanding kiwi fruit's anti-aging bioactivity.

Figure 1. Mechanistic Pathways of Anti-Aging Bioactives in Actinidia deliciosa

1. Reactive Oxygen Species Scavenging and Antioxidant Defense Anti-aging

Oxidative stress, the imbalance between ROS generation and antioxidant neutralization, is a primary driver of macromolecular damage underlying aging. Ascorbic acid directly neutralizes superoxide ($O_2^{\bullet -}$), hydroxyl radical (•OH), and singlet oxygen ($^1O_2$), while tocopherols intercept lipid peroxyl radicals (LOO•) in membrane environments. Polyphenols supplement this defense through both direct radical scavenging and indirect upregulation of the endogenous Nrf2-ARE antioxidant transcriptional pathway, thereby elevating cellular SOD, catalase, and GPx activities (López-Otín et al., 2013). Clinical studies using the ferric reducing ability of plasma (FRAP) and oxygen radical absorbance capacity (ORAC) assays confirm that kiwi fruit consumption significantly elevates plasma antioxidant capacity and reduces biomarkers of oxidative DNA damage (8-hydroxy-2'-deoxyguanosine; 8-OHdG) within weeks of dietary intervention (Nishiyama et al., 2004).

2. Collagen Biosynthesis and Dermal Matrix Preservation

Cutaneous aging is mechanistically characterized by reduced synthesis of type I and III collagen, increased MMP-mediated collagen degradation, and accumulation of advanced glycation end-products (AGEs) within the extracellular matrix (ECM). Ascorbic acid serves as an obligatory cosubstrate for prolyl-4-hydroxylase and lysyl hydroxylase enzymes that hydroxylate proline and lysine residues, which are essential for procollagen stability, cross-linking, and secretion (Wu et al., 2021). Ascorbic acid depletion results in the secretion of unstable procollagen that is rapidly degraded intracellularly. Epicatechin and quercetin from kiwi polyphenols suppress the expression and activity of MMP-1 (collagenase-1) and MMP-3 (stromelysin-1) in UV-irradiated

dermal fibroblasts by attenuating activator protein-1 (AP-1) and NF-κB signaling, thereby preserving the ECM architecture (Deters et al., 2005). The net clinical outcome is demonstrated retention of skin elasticity, reduced wrinkle depth, and improved dermal hydration, as evidenced in randomized controlled trials (Ivaskiene et al., 2025).

3. Anti-Inflammatory and Immunomodulatory Activity

Inflammaging, the chronic, sterile, low-grade systemic inflammation characteristic of advancing age, drives tissue deterioration, metabolic dysfunction, and increased susceptibility to age-related diseases. Quercetin exerts potent anti-inflammatory activity through direct inhibition of the IκB kinase (IKK) complex, preventing NF-κB nuclear translocation and transcriptional activation of pro-inflammatory cytokines (TNF-α, IL-1β, IL-6) and enzymes (COX-2, iNOS) (Ciacci et al., 2014). Chlorogenic acid independently suppresses toll-like receptor 4 (TLR-4)-mediated signalling and reduces circulating C-reactive protein (CRP). Kiwi pectin further modulates inflammatory tone via SCFA-dependent inhibition of histone deacetylase (HDAC) in intestinal immune cells, attenuating systemic endotoxin translocation (Kim et al., 2018; Richardson et al., 2018).

4. DNA Repair, Telomere Integrity, and Epigenetic Modulation

Genomic instability, arising from unrepaired oxidative DNA lesions and telomere attrition, is a primary hallmark of aging. Ascorbic acid reduces 8-OHdG, the principal oxidative DNA lesion, and facilitates nucleotide excision repair (NER) by maintaining the Fe(II) oxidation state of Tet methylcytosine dioxygenases responsible for DNA demethylation (Carr & Maggini, 2017). Folate (25 µg/100 g FW) is an essential one-carbon metabolism cofactor supporting de novo thymidylate synthesis, prevention of uracil misincorporation into DNA, and maintenance of S-adenosylmethionine (SAM) pools critical for epigenetic methylation reactions. Folate insufficiency is directly associated with telomere shortening in population studies. Vitamin C additionally activates TET enzymes to restore appropriate DNA methylation patterns and epigenetic changes that constitute a measurable 'epigenetic clock' of biological aging (Nishiyama et al., 2004; Richardson et al., 2018).

5. Mitochondrial Protection

Mitochondrial dysfunction, manifesting as reduced respiratory chain efficiency, elevated mitochondrial ROS production, and accumulation of mitochondrial DNA (mtDNA) mutations, is a recognized hallmark of aging with systemic consequences(Ma et al., 2023). Alpha-tocopherol is the principal antioxidant protecting the inner mitochondrial membranes against lipid peroxidation, thereby preserving membrane potential (Δψm) and electron transport chain (ETC) integrity (Lauridsen & Jensen, 2012). Ascorbic acid, by recycling tocopherol, extends mitochondrial membrane protection. Quercetin activates SIRT1 and downstream PGC-1α, the master regulator of mitochondrial biogenesis, potentially compensating for aging-associated mitochondrial loss. In vitro evidence demonstrates kiwi polyphenol extracts attenuate hydrogen peroxide-induced mitochondrial membrane depolarisation in primary human fibroblasts (Xu et al., 2025).

6. Skin Photoprotection and UV-Mediated Aging Attenuation

Photoaging, driven by UV-A (320–400 nm) and UV-B (290–320 nm) radiation, accelerates skin aging through direct DNA damage (cyclobutane pyrimidine dimers), ROS generation, MMP induction, and activation of the inflammatory cascade. Lutein and zeaxanthin from A. deliciosa

provide endogenous photoprotection through blue-light and UV absorption and by quenching singlet oxygen formed in irradiated skin chromophores (Działo et al., 2016; Stoykova et al., 2025). Kiwi peel extracts, tested in UV-irradiated keratinocyte models, significantly reduced intracellular ROS accumulation, suppressed caspase-3-mediated apoptosis, and restored cell viability, suggesting protective potential in UV-stressed epidermal cells (Działo et al., 2016; Luo et al., 2026; Stoykova et al., 2025). Vitamin C further prevents UV-induced oxidative inactivation of dermal fibroblasts and supports post-UV DNA repair(Luo et al., 2026).

7. Neuroprotective and Cognitive Anti-Aging Effects

Age-related cognitive decline involves oxidative neuronal damage, neuroinflammation, neurotransmitter depletion, and mitochondrial dysfunction within neural tissue. Serotonin from kiwi fruit contributes to tryptophan-5-HT-melatonin metabolism, supporting sleep quality itself a critical determinant of neuroinflammation and amyloid-β clearance via the glymphatic system (Moysidou et al., 2024a) Randomized controlled trials in healthy older adults consuming two gold kiwi fruit per day for 16 weeks reported significantly improved scores on validated cognitive assessments and subjective reduction in fatigue and mental fog, consistent with ascorbate-mediated neuroprotection (Billows et al., 2022; Richardson et al., 2018). Folate supports the methylation of homocysteine, which is an independent cardiovascular and neurodegenerative risk factor in aging populations.

Bioavailability, Synergism, and Food Matrix Considerations

The biological efficacy of kiwi bioactives is substantially influenced by bioavailability, the fraction of an ingested compound that reaches systemic circulation in an active form. Ascorbic acid from kiwi fruit demonstrates bioavailability equivalent to pharmaceutical ascorbic acid at physiological doses (≤200 mg/meal), with active intestinal transport via sodium-dependent vitamin C transporters (SVCT1/2) (Carr & Maggini, 2017). The food matrix of kiwi, characterized by high water content, pectin, and organic acids, facilitates ascorbate stability during digestion and enhances polyphenol solubility. Actinidin's protease activity also promotes gastric protein hydrolysis, thereby improving amino acid bioavailability, including tyrosine (a collagen precursor) and tryptophan (a serotonin precursor) (Satpal et al., 2021).

A critical feature of kiwi fruit bioactives is their documented synergism. The ascorbate-tocopherol recycling system, the simultaneous antioxidant-pro-collagenic activity of ascorbate, and the complementary anti-inflammatory mechanisms of quercetin and chlorogenic acid create a multi-target anti-aging system that exceeds the efficacy of individual compounds. This matrix synergism underscores the superiority of whole-fruit consumption over isolated supplementation for anti-aging outcomes (Boland, 2013; D'Evoli et al., 2015; Xu et al., 2025). Processing considerations are relevant: thermal processing reduces ascorbic acid content by up to 50%, whereas cold pressing and freeze-drying preserve >85% of the original polyphenol profile. Consuming whole kiwis (including seeds, where possible) maximizes total bioactive intake.

Safety Profile and Adverse Considerations

A. deliciosa is generally recognized as safe (GRAS) at typical dietary consumption levels (1–3 fruits/day)(Satpal et al., 2021). The primary adverse consideration is kiwi fruit allergy, which affects approximately 3–5% of the general European population and may manifest as oral allergy syndrome (cross-reactivity with birch

pollen and latex), urticaria, or, in rare cases, anaphylaxis (Kawamura et al., 2026; Nishiyama et al., 2004). The major allergenic proteins include Act d 1 (actinidin), Act d 2 (thaumatin-like protein), Act d 5 (kiwifruit), and Act d 8 (PR-10 protein). Latex-fruit syndrome, mediated by cross-reactive chitinases, is clinically relevant for latex-sensitive individuals(Satpal et al., 2021).

Actinidin's proteolytic activity may potentiate the anticoagulant effects of warfarin in susceptible individuals by enhancing the absorption of vitamin K antagonists, warranting clinical awareness in anticoagulated patients. High dietary vitamin C intake (>2 g/day equivalent) from concentrated kiwi sources may cause osmotic gastrointestinal discomfort(Richardson et al., 2018; Zehra et al., 2020). These considerations do not diminish the safety of kiwi fruit for the general population but indicate the need for personalized dietary advice in specific clinical contexts.

FUTURE RESEARCH DIRECTIONS

Despite substantial mechanistic and clinical evidence, several research gaps warrant prioritisation. First, large-scale, long-duration (≥6 months) RCTs with validated biological aging endpoints (telomere length, epigenetic age, mitochondrial biogenesis markers) are needed to establish causal anti-aging efficacy beyond surrogate biomarkers. Second, comparative trials comparing A. deliciosa and A. chinensis var. chinensis (gold kiwi) for anti-aging outcomes would clarify which varietal is superior for specific endpoints. Third, pharmacokinetic studies characterizing the tissue distribution of kiwi polyphenols, particularly in dermal and neural compartments, would strengthen mechanistic inference. Fourth, the gut microbiome-mediated metabolism of kiwi bioactives (e.g., equol-like metabolites from flavonoids) and their systemic anti-aging signalling represent a nascent but promising research frontier (Satpal et al., 2021). Fifth, topical formulation development exploiting combinations of actinidin, ascorbate, and polyphenols offers commercially viable applications in cosmeceutical anti-aging products that require rigorous clinical evaluation.

CONCLUSION

Actinidia deliciosa represents a scientifically validated, multi-target dietary anti-aging agent of considerable potency. Its phytochemical matrix, uniquely integrating high-concentration ascorbic acid, diverse polyphenols, carotenoids, tocopherols, actinidin, prebiotic fiber, serotonin, and folate, exerts concerted anti-aging activity across all major molecular hallmarks of aging: oxidative stress, chronic inflammation, collagen matrix degradation, genomic instability, mitochondrial dysfunction, impaired proteostasis, and neurodegeneration. The supporting clinical evidence from well-designed RCTs provides translational credibility to mechanistic insights generated from robust preclinical models. Regular consumption of two or more kiwi fruits per day constitutes a practical, safe, and phytochemically rational dietary strategy for attenuating biological aging across organ systems. Integration of kiwi fruit into evidence-based anti-aging nutritional frameworks is strongly supported by the totality of current evidence, while continued mechanistic and clinical research will further delineate optimal dosing, synergistic food combinations, and personalized applications in aging populations.

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HOW TO CITE: Priyanka Thakare, Rashmi Bachhav, Reehan Khan, Dr. Deepak Somavanshi, Anti-Aging Bioactives of Kiwi Fruit (Actinidia deliciosa): A Comprehensive Review Int. J. of Pharm. Sci., 2026, Vol 4, Issue 5, 5327-5337, https://doi.org/10.5281/zenodo.20310736