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The Potential Benefits of Natural Bioactive Compounds in an Anti-Inflammatory Diet on Sarcopenia in Older Adults

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Abstract. Sarcopenia, a progressive condition marked by the gradual decline in skeletal muscle mass, strength, and function, is increasingly prevalent among older adults. While resistance training remains an established intervention, dietary strategies have gained attention as feasible and complementary approaches to mitigate muscle decline. This paper summarizes recent studies from the past few years on the potential benefits of natural bioactive compounds commonly found in culinary spices, with a focus on curcumin (in turmeric), piperine (in black pepper), cinnamaldehyde and Cinnamic Acid (in cinnamon) and rosmarinic acid (in rosemary, RosA). For each compound, representative studies were selected to illustrate current evidence. Clinical trials investigating curcumin supplementation have reported modest improvements in muscle strength and endurance. Preclinical studies using animal models have revealed that piperine possesses both anti-inflammatory and antioxidant activities, along with its capacity to enhance curcumin bioavailability in humans. In vitro studies on cinnamaldehyde and RosA have shown protective effects against inflammation-induced muscle atrophy. Although these findings highlight promising mechanisms through which dietary bioactive compounds may contribute to the prevention and management of sarcopenia, most evidence to date is derived from animal models, cell culture experiments, or small pilot trials in healthy individuals. Large-scale, well-designed clinical studies targeting older adults with clinically diagnosed sarcopenia are warranted to confirm the efficacy and safety of these interventions.

Keywords: Sarcopenia, Anti-inflammatory diet, Curcumin, Piperine

1. Introduction

Sarcopenia is defined as “a progressive and generalized skeletal muscle disease that consists of low muscle strength, low muscle quantity, and low muscle-specific force” [1]. Proposed in 2024, this global consensus definition originated from the Global Leadership Initiative in Sarcopenia (GLIS). Adverse outcomes such as limited mobility and decreased physical performance are strongly associated with sarcopenia, impacting up to 97.9% of affected individuals [1]. Muscle mass can further decline during periods of illness, treatment, or prolonged bed rest, leading to a vicious cycle of functional deterioration. This progressive muscle loss severely impairs quality of life and may even become life-threatening.

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The prevalence of sarcopenia rises significantly after entering older adulthood. The World Health Organization (WHO) projects that the global demographic aged over 60 years will nearly double in proportion, increasing from 12% in 2015 to 22% by 2050 [2]. The count of seniors experiencing sarcopenia is forecasted to expand.

While sarcopenia is regarded as a potentially reversible condition, no definitive pharmacological treatments have been established to date. However, non-pharmacological approaches, particularly resistance exercise, have been shown to effectively improve muscle strength. However, for ageing population, particularly those who lacked regular exercise habits or awareness during their younger years, the likelihood of significantly increasing physical activity intensity or developing new exercise routines in later life is generally low. Attention has turned to lifestyle and dietary interventions recently.

Anti-inflammatory diets encourage the consumption of fruits, nuts, and spices that contain natural bioactive compounds while limiting foods known to promote chronic inflammation. Still, research on the relationship between anti-inflammatory diets—particularly the role of natural bioactive compounds—and sarcopenia remains limited.

This paper will mainly focus on the natural bioactive compounds, which are key constituents of anti-inflammatory diets, such as curcumin in turmeric, piperine in black pepper, cinnamaldehyde in cinnamon as well as rosmarinic acid in rosemary. It strives to provide a summary and updated overview of recent research about the anti-inflammatory effects of these compounds in the context of sarcopenia. These bioactive components may contribute to the preservation of muscle mass and function in older adults by modulating inflammation and further supporting bone–muscle interactions.

2. Composition of an anti-inflammatory diet

Although there is no universally defined anti-inflammatory diet, conceptualizing it by contrasting two opposing dietary patterns could be useful: pro-inflammatory diets, which exacerbate chronic inflammation, and anti-inflammatory diets, which may help attenuate it.

Pro-inflammatory diets are typically characterized by high intakes of red meats, refined carbohydrates, refined sugars, industrial trans fats, and ultra-processed foods. Additionally, certain cooking methods—particularly deep frying and high-temperature grilling—can further exacerbate inflammatory responses.

In contrast, anti-inflammatory diets emphasize increased intake of fruits, vegetables, fatty fish, whole grains, nuts, functional herbs and spices. Key anti-inflammatory nutrients include omega-3 fatty acids, vitamin C, polyphenols, and factors supporting gut health.

Major polyphenol subgroups comprise flavonoids (e.g., catechins in green tea, quercetin in onions and berries), phenolic acids (e.g., caffeic acid in coffee, ferulic acid in whole grains), tannins (e.g., in grapes and nuts), and lignans (e.g., in flaxseeds and whole grains). Particularly noteworthy are culinary spices rich in polyphenols, which, despite their small serving sizes, provide highly concentrated anti-inflammatory benefits. Examples include turmeric, cinnamon, black pepper, rosemary, thyme, and cloves.

Gut health also plays a pivotal role in modulating systemic inflammation. Foods rich in probiotics (e.g., yogurt, fermented vegetables) and prebiotics (e.g., asparagus, chicory, bananas containing inulin) stimulate the flourishing of beneficial gut microbes, thereby improve inflammation regulation.

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3. Inflammatory makers that influence sarcopenia for older adult

Tumor Necrosis Factor-α (TNF-α), a representative pro-inflammatory cytokine predominantly secreted by macrophages, triggers the nuclear factor kappa-B (NF-κB) signaling pathway. This activation upregulates the expression of the muscle-specific E3 ubiquitin ligases MuRF1 and Atrogin-1, while concurrently downregulating MyoD expression, thereby inhibiting myogenic differentiation and accelerating muscle atrophy. Similarly, IL-6, another key pro-inflammatory cytokine, transiently increases following muscle injury to promote satellite cell proliferation. Prolonged elevation of IL-6, however, stimulates the Janus kinase (JAK) / signal transducer and activator of transcription (STAT) pathway, resulting in the phosphorylation of STAT3. This cascade not only augments MuRF1 and Atrogin-1 expression but also elevates reactive oxygen species (ROS) production, ultimately impairing myocyte function.

One key measurement for the anti-inflammatory diet is the Dietary Inflammatory Index (DII). DII is established by measuring the effects of various dietary components on systemic inflammation, based on their documented influence on specific inflammatory biomarkers, including Interleukins (ILs), TNF-α, and C-reactive protein (CRP). These six biomarkers include both pro-inflammatory and anti-inflammatory cytokines, allowing the DII to reflect the comprehensive inflammatory influence of the diet. Based on data from 11 studies with 19,954 subjects (including 13,732 adults from 9 studies whose mean/median age was 50 years or older), the meta-analysis demonstrated a notable correlation between higher DII scores and rising incidence of sarcopenia [3].

ILs are associated with sarcopenia in aging populations. The review included data from 7,994 participants (including 4,579 participants from studies whose mean/median age was 60 years or older). IL-1β and IL-6 lead to muscle degradation and the decline of muscle mass and function, while IL-10 may have a compensatory protective effect by modulating inflammation and potentially mitigating muscle loss [4].

3.1. Curcumin

Scientific evidence from clinical trials demonstrates that curcumin supplementation effectively reduces inflammation and muscle damage. For instance, Varma et al. implemented a 3-month randomly assigned, double-blind, placebo-controlled trial in 30 healthy older adults (mean age around 70) to test the influence of Cureit™, a bioavailable curcumin supplement, on sarcopenia-related outcomes. The study found that the Cureit group showed a 1.43% increase in hand grip strength, a 6.08% improvement in weight lifting capacity, a 5.51% increase in distance walked before fatigue, and a 1.15% reduction in the time taken to walk a fixed distance. These improvements were not observed in the placebo group, and no serious side effects were reported.

However, the study had several limitations. First, the participants were healthy older adults without clinically diagnosed sarcopenia, which limits the relevance of the findings to those with actual sarcopenia. Second, the duration of 3 months for the intervention might not have been adequate to capture significant changes in inflammation markers or muscle mass. Third, the dosage of Cureit used might have been insufficient to elicit stronger systemic effects, particularly in reducing inflammatory biomarkers such as CRP [5].

In a randomized controlled clinical trial, Chaiworramukkul et al. investigated the effects of curcumin intake on cancer cachexia in 33 patients with advanced solid tumors. The patients had a median age of 58 years. Over an 8-week intervention period, participants in the treatment group received 1.6 grams of curcumin orally per day. Although both groups exhibited a decline in handgrip strength—a common proxy for muscle function deterioration—the curcumin group experienced a

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numerically smaller reduction than the control group. Specifically, right-hand grip strength declined by 2.47 kg in the curcumin group versus 5.36 kg in controls, and left-hand grip strength declined by 1.98 kg versus 5.43 kg, respectively. These findings suggest that curcumin may help attenuate muscle strength loss in cancer patients, although the difference was not statistically significant. This could be clinically meaningful, particularly in populations where cancer cachexia overlaps with sarcopenia in older adults [6].

3.2. Piperine

Liu demonstrated that piperine, the main bioactive compound in black pepper, significantly attenuated inflammation, oxidative stress, and skeletal muscle apoptosis in a rat experiment of exercise induced skeletal muscle damage (EISMD). The study showed that piperine reduced serum levels of IL-1β, IL-6, and TNF-α, as well as Creatine Kinase (CK) and CK-Muscle type levels, while increasing ATP content and antioxidant enzymes such as SOD (Superoxide Dismutase) and CAT (Catalase). These protective effects were linked to the activation of the PI3K/AKT signaling pathway. However, the findings were derived from a preclinical animal study involving six groups of male Sprague-Dawley rats. No human subjects were included, and thus the applicability of these results to elderly populations or sarcopenia patients remains uncertainty [7].

The administration of piperine not only reduces inflammation on its own but also enhances the bioavailability of curcumin by extending its half-life. Khajeh pour et al. developed a rapid and sensitive LC–MS/MS method for detecting curcumin in human urine. In a small pilot study involving three healthy adults, they found that co-ingestion of black pepper significantly increased curcumin's half-life (from approximately 1.4–3.0 to 3.7–5.3 hours) and its 24-hour urinary excretion (from approximately 36.5–62.4 to 123.2–313.1 μg), indicating improved absorption due to piperine [8].

3.3. Cinnamaldehyde and cinnamic acid

Cinnamaldehyde has demonstrated protective effects against skeletal muscle atrophy by modulating multiple cellular mechanisms. Specifically, it mitigates inflammation and oxidative stress, suppresses protein degradation, promotes protein synthesis, and preserves structural integrity of muscle cells. In a recent in vitro study, Kaur et al. employed C2C12 mouse myotubes to establish a TNF-α-induced atrophy model. The cells were pretreated with cinnamaldehyde at a concentration of 0.05 mM for four hours prior to 72 hours of TNF-α exposure. TNF-α stimulation resulted in an approximate twofold increase in IL-6 expression, a pro-inflammatory cytokine closely associated with muscle wasting. Notably, cinnamaldehyde pretreatment attenuated this response by nearly 50%. These findings suggest that cinnamaldehyde exerts its effects through a multi-targeted mechanism and may serve as a mechanistic basis for further exploration as a potential therapeutic agent against inflammation-induced muscle atrophy. No human subjects were included, and thus the applicability of these results to elderly patients with sarcopenia remains uncertain [9].

Another study recruited 15 hospitalized older adults (aged 77–90), grouped by normal and low handgrip strength (HGS), to investigate metabolic and microbial markers associated with muscle strength. Serum and fecal samples were analyzed using untargeted LC-MS and 16S rDNA sequencing. Spearman correlation and integrated multi-omics analysis were used to identify key metabolites and microbial taxa. Notably, serum levels of cinnamic acid derivatives—cinnamoylglycine, 4-methoxycinnamic acid, and (E)-3,4,5-trimethoxycinnamic acid—were significantly reduced in the low-HGS group and positively correlated with muscle strength. Gut

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microbiota such as Parabacteroides and Intestinibacter were enriched in the low-HGS group and inversely related to these metabolites. The study highlights the gut-muscle-metabolite axis and suggests that microbial-linked cinnamic acid derivatives may serve as early biomarkers of muscle strength decline in aging populations [10].

3.4. Rosmarinic acid

RosA has showed notable anti-inflammatory activity in diverse experimental contexts. It has been proved to reduce the concentrations of key inflammatory cytokines, including TNF-α and ILs. Furthermore, RosA downregulates the expression of NF κB, thereby mitigating pro-inflammatory signaling in inflammatory microenvironments [11]. Besides its anti-inflammatory effects, RosA exhibits therapeutic potential in a broad spectrum of pathological conditions, including anticancer, antidiabetic, antimicrobial, and cardioprotective activities. These multifunctional properties highlight RosA as a promising natural compound for the prevention and management of inflammatory medical issues.

The anti-inflammatory and antioxidant properties of RosA have been well documented, while its specific effects on skeletal muscle remain underexplored. Kim et al. investigated the role of RosA in skeletal muscle physiology using a C2C12 myotube model subjected to dexamethasone (DEX)-induced catabolic stress. DEX is commonly applied to mimic muscle-wasting conditions. After 24 hours of adding RosA (1 or 5 μM), C2C12 myotubes showed significant improvements in morphological and functional parameters. RosA increased cell viability, restored myotube diameter and fusion index to levels comparable to untreated controls, and upregulated the expression of myosin heavy chain (MHC)—a fundamental structural and contractile protein in skeletal muscle fibers. MHC is also a crucial developmental regulator of myogenesis, and its expression is closely related to the differentiation and maturation of skeletal muscle cells. Therefore, the ability of RosA to restore MHC expression under glucocorticoid-induced stress implies a critical role in maintaining muscle integrity and promoting muscle regeneration [12].

4. Conclusion

Turmeric, black pepper, cinnamon, and rosemary are common culinary spices that possess bioactive properties with potential benefits to prevent and manage sarcopenia in aging population. Moderate consumption of these spices may enhance anti-inflammatory responses and suppress pro-inflammatory cytokine expression, thereby block the progression of sarcopenia in aging populations. Furthermore, the use of these spices can increase the sensory richness of food, potentially reducing the need for added salt—an advantage particularly relevant to individuals with hypertension. Dietary patterns involving these spices vary geographically: cinnamon is predominantly used in regions such as the Middle East, North Africa, Latin America, and China; turmeric and black pepper, often combined in curry preparations, are characteristic of Indian and Southeast Asian cuisines; whereas in Australia and North America, black pepper and rosemary are more commonly utilized. However, excessive intake of these natural compounds warrants caution, as it may lead to risks such as liver and kidney strain or impaired blood coagulation.

Balanced nutrition is widely recognized in the current sarcopenia consensus as a key foundation for prevention and therapy. Nutritional guidelines and individualized dietary plans are increasingly recommended to support muscle health and slow the progression of age-related muscle decline. Although research on sarcopenia has expanded in recent years, much of the existing evidence is derived from animal models or specific human populations such as athletes and sedentary

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individuals. Clinical studies specifically targeting older adults remain relatively scarce and require further investigation. In addition to nutritional strategies, resistance training and pharmacological interventions are recognized as potentially effective approaches for managing sarcopenia. However, these interventions must be carefully adapted to accommodate the limited physical capacity and high prevalence of comorbidities in older population.

References

[1] Kirk, B., Cawthon, P. M., Arai, H., Ávila-Funes, J. A., Barazzoni, R., Bhasin, S., et al. (2024). The conceptual definition of sarcopenia: Delphi consensus from the Global Leadership Initiative in Sarcopenia (GLIS). Age and Ageing, 53(3), afae052.

[2] World Health Organization. (2024, October 1). Ageing and health. Retrieved July 13, 2025, from https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

[3] Diao, H., Yan, F., He, Q., Li, M., Zheng, Q., Zhu, Q., et al. (2023). Association between Dietary Inflammatory Index and Sarcopenia: A meta-analysis. Nutrients, 15(1), 219.

[4] He, Y., Duan, W., Xu, P., Lin, T., Xiang, Q., Dong, B., et al. (2024). Exploring the impact of interleukins on sarcopenia development: A systematic review and meta-analysis. Experimental Gerontology, 193, 112480.

[5] Varma, K., Amalraj, A., Divya, C., & Gopi, S. (2021). The efficacy of the novel bioavailable curcumin (Cureit) in the management of sarcopenia in healthy elderly subjects: A randomized, placebo-controlled, double-blind clinical study. Journal of Medicinal Food, 24(1), 40–49.

[6] Chaiworramukkul, A., Seetalarom, K., Saichamchan, S., & Prasongsook, N. (2022). A Double-Blind, Placebo-Controlled Randomized Phase IIa Study: Evaluating the Effect of Curcumin for Treatment of Cancer Anorexia-Cachexia Syndrome in Solid Cancer Patients. Asian Pacific journal of cancer prevention : APJCP, 23(7), 2333–2340.

[7] Liu, D. (2024). Piperine in pepper improves exercise-induced skeletal muscle damage in rats by regulating the PI3K/AKT pathway. Molecular Plant Breeding, 22(5), 1654–1662.

[8] Khajeh pour, S., Blanton, C., Ghimire, B., & Aghazadeh-Habashi, A. (2023). Development of a rapid, sensitive, and selective LC–MS/MS method for quantifying curcumin levels in healthy human urine: Effect of pepper on curcumin bioavailability. Food Science & Nutrition, 11(12), 7732–7741.

[9] Kaur, N., Gupta, P., Dutt, V., Sharma, O., Gupta, S., Dua, A., et al. (2024). Cinnamaldehyde attenuates TNF-α induced skeletal muscle loss in C2C12 myotubes via regulation of protein synthesis, proteolysis, oxidative stress and inflammation. Archives of Biochemistry and Biophysics, 753, 109922.

[10] Guo, Y., Wang, Q., Lv, Y., Xia, F., Chen, X., Mao, Y., et al. (2024). Serum metabolome and gut microbiome alterations are associated with low handgrip strength in older adults. Aging, 16(3), 2638–2656.

[11] Nadeem, M., Imran, M., Aslam Gondal, T., Imran, A., Shahbaz, M., Muhammad Amir, R., et al. (2019). Therapeutic potential of rosmarinic acid: A comprehensive review. Applied Sciences, 9(15), 3139.

[12] Kim, J. Y., Kim, H. M., Kim, J. H., Guo, S., Lee, D. H., Lim, G. M., et al. (2023). Salvia plebeia R.Br. and rosmarinic acid attenuate dexamethasone-induced muscle atrophy in C2C12 myotubes. International Journal of Molecular Sciences, 24(3), 1876.