Unveiling Fulvic Acid: A Review of Its Pharmacological Properties and Health Implications

Chakali Ayyanna* [1] ,Byrapu Jahnavi [2], Guddety Anusha [3], Garudampalli Lavanya [4], Ediga Sumathi [5], Akepogu Mamatha [6]

[1] Associate Professor, Department of Pharmacology, Creative Educational Society's College of Pharmacy, Chinnatekur, Kurnool, and Andhra Pradesh-518218, India.

[2,3,4,5&6] Department of Pharmacology, Creative Educational Society's College of Pharmacy, Chinnatekur, Kurnool, and Andhra Pradesh-518218, India.

Corresponding author: Chakali Ayyanna *

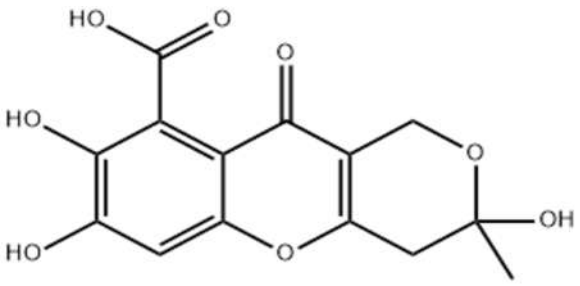
Abstract: Fulvic acid (FA), a naturally occurring humic chemical, has a wide range of pharmacological and physiological properties that have uses in human health, animal nutrition, agriculture, and environmental management. Preclinical and clinical studies show that it has antioxidant, anti-inflammatory, antimicrobial, anti-obesity, and immune-modulating properties, as well as the potential to treat chronic inflammatory disorders, type 2 diabetes, and neurodegenerative ailments like Alzheimer's disease. FA has been demonstrated to slow the progression of breast cancer in MCF-7 cell line models, improve skin health beyond lubricants alone, and give antidiarrheal properties. In animal husbandry, FA promotes growth, digestion, egg quality, and immunological responses in chicken, increases disease resistance in shrimp and fish aquaculture, and supports gut micro biome alteration.

FA improves soil fertility in agriculture by chelating, transporting nutrients, and regulating pH, and it has the potential to be a long-term weed management technique in rice cultivation. Toxicological studies, including a 90-day oral trial in Wistar rats, have confirmed a high safety margin with a NOAEL of 2,000 mg/kg/day. Collectively, our data emphasize FA's multifunctional potential as a natural, sustainable agent for health promotion, productivity increase, and environmental stewardship, while emphasizing the importance of standardized preparations and additional clinical validation.

Key words: Fulvic acid, antioxidant, anti-inflammatory, antimicrobial, anti-obesity, chronic inflammatory diseases, type 2 diabetes, and Alzheimer's disease.

1.INTRODUCTION

Fulvic acid (FA) is a low-molecular-weight, water-soluble humic molecule generated from the microbial degradation of organic materials. It is renowned for its high carboxyl and phenolic activity. These chemical properties give FA with substantial chelating, buffering, and nutrient-transport capabilities, which are fundamental to its historical use in improving soil health and pH management [1-2]. Fulvic acids can be bright yellow or brown in color.



Fulvic acid (FA)

FA has recently moved beyond its agronomic foundations, gaining recognition for its multifunctional pharmacological and applied effects. Human and preclinical research highlight FA's antioxidant, anti-inflammatory, antibacterial, and immunomodulatory properties, as well as emerging anti-obesity, antidiabetic, neuroprotective (Alzheimer's), and anticancer benefits, notably in MCF-7 breast cancer SCID mouse models [3-5]. In agriculture, FA boosts soil fertility by enhancing nutrient complexation and transport; increases crop tolerance to challenges such as salinity and low phosphorus; and shows potential as a sustainable weed management strategy in rice systems [6-8].

FA supplementation has been shown to improve growth metrics, feed conversion, antioxidant capacity, immunological defense, egg production, and gut micro biota in a variety of species, including shrimp, rainbow trout, laying hens, and grill chickens [9–12].Importantly, toxicological tests suggest a large safety margin for FA. Standardized investigations on rodents, including Sprague dawley, ICR, and wistar rats, reveal no deleterious effects up to a no observed effect level (NOAEL) of 2,000 mg/kg/day [13].

In view of the rising global incidence of chronic inflammatory, metabolic, and degenerative disorders, as well as the necessity for sustainable agriculture practices and animal production, FA's varied bioactivities make it an appealing choice for integrative applications. This review seeks to synthesize the chemical characteristics, biological roles, and translational potential of

FA, while emphasizing the need for mechanism-driven research, formulation standardization, and clinical validation.

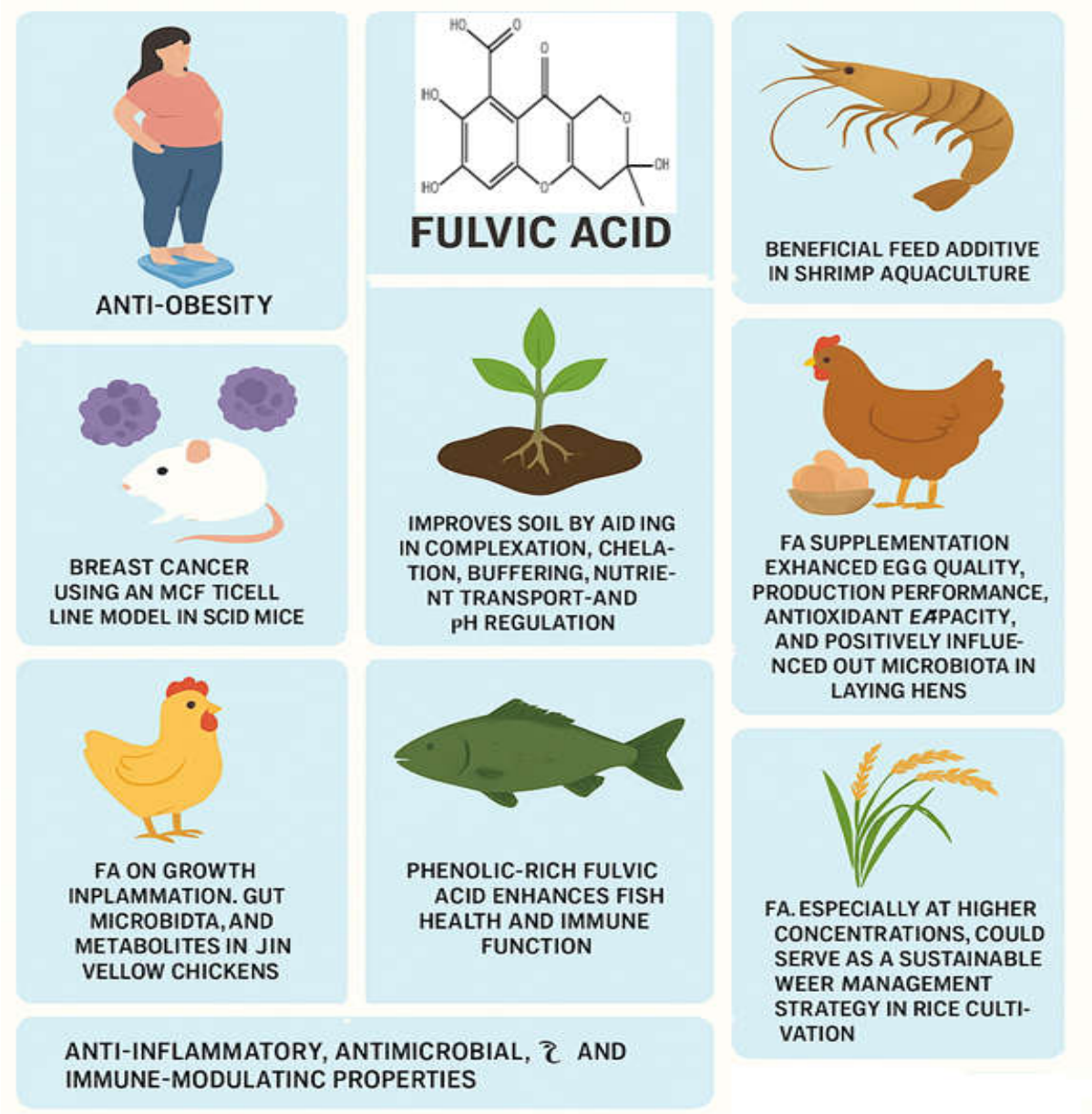


Figure No.1 Summary of the pharmacological features and health benefits of Fulvic acid

2.DISCUSSION

Fulvic acid (FA) has emerged as a versatile natural chemical with a variety of medicinal, agronomic, and environmental applications. Its bioactivity includes antioxidant, anti-inflammatory, immunomodulatory, antibacterial, and guts micro biota-modulating properties, making it a promising therapeutic candidate across multiple domains [13]. In agriculture, FA has shown promise as a helpful feed addition. In prawn aquaculture, supplementation increased growth performance, digestive efficiency, and immunological defense, demonstrating its potential as a sustainable aquaculture enhancer [14]. Similarly, in poultry production, FA supplementation in laying hens increased the quality of eggs, efficiency of production, and antioxidant capacity while positively altering gut micro biota [15].

In xianju yellow chickens, FA increased growth, decreased inflammation, and controlled gut microbial composition and metabolites [16]. In aquaculture species like fish, phenolic-rich FA has been demonstrated to improve immunity and disease resistance [17]. In crop production, FA enhances soil quality by complexing, chelating, buffering, and transporting nutrients, hence improving pH regulation and encouraging sustainable agriculture [18]. Furthermore, large quantities of FA have shown promise as an environmentally benign weed management method in rice production [19]. Pharmacologically, FA has broad therapeutic potential. It has been studied for anti-obesity properties [20] and examined in cancer models, such as breast cancer utilizing MCF-7 cell xenografts in SCID mice, exhibiting inhibitory effects on tumour growth [21].

FA has been suggested as an alternative therapy for chronic inflammatory disorders, such as type 2 diabetes, due to its capacity to control oxidative stress and immunological responses [22]. Preclinical investigations have demonstrated neuroprotective effects in Alzheimer's disease by inhibiting tau aggregation and reducing neuroinflammation[23]. In terms of safety, FA has a favorable toxicological profile. Standardized toxicological testing in Sprague dawley rats and ICR mice revealed no adverse effects, and a 90-day oral toxicity study in wistar rats determined a no-observed-adverse-effect limit (NOAEL) of 2,000 mg/kg/day [24]. Furthermore, FA-based topical formulations have proven to be more effective than emollients alone, particularly in people who are prone to skin irritation [25]. FA has also been used for its antidiarrheal properties in people and animals [26].

While FA's broad application is encouraging, difficulties persist. Variability in source materials, extraction processes, and chemical composition impedes reproducibility and standardization [27]. Furthermore, because there are so few high-quality clinical studies, preclinical data must be interpreted with caution before being translated into therapeutics. Future research should priorities well-designed, controlled human trials, molecular mechanism elucidation, and standardized quality control frameworks in order to fully realize FA's promise as a functional medicinal, agricultural biostimulant, and environmental enhancer.

3.CONCLUSION

Fulvic acid (FA) is remarkably versatile, providing benefits in human health, animal production, aquaculture, and agriculture. Its pharmacological potential includes anti-obesity properties, cancer modulation, antibacterial action, immunological regulation, antioxidant enhancement, and gut micro biota modification. In livestock and aquaculture, FA improves growth, disease resistance, and product quality, while in agriculture it promotes soil fertility and sustainable weed control. Preclinical and toxicological studies provide a favorable safety profile, with no reported deleterious effects at large dosages.

Recent evidence shows therapeutic potential in chronic inflammatory problems, metabolic disorders, neurological diseases, and skin health. Despite its widespread use, diversity in composition, limited clinical research, and a lack of standardization remain difficulties. The advancement of FA research requires robust human investigations, quality control, and mechanistic understanding. With further scientific validation, FA has the potential to be a long-lasting, multifunctional bioactive chemical with important implications for integrative healthcare, food security, and environmental sustainability.

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