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Review Article

Betaine: A Potential Nutraceutical for Health Benefits

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ABSTRACT

Betaine, a naturally occurring zwitterionic compound first identified in beets (*Beta vulgaris*), is increasingly recognized for its role as a potential nutraceutical. It is present in a variety of dietary sources associated with antioxidant, anti-inflammatory, hepatoprotective, and neuroprotective effects. This review aims to summarize current evidence on the therapeutic potential of betaine, highlighting its biochemical properties, mechanisms of action, and experimental findings across diverse disease models. Betaine has shown broad therapeutic potential in various in-vivo models. It reduces oxidative stress and inflammation, enhances antioxidant enzyme activity (SOD, CAT, GSH), improves metabolic function, and protects tissues in conditions such as Alzheimer's disease, Type 2 diabetes, Pulmonary arterial hypertension, Non-alcoholic fatty liver disease, Myocardial infarction, and Parkinson's disease. These findings highlight its antioxidant, anti-inflammatory, and metabolic regulatory properties, supporting betaine as a promising protective agent against diverse pathological conditions.

INTRODUCTION

For thousands of years, plants have been used to preserve human health and enhance the quality of human existence. They are also useful ingredients in beverages, cosmetics, medicines, colours, and flavours. According to estimates from the World Health Organization, around 80% of people on the planet receive their primary medical treatment from traditional medicine, which typically uses plant extracts or their active ingredients.

Moreover, plant extracts were the source of many Western medications. Digitalis was obtained from the foxglove plant (*Digitalis purpurea*) and used as a cardiac stimulant. Reserpine, which is commonly used to treat high blood pressure, was first taken from the herb *Rauwolfia serpentina*. Asthma was first treated with the Chinese herb ephedra, which contains the active ingredient ephedrine^[1]. Numerous scientific studies have demonstrated that a large number of these natural compounds have advantageous biological characteristics that support their therapeutic effects. Among these

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natural products is betaine, a stable and harmless chemical found in microbes, plants, and mammals. Other names for betaine, a zwitterionic quaternary ammonium molecule, include oxyneurine, glycine betaine, trimethylglycine, and lcyne. With a molecular weight of 117.2 and the formula $(\text{CH}_3)_3\text{NCH}_2\text{COO}$, it is a methyl derivative of the amino acid glycine. Because of its three chemically reactive methyl groups, it has been classified as a methylamine. Although betaine was initially discovered in beets (*Beta vulgaris*) in the 19th century, it is also present in significant amounts in microbes, aquatic invertebrates, and other dietary sources such as spinach, wheat bran, and wheat germ. Betaine can be obtained exogenously through diet or endogenously through the metabolism of choline. It also reduces

inflammation, cancer growth, oxidative stress, and endoplasmic reticulum stress. [1,2].

METHODOLOGY

All the data necessary to carry out this research were collected from works published in the last 10 years. These article are collected from Google scholar, Science direct, Research gate, Springer to identify scientific articles, Key words such as Betaine, antioxidant, inflammation, oxidative stress were used. After eliminating duplicates, we analyzed the articles based on the previously established inclusion criteria as mentioned in Figure 1. After a thorough analysis, articles that met the exclusion criteria were removed. The remaining articles were deemed relevant articles and included in this systematic review.

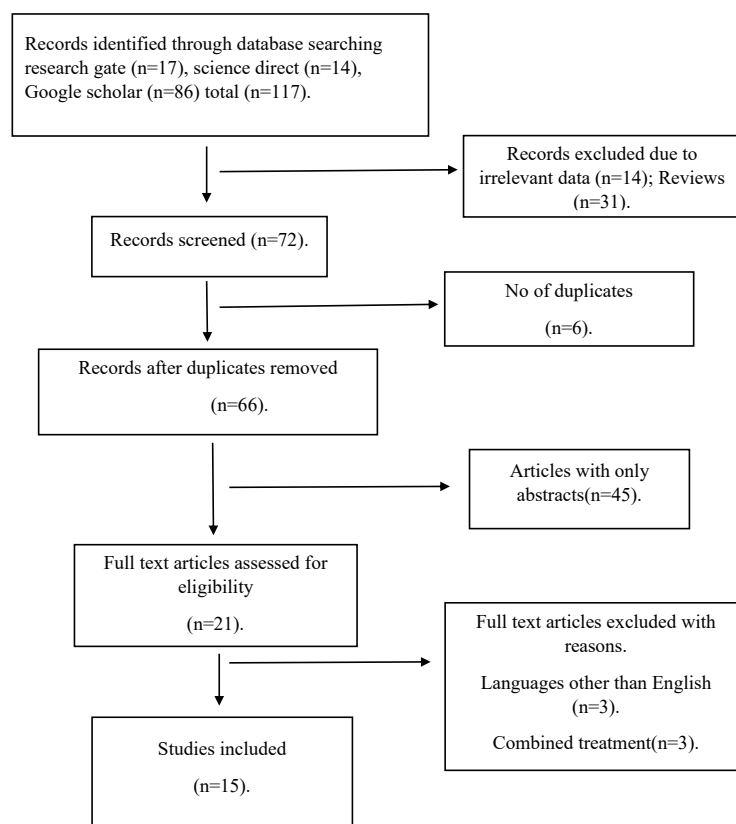


Figure:1

RESULTS AND DISCUSSION

A total of 15 article data was extracted. Betaine has attracted growing attention for its potential therapeutic applications. Beyond its well-



established role in liver function and methylation pathways, recent experimental studies suggest that betaine may exert protective effects. The following table summarizes current evidence on the therapeutic potential of betaine derived from various experimental models. This includes potential benefit of Betaine in different disease conditions including cardiovascular disorders, neurodegenerative diseases, diabetes, hepatic and renal injury, reproductive dysfunction, and ocular

inflammation—betaine has been investigated for its antioxidant, anti-inflammatory, metabolic, and cytoprotective properties. Collectively, these findings suggest that betaine may serve as a promising protective agent against oxidative damage and metabolic dysfunction in diverse pathological conditions.

Current evidence on the therapeutic potential of betaine from *in-vivo* studies

Sr. no	Source	Model	Treatment	Outcomes	Reference
1	Betaine	I/R-induced oxidative stress And inflammation in Sprague-Dawley rats.	Betaine Dose:75mg/kg and 150mg/kg 12hrs before surgery.	↓Proinflammatory cytokine Production. ↓ Reduces oxidative stress. ↑ Gene expression of antioxidative enzymes.	[3]
2	Betaine	Amyloid β -induced rat model of Alzheimer's disease A β (5 μ g/ μ L).	Betaine (5, 10, and 15 mg/kg, orally for 14 days.	↑Memory performance and restored GSH levels, and reduced MDA concentrations, confirming its antioxidant and neuroprotective properties..	[4]
3	Betaine	STZ induced diabetic disruption of the male mice blood-testis barrier.	BET (200, 400, 800 mg/kg) for 8 weeks.	↑ Weight of the reproductive organs and ↓ MDA and ROS contents , ↑ SOD, CAT, and GSH activities in DM testicular tissues ↓expressions of p38 MAPK phosphorylation.	[5]
4	Betaine	Monocrotaline-Induced Pulmonary Arterial Hypertension in Rats monocrotaline (50 mg/kg).	Betaine (100, 200, and 400 mg/kg) for 21 days.	↓ mPAP and RVSP. alleviated pulmonary arteries and right ventricle remodeling, and attenuated fibroplasia in the lungs of rats with MCT-induced PAH.	[6]
5	Betaine	Type 2 diabetes in male wistar rats.	Betaine 2% solution in drinking water for 8 weeks.	Exerted a hepatoprotective effect, ↓ Lipid accumulation in the skeletal muscle and ↑ Lipolytic activity of the adipose tissue cells, improved insulin action.	[7]
6	Betaine	Impaired Sulfur-Amino Acid Metabolism and Oxidative Stress in Non-alcoholic Fatty Liver in Rats.	Betaine (1%)in liquid diet for 3 weeks.	Protects the liver from induction of oxidative stress and steatosis by restoring transsulfuration activity.	[8]

7	Betaine	Isoproterenol-induced myocardial infarction in rat (Isoprenaline 200 mg/kg).	Betaine 50, 150, and 250 mg/kg for 60 days.	↓Serum creatinine, ↓TNF- α level and ↓Inflammation and kidney damage.	[9]
8.	Betaine	Experimentally Induced Myocardial Infarction in Rats (isoprenaline 11mg (dissolved in physiological saline)/ 100g body weight).	Betaine 250mg/kg for 30 days.	ATP energy levels stable, supporting TCACycle and respiratory enzymes. ↓ Oxidative stress.	[10]
9	Betaine	Lead-Induced Hepatic and Renal Toxicity in Albino Rats(Pb-acetate (50 mg/kg).	Betaine (250 mg/kg) for 6 weeks.	↓ Accumulation of fats in the liver, ↓lipid peroxidation levels, ↑ GSH levels.	[11]
10	Betaine	Dietary Betaine in Rats.	1% betaine for 28 days.	promoted hepatic cholesterol metabolism , ↑ Level of the bile acid salts export pump.	[12]
12	Betaine (Fructus lycii)	Experimental autoimmune uveitis in Lewis rats.	Betaine (100 mg/kg) for 9 consecutive days.	↓Oxidative stress and inflammation.	[14]
13.	Betaine	Pulmonary arterial hypertension in male SD rats- Monocrotaline (50 mg/kg.	Betaine (100, 200 and 400 mg/kg for 21 days.	Inhibiting pulmonary artery smooth muscle cell poliferation,↓ER stress, and activating the PERK–eIF2 α pathway, thereby preventing right ventricular hypertrophy and vascular remodelling.	[15]
14.	Betaine	Alcohol-induced hepatic and duodenal injury in rats.	Betaine(250 mg/kg) for 21 days.	↓ Acute ethanol-induced hyperemia, sinusoidal dilatation, inflammatory cell infiltration, and hepatocyte degeneration, protects the duodenal mucosa from the toxic effects of ethanol	[16]
15.	Betaine	Zebrafish	Betaine enrichment of diet at 0.1, 0.2 and 0.4 g/kg for 6 weeks.	Inhibit ROS production in zebrafish liver through Wnt10b/ β -catenin signalling pathway, enhanced gene expression and activity of SOD, glutathione peroxidase and catalase.	[17]

CONCLUSION

Betaine, a naturally occurring methyl donor and osmolyte, has been extensively studied in various experimental models, revealing its wide-ranging protective effects against oxidative stress, inflammation, and metabolic dysfunction. Across

multiple organ systems and disease conditions, betaine consistently demonstrates antioxidant, anti-inflammatory, and cytoprotective properties. These preclinical studies provide strong mechanistic insights; further clinical trials are needed to confirm translational benefits in humans. Nevertheless, betaine emerges as a



promising adjunctive agent for managing neurodegenerative diseases, cardiovascular and metabolic disorders, hepatic dysfunction, and inflammatory conditions.

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