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Fenugreek's Secondary Metabolites – Role in Agriculture, Biotechnology and Animal Sciences

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Abstract: The secondary metabolites of fenugreek (*Trigonella foenum-graecum*) are organic compounds that are not directly involved in the main metabolic pathways, being non-essential for growth, development, and reproduction. However, these secondary metabolites are usually synthesized in response to different environmental stresses, and various interactions with other living organisms, or are synthesized as a plant defense mechanism. Non-essential metabolites are usually biologically active compounds with critical ecological roles, including a role in the defense of plants against herbivores, with antagonistic effects towards other plants or towards attracting pollinators. Secondary metabolites of fenugreek include various alkaloids, terpenoids, flavonoids, and phenolic compounds, with pharmaceutical, agricultural, and industrial applications – with important contributions to plant adaptation to the environment or the possibility of being used for its medicinal properties.

• Introduction

Fenugreek (*Trigonella foenum-graecum*) is a plant known in some countries for its amazing culinary and medicinal uses. Its secondary metabolites, such as: alkaloids, flavonoids, saponins, and steroidal saponinins, among others, have various beneficial roles in agriculture, biotechnology, and animal sciences.

• Secondary metabolites of fenugreek

Fenugreek's secondary metabolites have multiple roles in agriculture, biotechnology, and animal science. In agriculture, compounds such as saponins and flavonoids promote plant growth, improve nutrient uptake, and provide natural pest control, reducing reliance on synthetic chemicals. Biotechnological advances allow the optimization of fenugreek extracts for medicinal applications, exploiting their anti-inflammatory, antimicrobial, and antidiabetic properties. In animal science, fenugreek seeds and extracts serve as nutritional supplements to animal feed, improving animal health and performance.

Furthermore, fenugreek's phytoremediation abilities help clean the environment by detoxifying soil and water contaminated with pollutants. Continued research and innovation in biotechnology further unlock the potential of fenugreek secondary metabolites, providing sustainable solutions for agriculture, medicine, and environmental remediation.

• Fenugreek's secondary metabolites – role in agriculture

Plant growth promotion: saponins and flavonoids from fenugreek promote plant growth by improving root development, nutrient uptake, and resistance to environmental stress. These properties make fenugreek extracts valuable biofertilizers and plant growth stimulants in agriculture.

Pest control: Fenugreek contains insecticidal compounds like alkaloids, saponins, and steroidal saponinins, which act as natural pesticides. These compounds repel or inhibit pests and pathogens, reducing the need for synthetic chemicals and promoting sustainable agriculture.

Bioremediation: Fenugreek's secondary metabolites possess phytoremediation properties, helping to detoxify soil or water contaminated with heavy metals or organic pollutants. These compounds aid in removing or degrading pollutants, supporting environmental cleanup in agriculture and industry.

• Fenugreek's secondary metabolites – role in biotechnology

Medicinal Applications: Secondary metabolites of fenugreek have long been used in traditional medicine for various purposes, including as anti-inflammatory, antimicrobial, and antidiabetic agents. Extracts rich in these compounds are used in pharmaceuticals, nutraceuticals, and herbal remedies. Biotechnological approaches are being explored to optimize the production of these compounds for medicinal purposes.



• FENUGREEK'S SECONDARY METABOLITES – ROLE IN ANIMAL SCIENCES

Animal Feed Supplements: Fenugreek seeds and their extracts are used as animal feed supplements due to their high protein content and potential health benefits.

Secondary metabolites such as saponins can also positively affect animal health, improving digestion, immunity, and growth performance. Incorporating fenugreek into animal feed formulations can improve nutritional value and overall welfare.

Biotechnological Production: Advances in biotechnology have facilitated the production of fenugreek secondary metabolites through plant tissue culture, genetic engineering, and metabolic engineering approaches. These techniques offer opportunities to improve fenugreek compounds' yield, purity, and functionality for various applications, including agriculture, medicine, and bioremediation.

• Conclusions

In plants such as fenugreek, secondary metabolites serve various ecological functions, including defense against herbivores, attraction of pollinators, and competition with neighboring plants.

These compounds are often characterized by their structural diversity and bioactivity, making them valuable for pharmaceutical, agricultural, and industrial applications.

Examples of secondary metabolites include alkaloids, flavonoids, terpenoids, and phenolic compounds, many of which possess medicinal properties or contribute to the adaptation of the plant to its environment.

