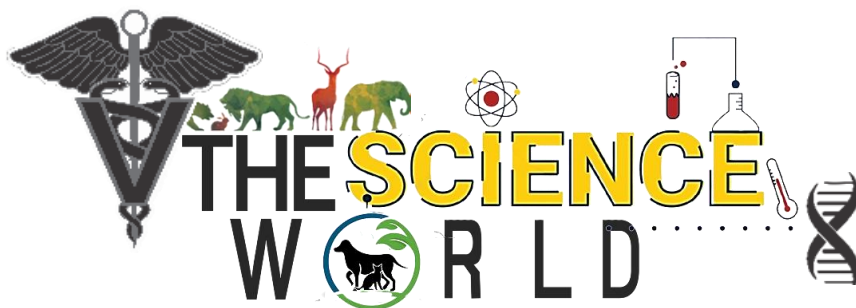




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Application of Metabolomics in Livestock Research

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Introduction

Metabolomics is the comprehensive high-throughput profiling of small-molecule metabolites (molecular weight less than 1kDa) like sugars, amino acids, organic acids and lipids in cells, tissues, or biofluids like plasma, serum, milk, ruminal fluid and urine etc. to help reveal any potential physiological changes in organism under certain conditions. It enables early disease detection, tracks metabolic disorders and monitors nutritional or physiological stress in animals. It measures the unique chemical fingerprints left by cellular processes to give a real-time snapshot of an animal's health, metabolism, and response to disease or environment. It indicates the biochemical status of an organism. Metabolites are of two types. Primary metabolites are directly involved in normal growth, development, reproduction, and central metabolic processes. Example-amino acids, carbohydrates and lipids. Secondary metabolites are organic compounds derived from primary pathways that are required for ecological advantages. Example- alkaloids, antioxidants, phenolics, flavonoids and antibiotics etc.

Application of metabolomics in animal science

Animal health: The use of metabolomics allows for early diagnosis of disease-related biomarkers by testing biological samples such as blood and urine. Metabolomics analysis identifies biomarker signatures before clinical signs of conditions like mastitis, lameness, or milk fever appear. By profiling and quantifying metabolites, researchers can gain insights into the biochemical pathways and mechanisms underlying different diseases.



Animal production: Metabolomics analysis tracks changes in energy and lipid pathways during critical transition periods (such as calving and early lactation) to detect ketosis or acidosis early.

Animal nutrition: Metabolic profiling can assess how different diets or forage quality impact digestion, nutrient absorption, and rumen microbial function. Blood and rumen metabolomics help pinpoint biomarkers related to energy and nitrogen utilization in ruminants.

Animal reproduction: Metabolic study analyzes blood or follicular fluid to evaluate fertility, oocyte quality, and pregnancy maintenance. It also identifies fertility markers in bull sperm thereby enhances sire selection, semen preservation, and fertility prediction.

Animal genetics and breeding: Mapping of metabolic traits linked to disease resistance, growth rates, feed efficiency and other economic traits can support precision breeding programs. In addition, marker metabolite screening for economic traits in livestock and its application in marker-assisted selection can improve selection accuracy.

Animal physiology: Comprehensive metabolic pathway analysis reveals how animals react to transport, heat, or environmental changes. Metabolomics can uncover subtle biochemical shifts that conventional measurements may overlook.

Animal Products: Metabolomic characterization links unique metabolic profiles to high-value production traits. Animal product (meat)-based metabolomic studies have confirmed that metabolomics profiles could screen out differential markers that distinguish meat from live and dead pork. Similarly high-throughput milk metabolomics have been used to study the quality and authenticity milk of dairy animals. In addition, the metabolome can also provide rapid and accurate detection of chemical contaminants, unwanted toxin residues that are present in animal products at very low levels or identification of milk/meat adulteration.

Metabolomics analysis strategies

Untargeted metabolomics

Untargeted metabolomics is the comprehensive analysis of all metabolites in a sample. It screens the overall profile of small molecules in samples and subsequent differential analysis by bioinformatic methods. In livestock science, it provides a comprehensive snapshot of an animal's physiological state, offering insights that traditional targeted testing misses. Recently untargeted liquid chromatography-mass spectrometry (LC-MS) of camel milk revealed abundance of important metabolites associated with brain development, cognitive functions, liver function and muscle activity that are required for general wellbeing.

Targeted metabolomics



Targeted metabolomics is the quantitative evaluation of specific candidate metabolites. It measures specific, predefined small molecules in biofluids and tissues. Typically, untargeted metabolomics is used to discover differential metabolites, which are then further systematically validated using targeted metabolomics.

Widely targeted metabolomics: It represents an advancement technique in the field of metabolomics, integrating the merits of both targeted and untargeted methods. This method facilitates both qualitative and quantitative identification of over a thousand metabolites.

Metabolomic Techniques

LC-MS and gas chromatography-mass spectrometry (GC-MS): For high-sensitivity metabolite detection, LC-MS and GC-MS are preferred especially for detection in nanomolar to picomolar range.

Nuclear Magnetic Resonance (NMR): It is the best method for quantitative and structural metabolomics studies requiring high reproducibility. i.e. for detection in micromolar range

Conclusion

Metabolomics is allowing researchers to focus on measuring the end-products of complex, hard-to-decipher genetic, epigenetic and environmental interactions. It can inform dairy management practices, allowing for earlier detection and targeted interventions to prevent and manage several conditions in dairy cows.

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