

Advancements in analysis of milk and milk products

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Introduction: Milk is a complex mixture of fats, proteins, sugars, and other major and minor components. The processing of milk into various milk products such as khoa, burfi, paneer, cheese, yogurt etc. brings about various physico-chemical changes in milk. The analysis of milk and milk products refers to the scientific process of assessing the composition, quality, safety, and nutritional content of milk and milk products. It involves the use of various analytical techniques and methods to quantify and characterize different components present in milk and its derivatives. Chemical analysis of milk is crucial for ensuring quality, detecting adulteration, and developing new dairy products.

1. Key aspects of milk and milk products analysis include:

1.1 Compositional Analysis: Determining the levels of major and minor constituents such as water, fat, protein, lactose, vitamins, and minerals etc. in milk and milk products.

1.2 Quality Assessment: Evaluating physical and chemical parameters like freshness, shelf-life, sensory attributes (e.g., taste, aroma), and presence of contaminants (e.g., pesticides, antibiotics, heavy metals)

to ensure value for money to the consumers.

1.3 Safety Testing: Detecting and quantifying potential contaminants or adulterants, including pathogens, allergens, chemical residues, and microbiological organisms to ensure safety of milk and milk products.

1.4 Nutritional Profiling: Measuring essential nutrients and bioactive compounds (e.g., fatty acids, amino acids, vitamins, antioxidants, nutraceuticals) to assess the nutritional value and health benefits of milk products.

1.5 Authentication and Traceability: Verifying the authenticity of milk products and tracing their origin through methods like DNA analysis, isotopic analysis, and fingerprinting techniques.

1.6 Process Control: Monitoring production processes to ensure compliance with regulatory standards and quality specifications.

Overall, the analysis of milk and milk products is critical for maintaining food safety, ensuring product quality, meeting regulatory requirements, and providing

consumers with accurate nutritional information.

2. Major advances in the analysis of milk and milk products:

The traditional methods used for analysis of milk and milk products viz., gravimetric methods, titration-based methods, volumetric methods were time-consuming, labour-intensive, and prone to errors due to manual handling and subjective judgment in measurements. However, advances in analytical technologies have greatly enhanced the precision, speed, and sensitivity of these analyses, making them indispensable tools for both research and industry applications in the dairy sector. Major advanced technologies employed these days in the analysis of milk and milk products include:

2.1 High-Performance Liquid

Chromatography (HPLC):

HPLC has revolutionized the analysis of various compounds in milk, such as vitamins, fatty acids, proteins, sugars and various contaminants. It allows for highly sensitive and accurate detection and quantification of these components, essential for nutritional labelling and quality assessment.

2.2 Gas Chromatography-Mass Spectrometry (GC-MS):

GC-MS is widely used for the analysis of volatile compounds in milk, including flavor components, aroma compounds, and contaminants such as pesticides and antibiotics. Its high specificity and sensitivity make it invaluable for food safety and quality control.

2.3 Near-Infrared Spectroscopy (NIRS):

NIRS enables rapid analysis of milk composition without the need for extensive sample preparation. It can provide information on fat content, protein content, lactose, and other constituents, offering a quick and non-destructive method for routine analysis. Milkoscreens and milkoscans make use of this technology to provide rapid real time results.

2.4 Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS):

These techniques are used for the analysis of trace elements and heavy metals in milk

and dairy products. They are crucial for ensuring compliance with safety regulations and assessing the nutritional quality of milk.

2.5 Enzyme-Linked Immunosorbent Assay (ELISA):

ELISA is employed for the detection of specific proteins and allergens in milk, such as casein and whey proteins, as well as for the detection of residues from cleaning agents or antibiotics.

2.6 Nuclear Magnetic Resonance (NMR) Spectroscopy:

NMR spectroscopy is used for the structural analysis of milk components like proteins and lipids. It provides detailed information on molecular composition and can be used to detect adulteration or changes in milk structure due to processing.

2.7 Real-Time PCR (Polymerase Chain Reaction):

PCR techniques are employed for the detection of genetic material from pathogens in milk, ensuring safety and hygiene standards are met.

2.8 Mass Spectrometry (MS):

MS techniques, including MALDI-TOF (Matrix-Assisted Laser Desorption/Ionization Time-of-Flight) MS, are used for the characterization of proteins and peptides in milk, aiding in the study of milk proteomics and identification of biomarkers.

2.9 Advancements in Data Analysis and Multivariate Statistics:

The integration of advanced data analysis techniques such as chemometrics and multivariate statistics has enhanced the interpretation of complex data obtained from various analytical techniques, leading to more reliable and meaningful results in milk analysis.

These advancements collectively contribute to improved food safety, quality assurance, and nutritional assessment of milk and milk products, supporting both consumer health and industry standards.

3. Advantages of advanced analytical methods over traditional methods:

- **Accuracy and Precision:** Advanced methods generally offer higher accuracy and precision compared to traditional

methods, reducing variability and measurement errors.

- **Speed and Efficiency:** Traditional methods were slower and more labour-intensive, whereas advanced methods are faster, automated, and require minimal manual intervention.
- **Sensitivity and Detection Limits:** Advanced methods can detect lower concentrations of analytes, making them suitable for trace analysis and ensuring compliance with stringent regulatory limits.
- **Complexity and Cost:** While advanced methods may require higher initial investment in equipment and expertise, they often provide cost savings in terms of labour, reagents, and time over the long term.
- **Automation:** Automation of analytical processes reduces human error and streamlines workflows, leading to more consistent and reliable results.

In summary, the shift from old to advanced methods in milk analysis has significantly improved the quality, safety, and efficiency of dairy product testing. These advancements have not only enhanced the analytical capabilities but also contributed to better consumer protection and regulatory compliance in the dairy industry.

Some applications of these advancements in dairy research and industry are:

- **Quality Control:** Rapid and precise analysis of fat, protein, lactose content ensures milk meets quality standards for consumption or further processing.
- **Adulteration Detection:** Sophisticated techniques can identify even small amounts of foreign substances added to milk, protecting consumers and ensuring fair trade practices.
- **Milk Component Analysis:** Detailed analysis of protein and fat profiles allows for the creation of dairy products with specific functionalities or targeted towards niche markets.
- **Flavor Profiling:** Advanced methods can pinpoint the volatile compounds responsible for desirable or undesirable flavors in milk and milk products, aiding in product development and consistency.

These are just a few examples, and new applications are constantly emerging. Advanced instrumentation is revolutionizing milk analysis, leading to a safer, higher quality, and more innovative dairy industry.

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