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A REVIEW ON ESTIMATION OF PRESERVATIVES IN FOOD BYUSING SPECTROSCOPIC TECHNIQUES

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Abstract:

Preservatives are essential substances added to food and pharmaceutical products to prolong shelf life by preventing spoilage and degradation caused by microorganisms. The onslaught of pathogens (disease-causing microbes) like bacteria and mold is responsible for the food deterioration. Particularly for products with high water content, these substances help to inhibit the growth of bacteria. Preservatives and food additives have been used in food to maintain product consistency, quality, and safety, and prevent spoilage of food, maintain quality, extend the shelf life the food, and helps to make food more appealing to consumersby maintaining its color, flavor, texture, and smell. Preservatives are typically added to food in low levels, ranging from parts per million(ppm) to 1-3% by weight. An increase in the range of preservatives in food can cause various health issues including allergies and intolerance, digestive issues like gas and bloating, cancer, increase the risk of heart disease, and increase the risk of breathing problems and asthma. This review highlights the various analytical methods useful for detection of different preservatives in foodstuffs and bevarages.

***Keywords**: Disease- causing microbes, Shelf life, Food safety, Preservatives, Analytical techniques, Food deterioration.*

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INTRODUCTION:

Food is an essential thing for human survival [1]. The purpose of these compounds (food additives) is to add dietary nutrition increase the shelf life and/or to improve the physicochemical, sensorial and microbiological properties of the foods. Food additives are essential constituents of food products in the modern world [2]. Food additives are utilized in food stuffs to enhance or obtain a specific flavor, extend the storage time, or obtain a desired texture [3]. Food safety has become an important issue in the food system to guarantee processed food is safe and in good condition from factories or industrial kitchens, to transit to warehouses and stores, and finally to consumers [4]. Any substance used in the preparation, treatment, packaging, handling, or storage of food is covered by this term. But the legal definition's main objective is to impose the need for premarket approval. Therefore, ingredients whose use is generally accepted as safe, ingredients whose use was authorized by the FDA or U.S. Department of Agriculture1 prior to the enactment of the food additives provisions of law, colour additives. The Scientific Committee on Food (SCF) is responsible for the safety evaluation of food additives in the European Union. Food can be contaminated unintentionally or intentionally [5] .in the food supply chain by three classes of contaminants such as microbes (bacteria, viruses, and fungi), chemicals (toxins, pesticides, adulterants), and physical contaminants (metals, glass, plastic). Preservatives are substances used to prevent food spoilage from microorganisms. This will inhibit the growth of microorganisms [6]. The term food preservation refers to any one of a number of techniques used to prevent food from spoiling. Food preservatives are used to keep bacteria, moulds, fungus, and yeast from spoiling food [7]. Food preservatives play an important role during food transportation. This will preserve the food for a long duration from spoilage. Other ingredients are also utilized in preparing the desired dosage form of the drug substance. Some of these agents may be used to achieve the desired physical and chemical characteristics of the product or to improve its appearance, odour, and taste. In each instance, the added ingredient must be harmless in the amount used; does not exceed the minimum quantity required to provide its intended effect; its presence does not impair the bioavailability, the therapeutic efficacy, or safety of the official preparation, and does not interfere with analysis and tests prescribed for determining compliance with the pharmacopeia's standards. Each and every food item has some preservatives; without them, the food can no longer survive. Radioactive materials like cobalt-30 are used as food preservatives. Food preservatives aim to preserve the appearanceof food, preserve the food characteristics like odour, taste, and food is preserved for a long time. There has been an increase in recent decades in the consumption of foods with high preservative content [8]. Most of the food safety analytical and detection methods are expensive, labor intensive, and time consuming. A safe, rapid, reliable, and non-destructive detection method is needed to assure consumers that food products are safe to consume. To ensure that food is safe for consumption, it is important to develop an effective analytical method to monitor the preservative levels [9]. By using various analytical techniques like UV- Visible, Calorimetry, HPLC, Mass spectroscopy, Gas chromatography, Nuclear magnetic spectroscopy and Electrophoresis, the proposed methods were employed to identify various preservatives in a variety of food stuffs. The estimation of preservatives in food products using spectroscopic techniques is a crucial aspect of ensuring food safety and quality. Several spectroscopic techniques have been proposed as promising alternatives to the traditional time-consuming and destructive methods [7]. Spectroscopy offers a range of non-destructive, rapid, and highly sensitive methods for detecting and quantifying preservatives in food samples. These techniques are essential for monitoring the levels of preservatives, which help extend shelf life and prevent spoilage by inhibiting microbial growth and oxidation

II. **Types of preservatives**

Food preservatives may be classified as Natural, Artificial, antimicrobial preservatives, Chemical preservatives and antioxidants

Natural preservatives

Natural food preservatives like sugar, salt, vinegar, and rosemary extracts are generally considered beneficial and safe for health, as they help extend the shelf life of food without the harmful effects associated with some synthetic preservatives. Here’s a bit more about each:

Sugar: Acts as a preservative by binding water, which inhibits the growth ofmicroorganisms.

Salt: Draws out moisture from foods, creating an environment where bacteria and fungi struggle to survive

Vinegar: Contains acetic acid, which is effective in preventing the growth of bacteria andmolds.

Rosemary Extracts: These are natural antioxidants that prevent oxidation in foods,especially in oils and meats.

Some common preservative techniques used in kitchens includes

Refrigerating: Slows down microbial growth by keeping foods at low temperatures.

Boiling: Kills bacteria and enzymes that can lead to spoilage.
Pickling: Uses acid (often vinegar) or salt to preserve foods.
Dehydrating: Removes water from food, preventing the growth of microorganisms.

Artificial preservatives

Artificial preservatives are the chemical substance that stops the growth and activities of the microorganisms and help to preserve the foods for a longer time without affecting its natural characterstics. It includes antimicrobial agents and Antioxidants. Antimicrobial agents are benzoates, nitrites, calcium propionate, Sorbates, EDTA. Certain antioxidants are BHT, BHA, Formaldehyde and ethanol [1]

Antimicrobial Preservatives

Antimicrobial compounds play a crucial role in maintaining the safety, quality, and shelf life of various products. They are either naturally present in foods or added as preservatives to prevent spoilage and contamination by harmful microorganisms like bacteria, yeasts, and molds. This preservation extends across applications, including foods, cosmetics, sterilepharmaceutical products (such as eye drops and multidose injections), and non-sterile pharmaceuticals (such as oral liquid and creams [10]. pharmaceuticals, preservatives are especially vital when the product cannot be sterilized in its final container and requires aseptic handling. However, certain injections, especially those into the cerebrospinal fluid, eyes, or heart, should not contain preservatives due to safety concerns.

Antimicrobial preservatives are classified into two main categories:

Anti-fungal preservatives

These inhibit the growth of molds and yeasts and include compounds like benzoic acid, ascorbic acid, and parabens such as methyl, ethyl propyl, and butyl p-hydroxybenzoate).

Antibacterial preservatives

These target bacterial growth and include compounds such as quaternary ammonium salts, alcohols, phenols, mercurials, and biguanidines. While antimicrobial preservatives are not added indiscriminately, they are essential in certain applications to ensure that products remain safe and effective throughout their use [3]

Antioxidants

Antioxidants in pharmaceutical products help prevent oxidation, which can cause deterioration. They are classified into three main groups:

True Antioxidants (Antioxidant agents)

These antioxidants prevent oxidation by interacting with free radicals, thereby halting chain reactions. Common examples include alkyl gallates, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), nordihydroguaiaretic acid (NDGA), and tocopherols (vitamin E).

Reducing Agents

These compounds have a lower redox potential than the substances they protect, making them more prone to oxidation. Some reducing agents can also react with free radicals.Notable examples include ascorbic acid (vitamin C), and potassium and sodium salts of sulphurous acid. These agents generally have minimal direct antioxidant effects but can enhance the activity of other antioxidants when combined with them [11]

Chemical preservatives

Chemical preservatives are essential for extending the shelf life of food products by preventing spoilage from microorganisms, enzymatic activity, and chemical reactions. Here's a breakdown of some common preservative categories with examples:

Benzoates

Example: Sodium benzoate.
Function: Inhibits the growth of yeast, mold, and some bacteria. Commonly used in acidic foods like salad dressings and carbonated beverages.

Sulphites

Examples: Sulphur dioxide, sodium sulfite.
Function: Prevents browning and spoilage in dried fruits, wines, and processed foods. Theyare effective antioxidants but can cause allergic reactions in sensitive individuals.

Nitrites

Example: Sodium nitrite.
Function: Used in processed meats to inhibit bacterial growth (especially Clostridiumbotulinum) and to maintain the pink color.

Propionates

Example: Calcium propionate.
Function: Prevents mold growth, particularly in baked goods like bread, extending theirfreshness.

Sorbates

Example: Potassium sorbate.
Function: Effective against yeasts and molds, commonly used in dairy products, baked goods, and beverages.

Antioxidants

Examples: Butylated Hydroxyanisole (BHA) and Butylated Hydroxytoluene (BHT).
Function: Synthetic antioxidants that prevent fats and oils from oxidizing and becomingrancid.

Acids

Examples: Citric acid, ascorbic acid (Vitamin C).
Function: Natural preservatives that also act as antioxidants, commonly used to prevent color and flavor changes in fruits and vegetables.

These preservatives play a critical role in food safety, extending shelf life, and reducing food waste by maintaining product quality over time [11].

Spectroscopic TechniquesMass Spectroscopy

Mass spectrometry (MS) is an analytical technique that identifies and quantifies chemicals in a sample by measuring the mass-to-charge ratio of ions [2]. Mass spectrometry is a promising technique for the study of food and nutrition domains as a result of its profiling,food authentication. In this process, the sample is ionized, typically via electron bombardment, producing positive ions that are then separated based on their masses. The resulting mass spectrum displays relative abundance against the mass-to-charge ratio, enabling the determination of elemental or isotopic signatures, the masses of particles and molecules, and insights into chemical structures [12]

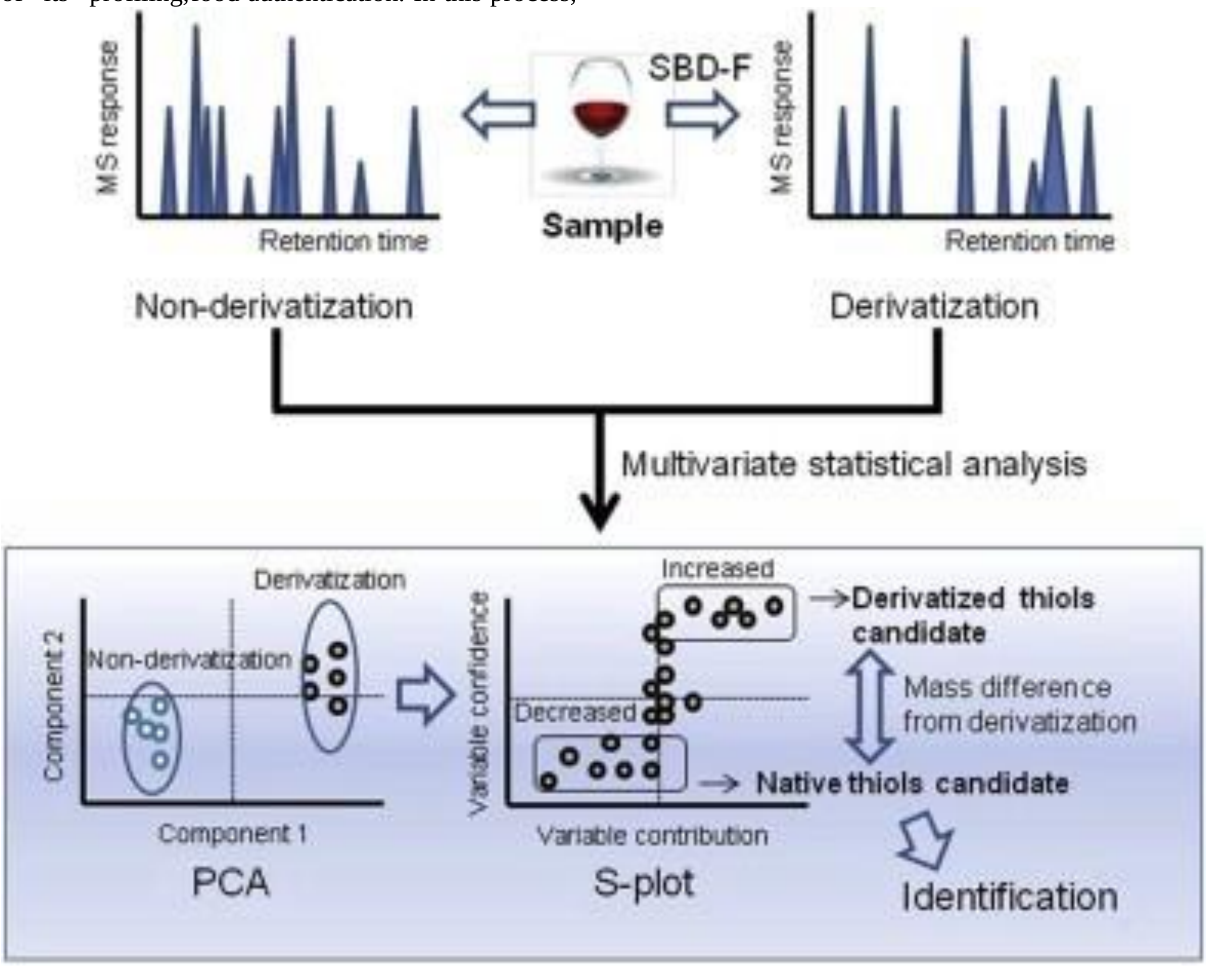

Figure 1: Mass Spectroscopy

Nuclear Magnetic spectroscopy

Nuclear Magnetic Resonance (NMR) spectroscopy is a powerful analytical technique that provides insights into the chemical and structural characteristics of molecules. By subjecting atomic nuclei, often hydrogen or carbon, to a strong magnetic field, NMR exploits the magnetic properties of certain isotopes [12]. These nuclei resonate at characteristic frequencies when exposed to radiofrequency energy, which shifts in response to the surrounding chemicalenvironment.

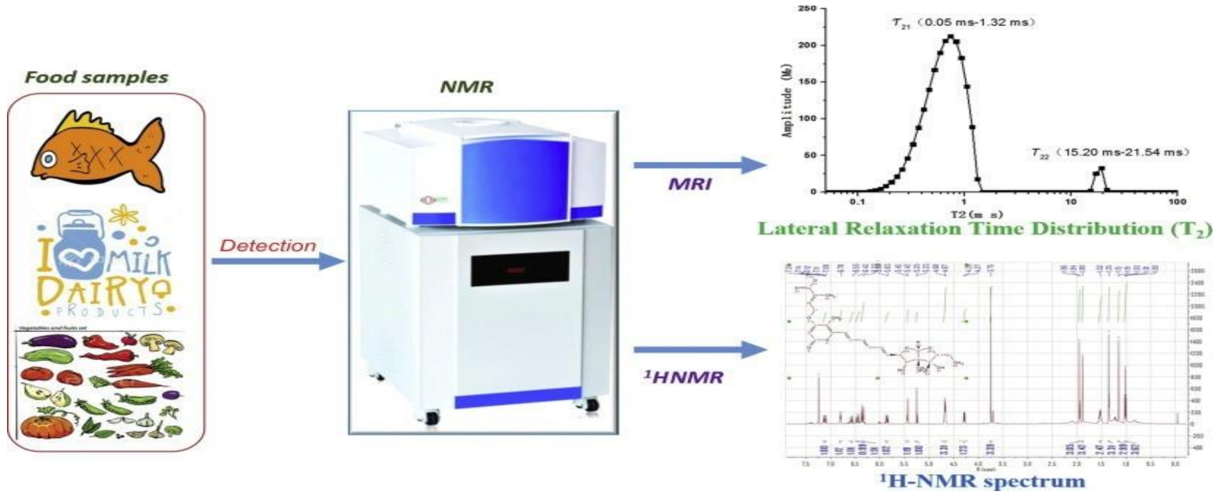

Figure 2: Nuclear Magnetic Spectroscopy

Low -field NMR (10–50 MHz) is well-suited for assessing water and lipid content, muscle structure, and emulsions in food matrices, mainly because it allows for non-invasive analysis of physical and structural changes. It's widely used in quality control, where quick, effective analysis is needed for large samples.

High-field NMR (>300 MHz), on the other hand, enables detailed molecular characterization due to its increased resolution and sensitivity, which is crucial in organic and pharmaceutical chemistry for identifying complex chemical structures. In food science, high-field NMR plays a key role in elucidating the detailed structures of biomolecules like proteins, carbohydrates, and lipids. This helps in understanding food composition and changes during processing and storage, as well as developing functional foods with targeted health benefits [13].

Atomic absorption spectroscopy

Atomic Absorption Spectroscopy (AAS) is one of the most valuable and well-established techniques in the vast application of food analysis [14]. It is employed to determine the elemental composition of an analyte by measuring the absorption of radiation by the specific chemical elements within a sample. Widely used for detecting essential elements like copper and zinc in various matrices (such as food products), AAS relies on absorption spectroscopy principles and is often referred to as metal analysis spectroscopy due to its focus on metal detection. Atomic absorption spectroscopy (AAS) is a technique for determining the elemental composition of an analyte present in samples by measuring the absorbed radiation by the chemical element of interest. The technique has been used widely for the analysis of essential elements such as copper and zinc in various matrices, including food products [15]. In AAS, the sample, typically in liquid form, is atomized, converting it into free atoms using a flame or graphite furnace. These free atoms absorb light at specific wavelengths unique to the elements of interest. When the atoms absorb light, the intensity of the transmitted beam decreases, as a portion of the light is removed. By measuring the unabsorbed light, AAS quantifies the element's concentration in the sample based on the extent of absorption. This correlation between atom concentration and light absorption allows for precise measurementsmetal concentrations [15]

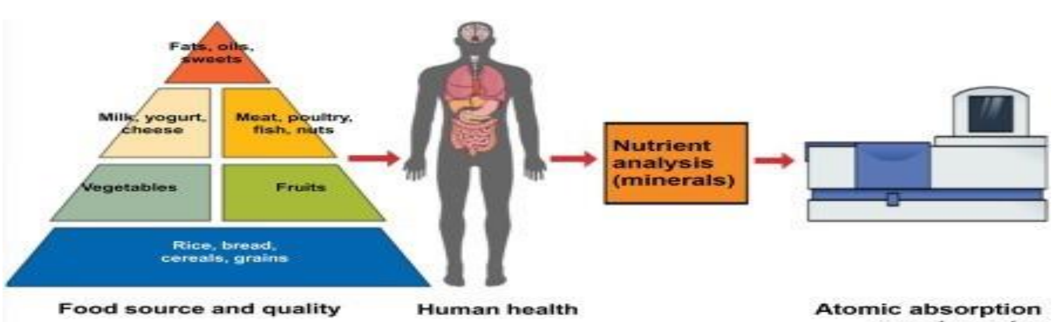

Figure 3: Atomic absorption spectroscopy

Gas Chromatography

In gas chromatography (GC) is used widely in applications involving food analysis. The mobile phase is a gas, allowing the separation of components as vapors, which differentiates it from other types of chromatography [16]. Food products can be verified based on their chemical composition, possible adulterations by using gas chromatography [17]. GC is primarily used for analyzing small, low molecular weight compounds in the gas phase. In the injection port, the sample is vaporized either as a gas or a liquid. Helium is commonly used as the mobile phase because of its low molecular weight and chemical inertness, which help carry the analyte through the column under applied pressure. Separation occurs in a column coated with a stationary phase, where the principle is based on partitioning equilibrium. Components in the sample distribute between the mobile and stationary phases. Compounds with a greater affinity for the stationary phase remain longer in the column, eluting later and exhibiting longer retention times than compounds with a higher affinity for the mobile phase. This affinity is influenced by intermolecular interactions, and selecting a stationary phase with the appropriate polarity can enhance these interactions to optimize separation [5].

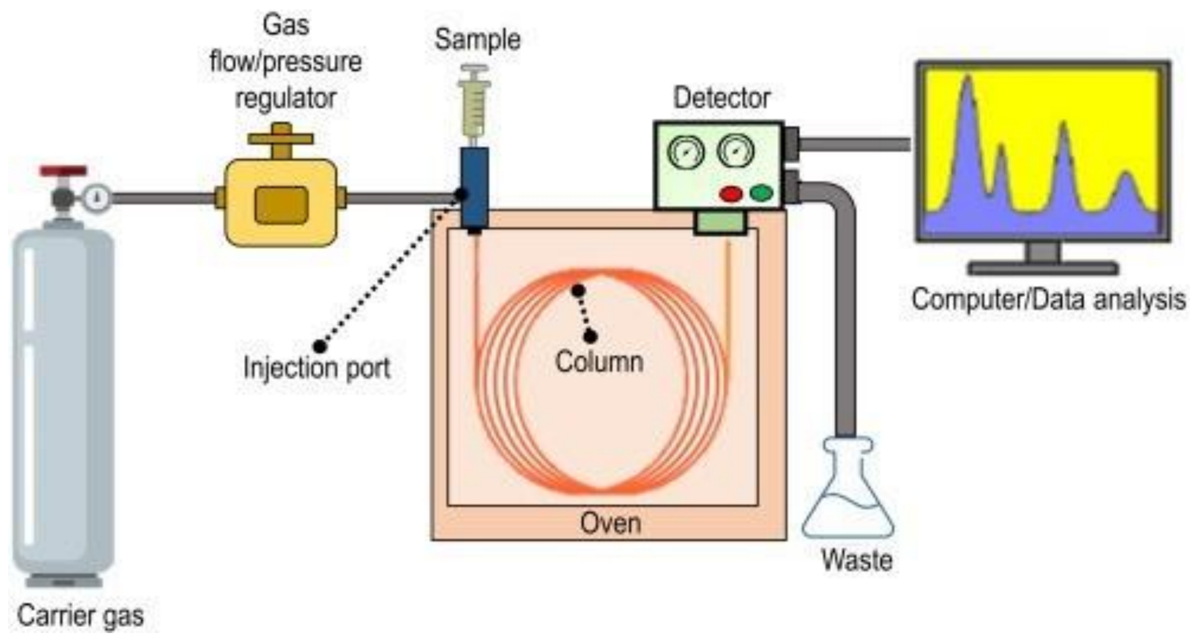

Figure 4: Gas Chromatography

High Performance Liquid Chromatography (HPLC)

High Performance Liquid Chromatography (HPLC) is indeed a cornerstone technique in analytical chemistry, highly valued for its speed, precision, and versatility in separating compounds. High - performance liquid chromatography is a powerful tool for product composition testing and assuring product quality [18]. Its development in the late 1960s and early 1970s transformed traditional chromatography by introducing high-pressure systems that allowed solvents to move through the column much faster and with higher resolutions. This capability is particularly beneficial in applications across fields such as pharmaceuticals, biotechnology, environmental science, and food analysis, where accurate separation and identification of compounds are crucial [12]. It is a rapid and reliable method is presented for the determination of the preservative's sodium benzoate and potassium sorbate in fruit juices,sodas, soy sauce, ketchup, peanut butter, cream cheese, and other food stuffs [19]. Recent advancements, including miniaturized HPLC systems, have extended its utility to areas requiring high sensitivity, such as nucleic acids, proteins, carbohydrates, and chiral compounds. These innovations have increased HPLC's analytical efficiency and broadenedits applicability. The ability to operate at pressures up to 400 atmospheres enables rapid analysis and maintains HPLC's relevance as a powerful method in both research and industry settings [20].

Figure 5: High performance liquid chromatography

Methods	**Sample Matrix**	**Preservative**	**Detection**
Mass spectroscopy	Food products including "pesto'' sauce, tomato sauce containing basil, "cola tasting'' Bevarages, Bolognasausage and fresh basil	Benzoic acid, Nitrates and nitrites	The calibration curves showed a good linearity for all the three compounds in the concentration range 0.5–25 ppm, with correlation coefficients ranging between 0.996 and 1.000. In a number of successive analyses, the estragole peak area repeatability (RSD) was 0.20 ng/ml.
Ion pair HPLC	Beverages, gelatin, syrups	Aminopolycarboxylic acids	520nm
Spectrophotometry	Commercially available dyes	Propylparaben	MULTv3.0 Quimio program
Solid phase spectroscopy	Soft drinks, ice creams	Benzyl alcohol	487nm
HPLC	Cheese samples	Sorbic acid,Natamycin	Sorbic acid levels in the cheese samples were found to be lower than the maximum acceptable limits (matured cheese: 1000 mg kg-1) of the Turkish food codex
UV Spectroscopy	Tomato products such as tomato juice	Sodium benzoate	472nm

DISCUSSION:

The application of 'natural' approaches to extend the shelf-life of food seems to be an interesting option and is gaining interest. The possibility of applying rapid analytical methods like gas chromatography, Mass spectroscopy, Nuclear magnetic spectroscopy, High performance liquid chromatography, Gas chromatography, UV spectroscopy. etc. for monitoring quality and detecting changes in food products taking place during processing or preservation has been successfully shown. However, the path for the implementation of new technologies in industrial production systems is not straightforward. Further development and advancements of both preservation strategies and analytical methods are expected in the future, thus encouraging wider industrial applications of natural preservatives and spectroscopic techniques.

CONCLUSION:

In conclusion, this review has highlighted the various impacts of food additives and preservatives on human health. Additives have long played a crucial role in preserving, flavoring, blending, thickening, and coloring foods, helping reduce nutritional deficiencies and ensuring the availability of safe, appealing, and affordable foods year-round. They are essential in preventing food spoilage caused by microorganisms, making them vital to the food industry. However, adverse effects associated with synthetic additives raise healthconcerns, as they may interact with cellular components and contribute to food-related health issues. To benefit from additives while minimizing risks, natural additives those recognized as safe are preferable, and any additives that are not generally recognized as safe should not exceed their acceptable daily intakes (ADIs). Spectroscopy techniques emerge as a pivotal and precise analytical tool, particularly within the realm of food safety and quality assessment. To reduce the health risks associated with food additives and preservatives, one should opt for fresh, organic foods free from artificial additives andcarefully read ingredient labels on packaged foods. Embracing a diet rich in unprocessed, whole foods—such as fresh fruits, vegetables, grains, beans, nuts, and seeds can promote healthier eating habits and reduce reliance on processed foods with synthetic additives.

By making these mindful choices, individuals can improve their health and enjoy a diverse diet rooted in natural, wholesome foods. In a government laboratory responsible for verifyingthe compositional or nutritional claims on food products and additives, accuracy is a critical criterion. Precise measurements ensure that claims meet regulatory standards and protect public health. In contrast, speed and the ability to perform non-destructive measurements are often more critical in a factory setting, where high sample volumes require rapid, efficient analysis for routine quality control. This review provides a comprehensive overview of the various types of food additives, including methods for their analysis and quantification. It highlights the need for tailored testing approaches depending on the specific requirements of regulatory verification versus industrial quality control, ensuring that food products meet safety and quality standards.

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Abbreviations

MS-Mass spectroscopy
NMR-Nuclear Magnetic Spectroscopy AAS- Atomic Absorption SpectroscopyGC- Gas Chromatography
HPLC- High performance liquid chromatography UV Spectroscopy- Ultra-Violet Spectroscopy SPS- Solid phase spectroscopy