UV-VIS Spectroscopy And Its Applications on Food Analysis

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Abstract- *Spectroscopy examines the interaction of electromagnetic waves and natural molecules.UV spectroscopy is a technique for determining the quality of water and has the potential to be used in food preparation.Because the variety of multi-component formulations, bio-therapeutic medications, and complex matrix materials in question is expanding, rapid and easy analysis processes are necessary. For this objective, several UV spectroscopic methods are used.This review aims to demonstrate various applications of UV Spectroscopy which has taken part in food analysis and bioprocess monitoring.This review provides information and application about the technological advances in this area and its industrial applications in food analysis and also in bioprocess monitoring.*

Keywords- UV spectroscopy, Spectrophotometer, Irradiation, Food processing, Evaluation.

I. INTRODUCTION

Many different remote sensing applications have been developed over the last ten years. Spectroscopy examines the interaction of electromagnetic waves and natural molecules. Spectrophotometry is rightfully considered one of the traditional approaches to drug analysis, although its importance has not diminished significantly over time. Because of new and improved UV and VIS light sources, detectors, interference filters, and optical materials, it is now possible to use UV/VIS analyzer methods that use a photodiode detector and holographic gratings for multi-component analysis, which was previously impractical. In general, the quantification of a diverse range of species, both inorganic and organic, finds remarkable utility in UV/VIS light absorption measurements.

Analysts must quickly analyze samples of complex matrices, bio-therapeutic medicines, and multi-component formulations in their daily work. The number of UV spectrophotometric techniques used to achieve these objectives. However, among all of these techniques, UV spectrophotometry is a favorite.

UV irradiation has been known for decades to be effective at inactivating bacteria. Other important considerations, such as the preservation of organoleptic or nutritional qualities, must be taken into account in food processing.UV light (UV) light has a lot of potential in food preparation as an alternative to standard thermal processing.
UV light (UV) light is widely used for water treatment, air disinfection, and surface cleaning. With public outrage over the use of chemicals in food on the rise, UV light has enormous potential in food processing.[1,2,4,6]

SPECTROSCOPY:

The word "spectrum" is derived from the Latin word "spectrum," which denotes a vision or an object to behold. In our context, a spectrum is a representation of the complete range of electromagnetic wavelengths, not only the visible portion.Skopein, a Greek word, means to glance at. A spectrograph is a device used to display these spectra, and spectrometry is the measurement of the different components of a spectrum. Spectroscopy is the study of these spectra.[3]

UV SPECTROSCOPY

Ultraviolet (UV) spectroscopy is a type of physical method. Optical spectroscopy employs light in the visible, ultraviolet, and near-infrared regions and is based on the Beer-Lambert equation, which asserts that the absorbance of a solution is exactly proportional to its concentration. Depending on the concentration of the absorbing species in the solution and the length of the route, as a result, a given route length may be used to calculate the concentration of an absorber in a solution.It is crucial to understand how quickly the absorbance varies with concentration. UV-VIS spectroscopy has been widely used for the last 37 years and has evolved into the most significant analytical tool in the modern laboratory. Other methods might be used in many applications, but none are as effective as UV-VIS spectroscopy.[7,6]

PRINCIPLE OF UV-VISIBLE SPECTROSCOPY

Absorption spectroscopy is the concept at work in UV-Visible spectroscopy. The fundamental property of absorption known as Beer-law Lambert underpins UV-Visible spectroscopy. This rule controls radiation absorption by an absorbent material (dilute solution).

The Beer-Lambert Law is the underlying concept of absorbance spectroscopy. A is absorbance (unit less, generally expressed as arb. units or arbitrary units) for a single wavelength, is the molar absorptivity of the substance or molecule in solution (M-1cm-1), b is the path length of the cuvette or sample container (normally 1 cm), and c is the concentration of the solution (M).

Where

A = absorbance,
a = absorptivity,
b = route length, and
c =concentration.
C = A /a b

To obtain UV-Visible spectra, three types of absorbance devices are used:

1. Spectrometer with a single beam.
2. A spectrometer with two beams.
3. Simultaneous spectrometer

All of these instruments feature a light source (often a deuterium or tungsten lamp), a sample holder, and a detector, but some also have a filter that allows them to choose only one wavelength at a time.

To study one wavelength at a time, the single-beam instrument contains a filter or a monochromator between the source and the sample. The double beam instrument has a single source and a monochromator, followed by a splitter and a series of mirrors to direct the beam to a reference sample and the sample to be analyzed, allowing for a more accurate monochromator between the sample and the source; instead, it has a diode array detector that allows the instrument to detect absorbance at all wavelengths simultaneously.The concurrent instrument is typically quicker and more efficient, although all of these spectrometers perform well.[8, 9, 11]

PORTABLE INSTRUMENTATION FOR FIELD APPLICATIONS: [12,13]

Companies create online, at-line, and in-line tools. Some spectrophotometers are modular, making them ideal for a wide range of applications.UV/VIS/ NIR. The measuring systems are exceedingly stable and reliable. The utilization of fiber optics provides tremendous versatility. These systems are quick. They are efficient, and precise, and provide many variants, making them helpful for a wide range of applications. Their uses are numerous (moisture, Protein, color, and so forth) with the option of field measurements.The more critical applications are

1. FOODS:

- Fat, starch, and protein determination
- Moisture detection in goods
- Monitoring of drying processes
- Incoming powder-based product examination, such as flour or milk powder

2. MEASURING RUNNING CONVEYOR BELT:

- Moisture and color determination in paper manufacturing
- Online textile and plastic line color
- Color and heat protection degree of architectural glass determination
- Foil layer thickness determination

3. OPTICAL INDUSTRY:

- Coated glass reflection and transmission characteristics
- Optical coating color characteristics

4. PLASTIC TECHNOLOGY:

- Plastics Identification
- Plastic line or component color
- Transparent coating layer thickness specification

5. PHARMACEUTICAL INDUSTRY:

- Raw material identification
- mixing powders

RECENT APPLICATIONS AND PROGRESS OF UV-VIS SPECTROSCOPY IN FOODS:

The variety of foodstuffs tested by the approach published in the literature demonstrates the use of UV-Vis spectroscopy (frequently in conjunction with other spectroscopic or chromatic methods) linked with chemo-metrics for food analysis. The following are some examples of UV-Vis spectroscopy used in various food products and commodities.[11,15]

A. UV AND ITS APPLICATIONS IN SOLID FOODS PROCESSING:

UV radiations are primarily used on fresh fruits and vegetables to achieve two major goals. The first and most important goal is to reduce the number of microbes on the product surface, and the second goal is to induce host resistance to the microbes.

UV light is beneficial in the processing of various types of food products, and this is known as hormesis. The agent used for this is UV light, which is known as hermetic, and the entire process is known as the Hormetic effect.This effect causes the formation and production of Phenylalanine ammonia-lyase, which in turn causes the formation of phytoalexins, which are phenolic compounds. It is the formation of phytoalexins that makes fresh pulpy fruits and vegetables resistant to a variety of microbes.

Fruits and vegetables have been shown to help reduce cardiovascular disease, diabetes, obesity, and some malignancies. Fruits and vegetables, whether eaten raw or cooked, must be safe and should not contain microorganisms. A variety of infections have been linked to a variety of fruits, vegetables, and other solid food items from diverse Genera. Salmonella, Listeria, Staphylococcus, Clostridium, and Bacillus are examples of pathogens. All of these are regarded to be hazardous bacteria, so food infected with them is not acceptable for ingestion, and all of these must be removed from the meal.As a result, there is a need for a solution that can properly and efficiently digest these solid food products, and UV plays a critical part in this.

Varying bacteria require different amounts of UV light exposure, which can range from a fraction of a second to many minutes. Since 1997, UV radiation irradiation of solid food items (mostly 180-280 nm with a maximum at = 254 nm) has been utilized as an alternative for chemical fungicides and bactericides to prevent certain postharvest illnesses.In this approach, UV demonstrates its use in improving shelf life and killing germs in solid foods such as fruits and vegetables.[18,19]

B. UV AND ITS APPLICATIONS IN LIQUID FOOD PROCESSING:

In the case of liquid meals and juices, the FDA has authorized UV irradiation as one of the most modern and successful procedures for processing such foods, and as a result, recent developments are being made to make the process more and more efficient without any adverse effects.

Initially, UV treatments were only relevant to solid meals and not liquid foods, but with numerous studies and developments in the process, UV irradiation has shown to be highly important for the preservation and processing of liquid food and beverage.Because of the presence of color components, organic solutes, and suspended particles, liquid foods such as fresh juice products and drinks transmit relatively little UV radiation, reducing the efficacy of UV pasteurization processes.This UV treatment can preserve liquid food products such as fruit juices such as orange juice, apple juice, and pineapple juice.

A lot of research has been done on various fruit juices to determine their shelf life. Experiments have also shown that this approach is successful for other liquids such as grape, cranberry, and pomegranate juices. This method has also demonstrated its ability to preserve liquid egg white and extend its shelf life. However, different levels of UV are used in different juices and beverages to kill different pathogens such as bacteria, yeast, fungus, protozoa, and algae.The essential dosage is known as the UV inactivation dose and is measured in MJ/cm2. The dose necessary for various bacteria is shown in the table below, and it is possible to deduce that algae require the largest dose when compared to other harmful microbes.[22,23]

UV inactivation doses are required for different pathogenic microbial groups.

Table 1.

Various Pathogenic microbes	Inactivation Dose required (in mJ/cm^{2})
Bacteria	1-10
Yeast	2-8
Fungus	20-200
Protozoa	100-150
Algae	300-400

(28,32,34)

C.UV AND ITS APPLICATIONS IN THE PACKAGING OF FOOD:

The primary goal of food processing might be considered to be satisfying the consumer with high-quality, safe, and healthy final goods. So it is not only the food that has to be kept, but the surrounding circumstances and environment should also be sterile and aseptic so that there is no danger of contamination and our food items may be preserved even throughout the packaging.

The finished food product should be surface decontaminated to avoid the formation of molds, which may be accomplished by removing fungal spores. UV light can be used to destroy these fungus spores.Different types of packaging, such as cartons, boxes, lids, bottles, and trays, must be disinfected to prevent contamination of food with pathogenic and hazardous bacteria.

At the industrial level, the food is stored on conveyor belts and is constructed in such a manner that the maximum amount of UV radiation goes through it. The treatment is known to lower the total number of washdowns required during the processing process, resulting in reduced water and energy usage and cost.

The most significant items in the dairy industry are yogurt, cheese dips, and creams, whereas the most important products in the bakery and baking sectors are bread, cakes, and biscuits. In these circumstances, UV tunnels are installed along the production line to effectively and efficiently process the food throughout the manufacturing process. Despite its numerous advantages, UV has several restrictions. However, one should bear in mind that UV is toxic to humans, particularly the eyes, and can be sight-threatening.All of the negative impacts, however, may be prevented by utilizing adequate and appropriate shields or non-reflective surfaces.(36,37)

2.APPLICATIONS AND EXAMPLES OF UV-VIS SPECTROSCOPY IN BIOPROCESS AND FERMENTATION MONITORING:

A. FERMENTATION IN RED WINE:

Phenolic chemicals contribute significantly to the color, taste, and "mouth feel" of wines. As a result, measuring phenolic compounds during fermentation is critical for improved understanding and management of the winemaking process. UV-Vis spectroscopy was utilized to monitor the phenolic content throughout winemaking, and models were created using partial least squares (PLS) regression to predict phenolic chemicals. Difficulties in monitoring bioprocesses are a disadvantage of solid-state fermentation (SSF), particularly when measuring enzyme activity in SSF. The activity of enzymes (protease and amylase) and protein concentrations in aqueous extracts were measured using a combination of PLS regression and artificial neural network (ANN) with UV-Vis spectroscopy.

The results show that this technique is suited for building a chemo-sensor for monitoring SSFs, minimizing the analytical labor required for enzyme activity measurement.The use of UV-Vis spectroscopy as an inline sensor to monitor changes in color and total phenol content during red wine fermentation was investigated. The authors' sensor was built with several light-emitting diodes (LEDs) (280-525 nm). These investigations, according to the authors, revealed that LED sensors may be used to assess the concentration of phenolic compounds in-line. The use of a 100 m route length flow cell eliminates the requirement for sample dilution, allowing for in-line measurements. During red wine fermentation, the sensor measures the evolution of total phenolic content and color extraction patterns in real time.(17,18)

B. FERMENTATION IN SUGAR UTILIZATION:

Monitoring sugar utilization during fermentation is critical for optimizing product development and maintaining a healthy ecosystem for microorganisms to grow and thrive. However, an industry-standard approach for the quick, low-cost, and sensitive detection of sugars in complex media (including nutrients, cell debris, waste, and the target products) has yet to be developed. Several writers have investigated the use of UV-Vis spectrophotometry for quantifying xylose during fermentation. Absorbance at 671 nm has a linear relationship with xylose content within a range of 0.1-0.5 g/L Fermentation 2018, 4, 18 5 of 8. The authors concluded that UV-Vis spectroscopy may be used to assess xylose levels during fermentation.(38,39)

ADVANTAGES AND LIMITATIONS OF THE USE OF UV-VIS SPECTROSCOPY:(38,40,41)

Table 2

Item	Advantages	Limitations
Samples and sampling	Allow the continuous sampling of the process	The sample and other interferences (e.g., damage cells, turbidity) are also analysed
Hardware	Commercially available instrumentation easily available	Type of instrument, fibre optic options, highly dependent on the type of sample (e.g., liquid, semisolid, turbid media).
Routine use	Easy to implement	Highly dependent on the type of sample, and process.
Data analysis	A lot of information and data can be collected to monitor the process	Not only information about the sample is collected, interferences, noise is also collected during the process.
Training	Easy to use in routine	Education and high understanding of the system, interpretation of the data and interferences.
Chemical compounds and properties	Several compounds can be measured	Limit of detection and quantification, depending on the process and sample.

II. CONCLUSION

For the last 37 years, UV-VIS spectroscopy has been widely utilized and has evolved into the most important analytical technique in the modern laboratory. As a result, UV-VIS Spectroscopy has been proven to be a useful approach for analyzing food processing, and bioprocess fermentation. Although the limits of separating matrix interferences remain, the integration of data mining and multivariate data analysis methodologies broadens UV-Vis spectroscopy's uses in bioprocess and fermentation monitoring in the food industry. With public outrage over chemical use in food on the rise, UV light has immense promise in food processing. UV-Vis spectroscopy technologies have also been investigated in recent years as valuable tools for monitoring many substances at the same time throughout various processes (e.g., in line, at a line). As a result, UV spectroscopy is used in all fields, has superior analytical properties, and works more efficiently than other techniques. UV spectrophotometry is the best option for an analyst in biopharmaceutical analysis.

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