WORLD
NAUČNO POSLOVNI CENTAR
SCIENTIFIC AND BUSINESS CENTER

MAK 2026

13TH JEEP INTERNATIONAL SCIENTIFIC AGRIBUSINESS CONFERENCE MAK 2026 - KOPAONIK

"GREEN TRANSFORMATION OF AGRIBUSINESS: INNOVATION AS THE KEY TO SUSTAINABLE AGRICULTURE"

PROCEEDINGS

Editors:
Danijela Šikuljak, Ph.D.
Milan Jovičić, Msc.

Kopaonik, Serbia
January 29th to February 1st, 2026.

Association science and business center, "WORLD", Kraljevo, Serbia
Institute for Plant Protection and Environment, Belgrade, Serbia

13th JEEP INTERNATIONAL SCIENTIFIC AGRIBUSINESS CONFERENCE, MAK 2026 – KOPAONIK
"GREEN TRANSFORMATION OF AGRIBUSINESS: INNOVATION AS THE KEY TO SUSTAINABLE AGRICULTURE"

PROCEEDINGS

Editors
Danijela Šikuljak, Ph.D.
Milan Jovičić, Msc.

Kopaonik, Serbia
January 29th to February 1st, 2026.

WORLD
NAUČNO POSLOVNI CENTAR
SCIENTIFIC AND BUSINESS CENTER

ИНСТИТУТ ЗА ЗАШТИТУ БИЉА И ЖИВОТНУ СРЕДИНУ
БЕОГРАД

Република Србија
МИНИСТАРСТВО НАУКЕ,
ТЕХНОЛОШКОГ РАЗВОЈА И
ИНОВАЦИЈА

13.
МАК
2026

ПРИВРЕДНА
КОМОРА
СРБИЈЕ
1857

Нама добро а никоме зло

Publishers

Association science and business center, "WORLD", Kraljevo, Serbia
Institute for Plant Protection and Environment, Belgrade, Serbia

In cooperation
City of Kraljevo

For publishers
Nenad Trkulja, Ph.D.
Marija Jovičić, Msc.

Editors
Danijela Šikuljak, Ph.D.
Milan Jovičić, Msc.

Technical editor
Dimitrije Milić

Printing
70 exemplars

Printed by
Kvark, Kraljevo, 2026.

REVIEWERS

Prof. Zorica Sredojević, **Ph.D.,** University of Belgrade, Faculty of Agriculture, Belgrade, Serbia,
Prof. Dragana Božić, **Ph.D.,** University of Belgrade, Faculty of Agriculture, Belgrade, Serbia,
Prof. Sava Vrbničanin, **Ph.D.,** University of Belgrade, Faculty of Agriculture, Belgrade, Serbia,
Prof. Snežana Janković, **Ph.D.,** Institute for Science Application in Agriculture, Belgrade, Serbia,
Sanja Đurović, **Ph.D.,** Institute for Plant Protection and Environment, Belgrade, Serbia,
Ljiljana Radivojević, **Ph.D.,** Institute of pesticides and Environmental Protection, Belgrade, Serbia,
Slađana Savić, **Ph.D.,** Institute for Plant Protection and Environment, Belgrade, Serbia,
Boris Pisinov, **Ph.D.,** Institute for Plant Protection and Environment, Belgrade, Serbia,
Jelena Gajić Umiljendić, **Ph.D.,** Institute of pesticides and Environmental Protection, Belgrade, Serbia,
Marija Sarić Krsmanović, **Ph.D.,** Institute of pesticides and Environmental Protection, Belgrade, Serbia,
Danica Mićanović, **Ph.D.,** Serbian Chamber of Commerce, Belgrade, Serbia,
Divna Simić, **Ph.D.,** Institute for Science Application in Agriculture, Belgrade, Serbia,
Slađan Stanković, **Ph.D.,** Institute for Science Application in Agriculture, Belgrade, Serbia,
Ana Anđelković, **Ph.D.,** Institute for Plant Protection and Environment, Belgrade, Serbia,
Prof. Siniša Mitrić, **Ph.D.,** University of Banja Luka, Faculty of Agriculture, Banja Luka, Republic of Srpska, B&H,
Marija Simić, **Ph.D.,** Institute for technology of nuclears and other mineral raw materials, Belgrade, Serbia,
Ahmet Uludag, **Ph.D.,** Canakkale Onsekiz Mart University, Faculty of Agriculture, Canakkale, Turkey,
Danijela Šikuljak, **Ph.D.,** Institute for Plant Protection and Environment, Belgrade, Serbia,
Svetlana Roljević Nikolić, Ph.D., Tamis Research and Development Institute, Pančevo, Serbia,
Mirela Matković Stojšin, Ph.D., Tamiš Research and Development Institute, Pančevo, Serbia,
Jelena Golijan Pantović, **Ph.D.,** University of Belgrade, Faculty of Agriculture, Belgrade, Serbia,
Miloš Rajković, **Ph.D.,** Institute for Medicinal Plants Research „Dr Josif Pančić'' Belgrade, Serbia,
Maja Meseldžija, **Ph.D.,** Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia,
Lelica Todorović, Ph.D., sci. med., Center for personal development, communication and leadership "Balance"
Biljana Kelečević, Ph.D., University of Banja Luka Faculty of Agriculture, Bosnia and Herzegovina,
Tanja Keškić, Ph.D., Institute for Animal Husbandry, Belgrade, Serbia.

HONORARY COMMITTEE

Academician Bela Balint, **Ph.D.,** Minister of Science, Technological Development and Innovation of the Republic of Serbia,
Prof. Dragan Glamočić, **Ph.D.,** Minister of Agriculture, Forestry and Water Management of the Republic of Serbia,
Nenad Trkulja, Ph.D., Institute for Plant Protection and Environment, Belgrade, Serbia,
Academician of the RAS, Alexey Vasilievich Soldatenko, Ph.D., Federal State Budgetary Scientific Institution Federal Scientific Vegetable Center (FSBSI FSVC), VNIISSOK, Moscow Region, Russia,
Marko Čadež, President of the Serbian Chamber of Commerce, Belgrade, Serbia,
Branko Azeski, President of the North Macedonia Chamber of Commerce, Skopje, North Macedonia,
Prof. Vesna Milić, **Ph.D.,** Dean of Faculty of Agriculture, University of East Sarajevo, Republic of Srpska, Bosnia and Herzegovina,
Prof. Bratislav Ćirković, **Ph.D.,** Dean of Faculty of Agriculture in Lešak, University of Priština temporary settled in Kosovska Mitrovica, Kosovo and Metohija, Serbia,
Prof. Mile Markoski, **Ph.D.,** Dean, Faculty of Agricultural Sciences and Food, Skopje, North Macedonia,
Prof. Gordana Dimitrovska, **Ph.D.,** Dean Faculty of Biotechnical Sciences, UKLO, Bitola, North Macedonia,
Prof. Kapllan Sulaj, **Ph.D.,** Dean, Faculty of Biotechnology and Food, Agriculture University of Tirana, Albania,
Prof. Muzaffer Denli, Ph.D., Dean, Dicle University Faculty of Agriculture, Turkey,
Prof. Boro Krstić, Ph.D., Dean, Faculty of Agriculture in Bijeljina, University of Bijeljina, Republic of Srpska, Bosnia and Herzegovina,
Rade Jovanović, Ph.D., Director, Institute for Science Application in Agriculture, Belgrade, Serbia,
Dejan Sokolović, **Ph.D.,** Director, Institute for Forage Crops, Kruševac, Serbia,
Jonel Subić, Ph.D., Director, Institute of Agricultural Economics, Belgrade, Serbia,
Prof. Nenad Đurić, Ph.D., Director, Institute for Vegetable Crops, S. Palanka, Serbia,
Prof. Andrea Andrejević Panić, Ph.D., Rector, Educons University, S. Kamenica, Serbia,
Prof. Mira Pucarević, Ph.D., Dean, Educons University, Faculty of Environmental Protection, S. Kamenica, Serbia,
Prof. Anka Vojvodić, Ph.D., High School of Health and Sanitation of Vocational Studies "Visan", Belgrade, Serbia,
Rado Savić, Mayor of Lopare Municipality, Republic of Srpska, Bosnia and Herzegovina,
Milan Damjanović, President of the Municipality of Bogatić, Serbia,
Nikola Lončar, President of the Tesla Science Foundation, NYC, USA,
Predrag Terzić, **Ph.D.,** Mayor of Kraljevo City, Kraljevo, Serbia,
Boban Đurović, President of the Municipality of Vrnjačka Banja, Vrnjačka Banja, Serbia,
Mahmud Aldagstani, Serbian Cinology Association, Belgrade, Serbia,
Prof. Dragan Damjanović, **Ph.D.,** Serbian Royal Academy of Scientists and Artists, Belgrade, Serbia,
Slobodan Krstić, President of e-Development association, Belgrade, Serbia.

SCIENTIFIC COMMITTEE

Danijela Šikuljak, Ph.D., President of the scientific committee, Institute for Plant Protection and Environment, Belgrade, Serbia,
Prof. Snežana Janković, Ph.D., Vice-President of the scientific committee, Institute for Science Application in Agriculture, Belgrade, Serbia,
Danica Mićanović, Ph.D., Serbian Chamber of Commerce, Belgrade, Serbia,
Ljiljana Radivojević, Ph.D., Institute for Pesticides and Environmental Protection, Belgrade, Serbia,
Svetlana Roljević Nikolić, Ph.D., Tamiš Research and Development Institute, Pančevo, Serbia,
Sladjana Savić, Ph.D., Institute for Plant Protection and Environment, Belgrade, Serbia,
Veselinka Zečević, Ph.D., Institute for Vegetable Crops, S. Palanka, Serbia,
Adisa Tufo, Ph.D., Faculty of Management and Business Economics Sarajevo, B&H,
Prof. Dragutin Đukić, **Ph.D.,** Faculty of Agriculture in Čačak, University of Kragujevac, Serbia,
Prof. Nikolay I. Bukhatoyarov, **Ph.D.,** Voronezh State Agrarian University, Voronezh Russia,
Prof. Siniša Berjan, **Ph.D.,** Faculty of Agriculture, Department of Agricultural Economics and Rural Development, University of East Sarajevo, B&H,
Prof. Mirjana Menkovska, Ph.D., SS Cyril and Methodius University in Skopje, Institute of Animal Science, Skopje, N. Macedonia,
Prof. Milivoje Ćosić, Ph.D., Faculty of Agriculture in Bijeljina, University of Bijeljina, Republic of Srpska, B&H,
Prof. Zoran Jovović, **Ph.D.,** Biotechnical Faculty, University of Montenegro, Podgorica, Montenegro,
Prof. Ivana Penjišević, Ph.D., Faculty of Science, University of Pristina temporary settled in Kosovska Mitrovica, Kosovo and Metohija, Serbia,
Mirela Matković Stojšin, Ph.D., Tamiš Research and Development Institute, Pančevo, Serbia,
Prof. Julijana Tomovska, **Ph.D.,** Faculty of Biotechnical Sciences, UKLO, Bitola, N. Macedonia,
Prof. Nese Yaman, **Ph.D.,** Dicle University, Faculty of Agriculture Diyarbakir, Turkey,
Prof. Mehmet Yildirim, Ph.D., Dicle University, Faculty of Agriculture, Department of Field Crops, Diyarbakır, Turkey,
Prof. Vera Popović, Ph.D., Institute of Field and Vegetable Crops, Novi Sad, Serbia,
Prof. Siniša Mitrić, **Ph.D.,** University of Banja Luka, Faculty of Agriculture, Banja Luka, Republic of Srpska, B&H,
Prof. Olivera Nikolić, Ph.D., Faculty of Ecological Agriculture, Educons University, S. Kamenica, Serbia,
Prof. Slađan Rašić, **Ph.D.,** Faculty of Ecological Agriculture, Educons University, S. Kamenica, Serbia,
Prof. Zorana Srećkov, Ph.D., Faculty of Ecological Agriculture, Educons University, S. Kamenica, Serbia,
Ahmet Uludag, **Ph.D.,** Canakkale Onsekiz Mart University, Faculty of Agriculture, Canakkale, Turkey,
Prof. Carmelo Rapisarda, Ph.D., University of Catania, Italy,

Prof. Gordana Đurić, **Ph.D.,** Faculty of Agriculture, University of Banja Luka, Republic of Srpska and Foundation "Alica", Banja Luka, Republic of Srpska, B&H,
Zoran Lugić, Ph.D., Institute for Forage Crops, Kruševac, Serbia,
Prof. Aleksandra Ivetić, Ph.D., Institute for Science Application in Agriculture, Belgrade, Serbia,
Divna Simić, **Ph.D.,** Institute for Science Application in Agriculture, Belgrade, Serbia.

ORGANIZING COMMITTEE

Milan Jovičić, **Msc.**, President, Kraljevo, Serbia,
Nenad Nikolin, **Msc.,** Deputy President, Belgrade, Serbia,
Marija Jovičić, **Msc.,** Deputy President, Kraljevo, Serbia,
Prof. Mirsad Nuković, **Ph.D.,** Novi Pazar, Serbia,
Milutin Matić, **Ph.D.,** Kragujevac, Serbia,
Stevan Petković, **Ph.D.,** Banja Luka, Republic of Srpska**,** B&H,
Adnan Tutić, **Ph.D.,** Tutin, Serbia**,**
Zoran Jelenković, Raška, Serbia,
Miša Ćirić, Belgrade, Serbia,
Ivan Trifunović, Vrnjačka Banja, Serbia,
Bojan Katanić, Kragujevac, Serbia,
Darko Mašić, Bogatić, Serbia,
Zlatko Milenković, Brus, Serbia,
Svetlana Kovačević, Belgrade, Serbia.

Doi: 10.46793/MAK2026.198T

INTEGRATING UV-VIS SPECTROPHOTOMETRY INTO FOOD QUALITY MANAGEMENT SYSTEM

Kristina Tomska*, Viktorija Stojkovski

University "St. Kliment Ohridski" Bitola; Faculty of Biotechnical Sciences, Bitola, N. Macedonia,
***Corresponding author: kristina.tomska@uklo.edu.mk**

Abstract: UV-Vis spectrophotometry has become a common and very practical tool in food quality control because it is quick, simple to use, and sensitive enough for everyday analyses. With this technique, laboratories can easily check the levels of nutrients, colorants, additives, and natural pigments in different food products. It is also frequently used to screen for possible contaminants, detect signs of adulteration, and observe how products change during processing or storage. In the context of quality management, UV-Vis helps laboratories make informed decisions and stay aligned with standards such as HACCP, ISO 22000, and ISO/IEC 17025. These systems depend heavily on reliable analytical results to identify potential hazards, confirm critical control points, and keep product specifications stable over time. Although its selectivity is lower than that of more advanced chromatographic methods like HPLC or GC, UV-Vis remains widely used because it is affordable, fast, and requires minimal preparation. This review summarizes the fundamental principles of UV-Vis spectrophotometry, discusses its key applications across different food categories, and illustrates how the method contributes to quality management and food safety in modern production. The paper also emphasizes its broad role in ensuring product safety and its ongoing relevance as part of integrated quality management systems.

Keywords: UV-Vis spectrophotometry, Food, Quality, Control, Analysis, Safety, Analytical methods, Monitoring

INTRODUCTION

Safety of the food is vital to food businesses and protects consumers from possible health-related threats. Quality of food is the basis of several concepts including the organoleptic qualities of food (smell, taste, sight) and their nutritional value. In addition to quality of food, food safety provides producers with information necessary to reduce the risk of contamination of their products by potentially dangerous microorganisms (and/or other hazards) via the use of food safety procedures. Ultraviolet-visible spectrophotometry has become an essential analytical technique for quality control and management in the food industry (Rocío Ríos-Reina, 2023). Ultraviolet-visible spectrophotometry is one of the many analytical techniques available for the measurement of the absorption (or transmission) of light within a specific wavelength (range between 200 nm to 700 nm) by a sample and is primarily used to determine the qualitative and quantitative analysis of the chemical components present in a sample. Using Beer-Lambert Law, this analytical technique measures the amount of light absorbed by the chemical components that are responsible for the qualitative and quantitative identification of the chemical components (nutrients, colorants, additives, contaminants etc.) present in the sample. The amount of light absorbed is directly proportional to the number of chemical component(s) that cause the light to be absorbed by the sample.

$$A = \varepsilon \cdot c \cdot l$$

A = absorbance

ε = molar absorptivity coefficient ($L \cdot mol^{-1} \cdot cm^{-1}$)

c = concentration of the analyte ($mol \cdot L^{-1}$)

l = path length of the cuvette (cm)

As a result of its simplicity, rapidity, low cost, and nondestructive nature, ultraviolet-visible spectrophotometry has been widely applied in both qualitative and quantitative analyses in the food industry. For example, ultraviolet-visible spectrophotometry has been used to detect adulterations (e.g. dilutions or contaminants), quantify additive levels (preservatives, dyes), and monitor changes resulting from processing.

This review highlights the principles behind ultraviolet-visible spectrophotometry and emphasizes its qualitative (presence/absence and fingerprinting) and quantitative applications in different areas of the food industry, using examples of recent studies and current practices in the food industry.

A UV-Vis spectrophotometer uses a light source that includes a deuterium lamp for the ultraviolet spectrum and a tungsten lamp for the visible spectrum, and the monochromator selects a wavelength for which to allow the selected wavelength of radiation to pass through the sample. As a result of this requirement, the sample must be clear or transparent, thereby requiring extraction or dilution before analysis if the sample is solid or contains suspended particles. Calibration curves established from known concentrations of standards must be prepared prior to quantitative analysis.

In addition to ensuring food safety and quality, the implementation of ISO 9001, HACCP, and other quality standards in laboratory practice - especially in UV-Vis spectrophotometry - represents a fundamental aspect for regulatory compliance in the food industry. These standards define the functions of laboratories, provide guidelines for validating analytical methods, and describe the presentation of analytical data that will support decision-making in the food industry.

Application of UV-Vis Spectrophotometry in Quality Control

Dairy Products

For instance, using UV-Vis spectrophotometry, Xie et al. (2015) proposed the development of a rapid and sensitive colorimetric method called UV quantification for the detection of melamine (MEL) in milk samples. This method was based on the aggregation of gold nanoparticles (AuNPs) induced by the interaction of AuNPs with MEL, causing the AuNPs to change from red to purple. Results indicated that the amount of MEL present in milk samples could be determined in approximately 15 min, with a minimum limit of detection of 2 ppm (Xie et al., 2015).

With respect to hazardous substances, the UV-Vis spectrophotometer plays an additional role in investigating the stability of nutrients in milk (Mohamed and Farag, 2022). It assesses the interactions between milk proteins and some lipophilic nutrients such as lutein using UV studies at 500 nm, in terms of changes in turbidity. Since the aromatic amino acids contained in milk proteins absorb light at 280 nm, the amount of protein in milk can be easily measured.

Beverages (Alcoholic and Non-Alcoholic)

The use of UV-Vis spectroscopy in the quality control of alcoholic and non-alcoholic beverages is widespread because of its rapidity, simplicity, and adherence to industry standards. The UV-Vis technique has standard procedures for determining many important features of beverages. Beer brewing is one of the most well-known uses of UV-Vis, in particular for determining the color and bitterness of beer. Isooctane extracts hop-derived iso-alpha-acids, and the amount of these compounds present in isooctane is determined by measuring the absorbance at approximately 275 nm (the International Bitterness Unit (IBU)). It allows the brewer to determine the exact amount of substances that contribute to the bitter taste of the beer (Do Nascimento et al., 2021).

In winemaking, UV-Vis is also critical for tracking the color and phenolic content of wines (Onache et al., 2023). The absorption of total phenols occurs about 280 nm, whereas the absorption of anthocyanin, which contributes to the color of red wine, occurs in the visible spectrum at wavelengths of 520-540 nm. Therefore, UV-Vis enables rapid determination of the polyphenol content and color strength of wine. Some researchers have even used multivariate statistical analysis (i.e. PCA) in combination with complete UV spectra (200-600 nm) to identify grape varieties and vintages based on the specific phenolic fingerprint of each.

Fruit juice clarity and haze are other important quality parameters that affect the visual appearance and acceptance of fruit juices (Pappalardo, 2022). Caffeine absorbs strongly at about 273 nm; therefore UV-Vis is often used to measure caffeine in non-alcoholic beverages, i.e., coffee and tea. Colorimetric techniques using UV-based methodology are also commonly used to perform routine color monitoring to ensure product consistency.

Modern breweries mainly rely on UV-Vis sensors to rapidly and effectively monitor a variety of quality indicators such as color, bitterness, carbohydrate content, polyphenol content, and even sulfite concentration. All things being equal, UV-Vis is a key analytical instrument for ensuring the quality of beverages as it provides rapid, reagent-free assays that often meet or exceed regulatory requirements.

Vegetable Oils and Fats

UV-Vis spectroscopy is a valuable method for evaluating the quality of edible vegetable oils and for detecting adulterations. Vegetable oils such as olives and sunflowers contain natural UV-absorbing compounds such as chlorophyll and carotenoids. Additionally, when oils undergo degradation - especially oxidation - conjugated compounds are formed that also absorb UV light. For example, conjugated diene formation, indicative of early oxidation products, results in absorbance at approximately 232 nm, whereas conjugated triene formation, indicative of later stage oxidation, results in absorbance at approximately 270 nm, and thus UV-Vis spectroscopy can be used to evaluate rancidity.

A study demonstrated how UV-Vis, in combination with multivariate analysis (MCR-ALS), can follow the decrease of α-tocopherol (vitamin E) in oils as they are heated (Gonçalves et al., 2014). As the level of antioxidants decreases, the level of UV-absorbing oxidation products increases, demonstrating that UV-Vis can evaluate both the degradation of oils and the nutrient loss during frying process.

UV-Vis is also utilized to measure the levels of pigments in oils. Chlorophyll absorbs strongly at a wavelength of 670 nm, whereas carotenoids absorb at wavelengths of 450-480 nm. By measuring the absorbance at these wavelengths, the degree of freshness and type of oil can be assessed. UV-Vis assays have been used to measure total chlorophyll and carotenoids in olive oils, resulting in distinct differences in the fresh and extra-fresh grades (Borello and Domenici, 2019).

Another significant application of UV-Vis is the detection of adulteration. When UV-Vis spectra collected between 200-700 nm are analyzed using chemometric techniques, they can differentiate between pure olive oil and mixtures containing lower-cost seed oils such as sunflower, corn, or canola. Research shows that even portable UV-Vis instruments can detect adulteration levels of 10% or higher due to variations in the patterns of oxidation of fatty acids and in the pigment content. More sophisticated techniques, such as photoionization IMS (PIIMS), have further decreased detection limits, allowing for the identification of olive oil adulteration at levels comparable to 10%, within a time frame of less than 20 minutes (Garrido-Delgado et al., 2018).

In conclusion, UV-Vis spectroscopy offers a fast, environmentally friendly means for screening oils for oxidative stability, freshness and purity. However, for detecting very low levels of adulteration (less than 5%), more sensitive analytical techniques will likely be required.

Grains and Cereals

UV-VIS Spectroscopy has very low frequency of application in Grain/Cereal analysis, yet it is an important tool for that type of food. Examples include measurement of specific pigments and some of the nutrients found in Grains (Yisak, 2022); the antioxidant properties, including polyphenols; and the mineral properties of flours (Jaćimović et al., 2023) that exhibit absorption in the ultraviolet spectrum and therefore may be utilized to assess flour quality. UV-VIS is also an important tool in determining protein concentrations in Flour by employing Colorimetric Assays. An example of a common assay is the Biuret Reaction (which creates a Violet colored Complex that can be measured at 540-560 nm).

UV-VIS is also a useful tool in contaminant analysis. Many toxic mycotoxins (such as Aflatoxins and Ochratoxins) display a High level of UV Absorbance; therefore, UV-VIS is a viable Rapid Screening Method and/or can be employed as a Detector in more sophisticated procedures such as HPLC.

High End Methods such as HPLC or LC-MS are considered the Gold Standard for Toxin Detection; however, UV-VIS can provide initial, rapid insights into the presence of Toxins that contain Conjugated Double Bonds.

Additionally, researchers have successfully applied Chemometric Techniques utilizing UV-VIS Spectral Data to Identify Adulteration in Milled Products such as Bread/Flour, e.g., Wheat Flour blended with lower cost Grains such as Barley.

UV-VIS performs a more defined role in Grain Analysis generally, typically supporting other established methods for Protein Level Determinations, Sugar Content Determinations, or Contaminant Testing.

Other Foods (Honey, Spices, etc.)

UV-Vis Spectrophotometry is not limited to General Food Analysis; UV-Vis is also gaining utility for Specialty Foods such as Honey and Spices. Honey is known for being a Superfood containing a wealth of Nutrients along with its High Sugar Content and Polyphenols as part of its Distinct Secondary Metabolite Bioactive Composition (Ansari et al., 2018). These make UV-VIS a rapid and efficient Tool for Honey Authentication.

For Spices and Extracts, UV-VIS can aid in Identifying and Quantifying Key Active Compounds. UV-VIS measures Curcumin in Turmeric at 425nm and Capsaicinoids in Chili Peppers near 280nm. UV-VIS can also Identify Illegal Dyed Products that have been Tampered with. Food Colorants, whether Natural or Synthetic, are commonly Analyzed with this Method. Dyed Products such as Tartrazine and Sunset Yellow absorb Strongly in the Visible Spectrum, making them Easy to Detect and Quantify. In summary, UV-VIS Spectrophotometry is a valuable Addition to Food Testing, allowing the monitoring of Color, Additives and Product Purity in everything from Honey to Spices.

UV-Vis Spectrophotometry in Food Quality Management Systems

To ensure that analytical information generated in food laboratories accurately and reliably reflects the quality of food products, UV-Vis spectrophotometry should be implemented in conjunction with quality management systems (QM). International Standards (2017, 2018) and Regulations Provide Frameworks for QM in Food Laboratories. Key to establishing a quality management system is compliance with relevant international standards and regulations that guide the establishment of laboratory quality management systems.

ISO/IEC 17025 - General Requirements for Testing and Calibration Laboratories

In addition to providing guidelines for general laboratory operations, including proficiency, objectivity and reliable performance of laboratories, ISO/IEC 17025:2017 provides specific guidance for ensuring that UV-VIS spectrophotometers have been properly calibrated, validated and maintained.

Applicability to UV-Vis Spectrophotometry:

• The standard requires that UV-Vis methods use documented Standard Operating Procedures (SOPs) and reference materials that are traceable,

• The standard requires that all UV-Vis methods undergo thorough validation and include assessments of quantitative capability (LOQ), linearity, accuracy, precision and LOD,
• By requiring that laboratories utilize QC samples regularly and participate in proficiency testing programs for UV-Vis, the standard supports the reliability of UV-Vis data and facilitates comparison among laboratories.

HACCP - Hazard Analysis and Critical Control Points

The purpose of a HACCP (www.fao.org/4/y1579e/y1579e03.htm) food safety system is to identify, evaluate and control physical, chemical and biological hazards in the food processing environment. In many cases, the use of UV-Vis spectrophotometry can be useful in the development of HACCP plans, particularly at CCPs. Ensuring that the analytical data generated from UV-Vis is properly documented and traced, may be beneficial in using UV-Vis as a CCP verification tool. Additionally, UV-Vis can assist in verifying control measures by detecting spoilage indicators or oxidation products in fats and oils.

ISO 22000 - Food Safety Management Systems

ISO 22000:2018 builds upon HACCP principles but goes further by providing the requirements for a Food Safety Management System (FSMS) and provides for certification against it. ISO 22000:2018 defines the steps organizations need to take to demonstrate their ability to manage food safety risks so that they can produce food that is safe to eat. ISO 22000:2018 also ensures that laboratory data generated during the use of UV-Vis instruments is reliable and supports informed decisions related to food safety. UV-Vis methods can be utilized to monitor chemical contaminants in foods that affect food safety including mycotoxins, food colorants, and preservatives.

Good Laboratory Practice (GLP) and Good Manufacturing Practice (GMP)

In addition to verifying that raw materials and final products meet established standards, and that labeling claims are accurate, GLP validation of UV-Vis methods ensures that these methods are both reliable and reproducible and that all aspects of the methods have been documented.

Advantages and Limitations of UV-Vis Spectrophotometry in Food Analysis

UV-Vis spectrophotometry is widely used for food quality control due to numerous advantages of this technique, including speed, affordability, and flexibility. Using a single instrument, UV-Vis spectrophotometers measure color, clarity, and concentration of samples with minimal sample preparation. This technique is non-destructive and produces results within seconds to minutes, making it ideal for continuous monitoring of food quality.

One of the major advantages of UV-Vis spectrophotometry is accessibility. Portable systems are common today and allow for on-site testing in food processing plants or in the field; this technology requires minimal consumable supplies, typically limited to solvents or simple reagents. Full-scan UV-Vis methods are particularly advantageous for developing “fingerprints” for new products and can measure multiple analytes simultaneously.

Like any analytical method, however, UV-Vis has limitations. Derivatization or other forms of treatment may be required when analyzing compounds that do not absorb radiation in the visible or ultraviolet regions of the electromagnetic spectrum, i.e., many sugars and salts. Generally, UV-Vis methods have less sensitivity and specificity than more sophisticated techniques, e.g., mass spectrometry or chromatography. Additionally, broad, overlapping absorption bands are often observed in UV-Vis spectra, which complicates identification of specific ingredients in complex food matrices. Turbidity, light scattering caused by emulsified fat, and matrix effects can all interfere with UV-Vis measurements, and careful construction of calibration curves must be performed to obtain accurate results. UV-Vis may lack the detection limits needed to detect trace levels of contaminants, or subtle adulteration in foods. While UV-Vis is an excellent tool for quality control, its lack of discriminative power compared to more advanced spectral technologies, as noted by Farag et al., precludes it from being a standalone method. Therefore, UV-Vis is often used as a screening tool, with subsequent confirmatory analysis using more sensitive methods (e.g., PCR, HPLC).

CONCLUSION

UV-Vis spectrophotometry continues to be an important and versatile tool in quality assurance (QA) programs in the food industry. Its ability to rapidly and cost-effectively assess color, concentration, and compositional fingerprints makes it a valuable tool for many types of food and beverage products, including dairy, meat, beverages, oils, grains, and specialty foods. The fundamental benefits of UV-Vis spectrophotometry make it well-suited for both routine QA and process monitoring; these include speed, ease-of-use, and low operating costs.

The inclusion of UV-Vis spectrophotometry into larger quality management frameworks, such as ISO/IEC 17025, ISO 22000, HACCP, and GMP, will provide traceable, verifiable information that supports both food safety and regulatory compliance. Specifically:

Maintaining the sensory attributes and consistency of the product,
Validating the labeling and nutritional claims of the product,
Detecting contaminants and adulterants,
Improving recordkeeping and audit preparation.

While UV-Vis is a reliable screening technique, users should remain aware of the limitations of UV-Vis spectrophotometry particularly concerning its sensitivity, specificity and potential for matrix effects. Ultimately, UV-Vis spectrophotometry enhances food safety, builds consumer confidence and enables continuous development of food quality control systems within the global supply chain.

REFERENCES

Ansari, M., Al-Ghamdi, A., Khan, K., Adgaba, N., El-Ahmady, S., Gad, H., *et al.* (2018). Validation of botanical origins and geographical sources of some Saudi honeys using ultraviolet spectroscopy and chemometric analysis. Saudi J. Biol. Sci., 377-382.

Borello, E., Domenici, V. (2019). Determination of Pigments in Virgin and Extra-Virgin Olive Oils: A Comparison between Two Near UV-Vis Spectroscopic Techniques. Foods, 18.

Do Nascimento, I.L., Caladob, L., Bojorgec, N., Silvad, V., Peixotoe, F. (2021). Dynamic Evolution of Bitterness Units in Beer Worts: Modeling and Concerns. American Scientific Research Journal for Engineering, 80(1), 145-155.

Garrido-Delgado, R., Muñoz-Pérez, M., Arce, L. (2018). Detection of adulteration in extra virgin olive oils by using UV-IMS and chemometric analysis. Food Control, 292-299.

Gonçalves, R., Março, P., Valderrama, P. (2014). Thermal edible oil evaluation by UV-Vis spectroscopy and chemometrics. Food Chem., 83-86.

Hazard Analysis and Critical Control Point (HACCP) system and guidelines for its application, Annex to CAC/RCP 1-1969, Rev. 3. www.fao.org/4/y1579e/y1579e03.htm

International Standard, Food safety management systems - Requirements for any organization in the food chain ISO 22000:2018, Edition 2 2018-6, www.iso.org/standard/65464.html

International Standard, General requirements for the competence of testing and calibration laboratories ISO/IEC 17025:2017, Editon 3 2017-11, www.iso.org/standard/66912.html#lifecycle

Jaćimović, S., Kiprovski, B., Ristivojević, P., Dimić, D., Nakarada, Đ., Dojčinović, B., Sikora, V., Teslić, N., Pantelić, N.Đ. (2023). Chemical Composition, Antioxidant Potential, and Nutritional Evaluation of Cultivated Sorghum Grains: A Combined Experimental, Theoretical, and Multivariate Analysis. Antioxidants (Basel), 12(8):1485. doi: 10.3390/antiox12081485. PMID: 37627480

Mohamed, A., Farag, M.S. (2022). UV Fingerprinting Approaches for Quality Control Analyses of Food and Functional Food Coupled to Chemometrics: A Comprehensive Analysis of Novel Trends and Applications. Foods, 11(18), 2867.

Onache, P.A., Florea, A., Geana, E.I., Ciucure, C.T., Ionete, R.E., Sumedrea, D.I., Tița, O. (2023). Assessment of Bioactive Phenolic Compounds in Musts and the Corresponding Wines of White and Red Grape Varieties. Appl. Sci., 13, 5722. doi: 10.3390/app13095722

Pappalardo, L. (2022). Pomegranate fruit juice adulteration with apple juice: detection by UV-visible spectroscopy combined with multivariate statistical analysis. Scientific Reports, 12(1), 5151. doi: 10.1038/s41598-022-07979-7

Rocío Ríos-Reina, S.M. (2023). How Chemometrics Revives the UV-Vis Spectroscopy Applications as an Analytical Sensor for Spectralprint (Nontargeted) Analysis. Chemosensors, 11(1), 8.

Xie, W., Huang, Y., Yun, W., Tang, D., Zhang, H., Du, C. *et al.* (2015). Simple Pretreatment and Portable UV-Vis Spectrum Instrument for the Rapid Detection of Melamine in Milk Products. J. Food Qual., 297-304.

Yisak, H., Tukue, H., Redi-Abshiro, M., Chandravanshi, B.S., Yaya, E.E. (2022). Development of Green UV-Vis Method for Direct Determination of Total Sugars in the Aqueous Extract of Teff (*Eragrostis tef* (Zuccagni) Trotter) Grains and Other Cereals. Int J Anal Chem., 1;2022:5129510. doi: 10.1155/2022/5129510. PMID: 36388771; PMCID: PMC9643061.