



AgriTech Today

AGRICULTURE AND ALLIED SCIENCES E-MAGAZINE

SPECIAL ISSUE ON FOOD SAFETY AND QUALITY

CHAITRADEEPA G. M.
GUEST EDITOR



VOLUME 1
SPECIAL ISSUE (JANUARY, 2024)

<https://agritechmagazine.com>



Volume 1, Special Issue
(January, 2024)

President

Veerendra Simha H.V.
Valmiki Sahitya Sampada

Editor-in-chief

Vikram Simha H.V.

Guest Editor

Chaitradeepa G. M.

Editorial Board

Jaishankar N.
Gurumurthy S. B.
Kiran Nagajjanavar
Basavaraja D.
Hadimani D. K.
Kambale J. B.
Gangadhara K.
Umesh Barikara
Arun Kumar P.
Chetan T.
Prabhugouda Kamaraddi
Bhawar R. S.
Veena T.

Reviewers

Sharanabasava
Akshay Kumar

Graphic Designer

Sanjeevkumar Patil
Ajay

Publisher

Valmiki Sahitya Sampada
Harthikote Post
Hiriyur, Chitradurga Dist.,
Karnataka - 577545

Contact

agritech.editor@gmail.com

Disclaimer: The articles published in AgriTech Today magazine are the personal views of authors. It is need not necessarily be those of the editor/publisher. The magazine will not be held responsible for any errors/ copyright infringement in the article as we do not alter the information provided by the author, therefore the author bears full responsibility.

From the Editor-in-Chief's Desk

I am happy and proud to announce the Volume 1, Special issue (January, 2024) on Food Safety and Quality.

Food safety is paramount to ensure that the food we consume is free from harmful contaminants, pathogens, and toxins that could pose a risk to human health. Quality control measures in food production play a crucial role in maintaining the nutritional value, taste, and overall appeal of food products, meeting consumer expectations. Adherence to proper hygiene practices during food handling, processing, and storage is essential to prevent the spread of foodborne illnesses and maintain high standards of food safety. Stringent regulations and standards set by regulatory bodies help ensure that food producers follow best practices, conduct regular inspections, and implement quality control measures throughout the supply chain. Consumer awareness and education regarding food safety practices empower individuals to make informed choices, encouraging a collective effort to prioritize and demand high standards in the production and handling of food.

It gives me great pleasure to inform you that we have curated and finalized 23 articles for publication in this issue. I extend my heartfelt gratitude to Ms. Chaitradeepa G. M. for her contribution as Guest Editor in this Issue and also for the dedicated editorial team and the talented authors for their invaluable contributions in bringing this issue. Your efforts have played a pivotal role in making AgriTech Today Magazine a source of enlightenment and knowledge in the agricultural domain.

Editor-in-chief

EDITOR'S MESSAGE



"Healthy Food- Where Quality meets Safety"

Food Safety and quality are essential and vital components of every food industry encompassing standards and practices that ensure storage, production, handling, transportation and consumption in a way that satisfies strict standards of excellence, safety, nutritional value and freshness. Both Food safety and Quality aspects are critical for safeguarding public health, maintaining integrity of the global food supply chain and building consumer trust. As consumers are becoming more informed and demanding, the food technologists, researchers, and food industries must continually adapt innovations to meet the demands and prioritize the well being of individuals and community.

This special issue has been released to shed light on a number of topics related to food safety and quality such as nutrition value, freshness, food-borne illness prevention, cleanliness and sanitation. I want to express my sincere gratitude to the AgriTech Today magazine's editorial board for granting me the chance to serve as the guest editor of this special edition on "Food Safety and Quality."

A handwritten signature in blue ink, appearing to read 'Chaitradeepa'.

Ms. Chaitradeepa G. M.
GUEST EDITOR
PhD Scholar

Department of Food Technology, FLAHS
Ramaiah University of Applied Sciences
Bangalore, Karnataka -560054

TABLE OF CONTENTS

i	Editorial and Table of Contents	i-iv
1	Significance of RFID (Radio Frequency Identification) in the Food Industry Charu Bisht and Hitesh Khurcha	1
2	Non-Destructive Methods in the Detection of Food Adulteration Adrita Banerjee	5
3	Adulteration in Food Rajeshwari N., Shweta Biradar and Geeta Tamgale	10
4	Guardians of Food Safety: Navigating Physical, Chemical and Biological Hazards in the Culinary Landscape P. Jayamma, S. Pavana Deepthi, R. Aruna and B. Manjula	13
5	Antibiotic Residues in Milk-A Threat to Food Safety and Quality Prince, Somveer, Dimple, Deshmukh R. R. and Nitish	15
6	Conjugated Linoleic Acid (CLA) Sneha Shende, Gajanan Narnaware and Prashant Wasnik	18
7	Edible Coatings for Fruits and Vegetables- A New Opportunity for Farmers Sandeep Bhardwaj and Rupali Sharma	22
8	Ensuring Food Safety and Quality: A Comprehensive Approach Pooja M. Eranna and Madhusudhan Nayak C.	25
9	Food Toxins: A Comprehensive Exploration Abhishek Chitranashi, Aditi Mathur, Nandini GA, Mallesh Gampa and Ashok Kumar	28
10	Quality Standards of Ghee B.P. Pushpa	31
11	Antinutritional Factors in Cereals Abhishek Chitranashi, Aditi Mathur, Nandini G. A., Mallesh Gampa, Ashok Kumar and Diksha Srivastava	33
12	Non-Thermal Processing Methods for Food Safety and Shelf-Life Enhancement Kumari M., Somveer, Ravikant V. Vinchurkar, Soniya Mor and Deshmukh R. R.	37
13	Exploring the Application of Radio Frequency (RF) Heating in Food Commodities: Eco-Friendly Disinfestation C. Indumathi., P. Krishnakumar, S. Chittibabu and S. Shanmugasundaram	40
14	Stable Isotope Ratio Analysis (Sira): A Tool for Isotopic Analysis for Food Authentication and Traceability in Dairy Industry Ashritha B., N. Veena, Avinash C. Gautham and Somveer	43
15	FSSAI's Pioneering Role in Enhancing Food Safety and Quality in the Indian Subcontinent Somveer, Kumari M, Ravikant V Vinchurkar, Deshmukh R R and Bakeeru L	49

16	Surveillance and Impact of Antibiotic Resistance in Emerging Food Borne Pathogens Ravikant V. Vinchurkar, Kumari M., Somveer, Deshmukh R. R. and B. Lakshmaiah	53
17	Revolutionizing Food Safety in Food Supply Chain: A Comprehensive Survey of Modern Technologies Suneel Subray Hegde	57
18	Technologies For Pesticide Residue Elimination on Temperate Fruits for Safe Consumption Shugufta Parveen, Sajad Un Nabi, Bisma Rashid and Mahendra K Verma	60
19	Tech-driven Advances in Safeguarding Food: A Paradigm Shift in Microbiological Quality Assurance Varshaa Arer	64
20	Food Safety: Challenges, Major Food Borne illnesses, Advance Techniques to Ensure food safety & Future Food safety Manjit M Khatal	68
21	Safeguarding Palates: Navigating the Terrain of Food Safety and Quality Sangya Singh	70
22	A Comprehensive Analysis of Antibiotic Resistance in Food Grade Bacteria Ravikant V. Vinchurkar, Monica Rose, Somveer, Deshmukh R. R. and Sunita Rani	72
23	Evaluation of Edible Oil for Quality and Adulteration Twinkle Mishra, Avinash Pandey, Omkar M. Limbalkar and Kishor U. Tribhuvan	76

Significance of RFID (Radio Frequency Identification) in the Food Industry

¹Charu Bisht and ²Hitesh Khurda

¹ PhD Scholar, Department of Food Science & Technology, G.B.P.U.A&T, Pantnagar, Uttarakhand

² Post Graduate, Department of Food Technology, Maharshi Dayanand University, Rohtak, Haryana

*Corresponding Author: bishtc123@gmail.com

Abstract

Radio Frequency Identification (RFID) stands as a viable alternative to conventional Universal Product Code (UPC) barcodes. Unlike barcodes, RFID allows for non-line-of-sight object identification from a distance. RFID tags have the capability to store extra information, including product details and manufacturer information, and can also transmit environmental data like temperature and relative humidity. The fundamental components of RFID include the tag, reader with an antenna, and associated software. The technology operates based on either magnetic induction or capturing electromagnetic waves. Its extensive applications are particularly evident in the food industry.

Introduction

The surge in food product demand has spurred substantial changes in food production and distribution processes, driven by advancements in food product technology. Rapid identification technologies, particularly those relying on wireless communication such as radiofrequency waves, have greatly enhanced the handling of raw materials and finished goods in the food industry. The origins of RFID (Radio Frequency Identification) trace back to World War II, where it was initially employed for Friend or Foe (IFF) identification of military aircraft (Kumari *et al.*, 2015). Unlike other identification systems like barcodes, RFID offers more convenience in product identification, allowing for non-line-of-sight object recognition from a distance (Bibi *et al.*, 2017). These RFID tags can be placed within objects, containers, or even injected into animals, providing a versatile solution (Finkenzeller, 2003).

Compared to barcodes, RFID offers a longer reading range of over 100 meters, and RFID readers can differentiate between multiple tags in the same area without human intervention. RFID technology operates in various frequency ranges, including low frequency, high frequency, amateur radio band, ultra-high frequency, and microwave frequency (Brown,

2007). Despite its advantages, it's worth noting that RFID technology is more expensive than traditional barcode technology (Want, 2006). The ongoing technological advancements in networking devices, sensors, and communication technologies are crucial for the sustainability of the Agri-food sector. RFID, as a pervasive technology, is increasingly being utilized in various facets of the food industry, including logistics, supply chain management, cold chain monitoring, and retail (Ruiz-Garcia & Lunadei, 2011).



Figure 1: RFID in food industry

Main Components of RFID

Following three are the main components of RFID:

Tag

An RFID tag, also referred to as a transponder, is a compact device designed for attachment to an object to facilitate its identification and tracking. It serves as the storage unit for information, containing an integrated circuit (IC) chip and an antenna enclosed within suitable packaging. The tag's dimensions are typically determined by the size of its antenna, as the microchip itself is generally quite small (Brown, 2007). RFID tags come in various shapes, sizes, and protective housings, with the smallest commercially available tags measuring 0.4×0.4 mm² and being thinner than a sheet of paper (Roberts, 2006).

Reader or Interrogator

The RFID reader is instrumental in retrieving the information stored in a tag. It comprises a decoder for interpreting tag information and an antenna. The reader is a device that both powers and communicates with the tag. Its components include a high-frequency (HF) interface, consisting of a transmitter and a receiver, an antenna, and a control unit. The HF interface generates power to activate the tag, sends and receives data from the tag. The antenna, a conductive element, facilitates communication between the tag and the RFID reader. Both the reader and the tag in an RFID system possess antennas for data transmission and reception. The size of the antenna is crucial as it determines the operational range of the reader. The control unit, based on a microprocessor, manages communication with the tag, coding, and decoding signals. Reader performance is typically gauged by its range and the speed at which it can identify, read, or write to a tag (Finkenzeller, 2003; Brown, 2007).

Software

This component is employed for managing the data received and overseeing the operations of the reader and tag. The software is crucial for tasks such as communication with RFID readers, filtering and cleaning RFID data, and adapting the data for high-level applications, including automatic data transformation and aggregation.

RFID tags classification

- I. Passive Tag: Passive tags lack an external power source and become operational when they enter the proximity of an RFID reader.
- II. Active Tag: Equipped with a built-in battery, active tags maintain constant functionality, enabling communication with the reader at any given moment. These tags offer an extended read range and support read/write capabilities, albeit at a higher cost and with increased bulkiness due to the embedded battery.
- III. Semi-passive Tag: Semi-passive tags incorporate a power source (battery) utilized solely to activate the chip's circuitry. Unlike active tags, they rely on the electromagnetic

field generated by the reader for communication. The battery remains dormant until triggered by a signal from the reader. This approach conserves battery power, extending the tag's lifespan.

Principle

An RFID system consists of two primary components: a tag and a reader. The reader initiates communication by generating and transmitting an interrogation signal to the tag. A passive tag relies on the reader for power, utilizing either magnetic induction (near-field coupling) or electromagnetic wave capture (far-field coupling). The near-field coupling, based on Faraday's principle of magnetic induction, involves the reader generating an alternating magnetic field through its antenna coil by passing a large alternating current. If a passive tag, featuring a smaller antenna coil, is placed within this magnetic field, it induces an alternating voltage across the tag's coil. This voltage is rectified, coupled to a capacitor, and accumulates charge to power the chip of the passive tag. In the case of far-field coupling, resembling the principles of a radio set, far-field RFID systems operate by capturing electromagnetic waves from the dipole antenna attached to the reader. The smaller dipole antenna in the tag receives this electromagnetic energy as an alternating potential difference. The potential difference is rectified, coupled to a capacitor, and accumulates charge to power the chip of the passive tag.

Both methods effectively transfer sufficient power to sustain the operation of a passive tag. RFID systems operating in the frequency range between 100 kHz and 30 MHz utilize magnetic induction, while those based on microwave frequencies (2.45 and 5.8 GHz) operate using electromagnetic wave capture (Finkenzeller, 2003).

Application in food industry

Supply chain management

Effectively managing the supply chain of perishable food items presents a crucial and challenging task due to the inherent variability in products, stringent traceability requirements, limited shelf life, and the necessity to maintain optimal environmental conditions from production to end-

user. RFID technology emerges as a promising solution to enhance supply chain efficiency by addressing issues such as inventory losses, management costs, dynamic logistics planning, reduced labor costs, and improved product flow efficiency (Tajima, 2007). The information provided by RFID is both accurate and rapidly collected, contributing to enhanced inventory visibility in the retail sector. RFID facilitates automated material inspection and handling, reducing instances of out-of-stock occurrences. Managing the spoilage of perishable products is critical, and RFID aids in effective stock rotation by ensuring products are sold in the correct order based on their expiry dates. RFID technology plays a pivotal role in boosting operational efficiencies by minimizing labor costs associated with inventory counts, enhancing theft prevention measures, and ensuring authenticity control. Additionally, RFID helps eliminate inventory record inaccuracies in the supply chain. Major companies such as Wal-Mart, GAP, P&G, JC Penney, and Old Navy have adopted RFID tags for supply chain management. The ability of RFID to track and trace individual items in real-time provides valuable information that can be shared among supply chain partners.

Temperature monitoring

RFID technology finds applications across various agrifood sectors, including horticulture, meat, pork, fisheries, dairy, bakery, and beverages. Freshtime™ Infratab Inc.'s semiactive RFID tags, based in Oxnard, California, U.S.A., are specifically designed to monitor the shelf life of attached food products. These tags incorporate temperature-sensing capabilities, integrating temperature data over time to assess and communicate the remaining shelf life of a product to a reader. Equipped with a battery, these tags also feature an optional visual display that indicates the item's status through color-coded indicators – green for freshness and red for potential safety concerns. The operational range of these tags' spans from -25 to 70° Celsius.

Livestock management

The demand for animal identification and traceability is steadily rising. In numerous countries,

farmers have traditionally maintained animal records using various identification methods, including paint marks, tattoos, ear notches, and ear tags. However, ear tags are susceptible to loss (5–60% of the time), and paint marks or tattoos may suffer damage or fade over time. To stay globally competitive and ensure traceability, many countries are turning to RFID technology for livestock data recording and management. RFID systems offer superior livestock management as they are faster, cleaner, and more efficient than conventional methods. Implementing RFID in livestock operations streamlines automation, reducing labor costs and increasing profits. RFID tags are easily applied to animals, ensuring successful readings. Compared to traditional systems, RFID systems are estimated to introduce only one error per 1000 animals, while traditional methods may incur six errors for every 100 animals. In livestock markets, detailed data and information about animals can serve as product certificates, especially in situations where disease outbreaks occur.

The uniqueness of RFID tags ensures reliable and efficient tracking of animals from birth through various life stages, including transportation to different locations and up to the point of slaughter. RFID tags provide traceability information for chickens and enhance farm management in disease control, breeding management, and stock management. In pig farming, RFID technologies have proven beneficial by automating the feeding process and regulating individual pig feed intake. In addition to unique identification, RFID systems can store detailed information about animals, including growth status, medical treatment records, transportation history, and feedback data. This detailed information can be shared among farmers, processors, stockmen, or veterinarians through computer and database management systems. RFID is also employed for tamper detection of animal products along the supply chain, such as detecting unauthorized openings of poultry shipments during transportation. Generally, RFID tags used for animal identification include boluses, ear tags, and injectable glass tags.

Conclusion

Like any emerging technology, RFID technology presents both challenges and opportunities. Implementing this technology faces obstacles such as its unreliability in retail settings, limitations in read range and accuracy, nonuniform standards, cost considerations, and concerns related to recycling. Consumer apprehensions regarding privacy and security further impede the widespread acceptance of this technology. Notwithstanding these challenges, RFID holds great promise for various applications, including supply chain management, temperature monitoring, and ensuring food safety in the food industry. The adoption of RFID technology can enhance efficiency and productivity by improving inventory management, reducing instances of out-of-stock supplies, and minimizing food product spoilage. The establishment of uniform standards and the cost-effectiveness of implementing RFID technology could drive its widespread adoption in the food industry.

References

- Bibi, F., Guillaume, C., Gontard, N., & Sorli, B. (2017). A review: RFID technology having sensing aptitudes for food industry and their contribution to tracking and monitoring of food products. *Trends in Food Science & Technology*, 62, 91-103.
- Brown DE. 2007. RFID implementation. New York: McGraw-Hill. 466 p.
- Finkenzeller, K. (2003). RFID handbook [electronic resource]: fundamentals and applications in.
- Kumari, L., Narsaiah, K., Grewal, M. K., & Anurag, R. K. (2015). Application of RFID in agri-food sector. *Trends in Food Science & Technology*, 43(2), 144-161.
- Roberts CM. 2006. Radio frequency identification (RFID). *Comput Secur* 25:18–26
- Ruiz-Garcia, L., & Lunadei, L. (2011). The role of RFID in agriculture: Applications, limitations and challenges. *Computers and electronics in agriculture*, 79(1), 42-50.
- Tajima, M. (2007). Strategic value of RFID in supply chain management. *Journal of purchasing and supply management*, 13(4), 261-273.
- Want R. 2006. An introduction to RFID technology. *IEEE Pervasive Comput* 5(1):25–33.

* * * * *

Non-Destructive Methods in the Detection of Food Adulteration

Adrita Banerjee

PhD Scholar, Department of Food Technology, Faculty of Life & Allied Sciences, Ramaiah University of Applied Sciences, Bengaluru, India

*Corresponding Author: banerjee.adrita01@gmail.com

Economically motivated food adulteration or food fraud is currently recognized as a global threat to public health and a major food safety concern. The detection methods of food adulteration are often time consuming and involve high-end mechanisms. Therefore, considerable interest has emerged for non-destructive, rapid techniques so as to achieve highly efficient results with use of minimal analytical technology. Although sophisticated lab techniques are accurate, precise, and reliable, yet they are costly and time consuming. It is essential to develop screenings tests which are reliable and quick. "Non-destructive detection of food adulteration" indicates that the analysis of the sample and the collection of its essential features are made in such a way that the physical and chemical properties of the food are not altered.

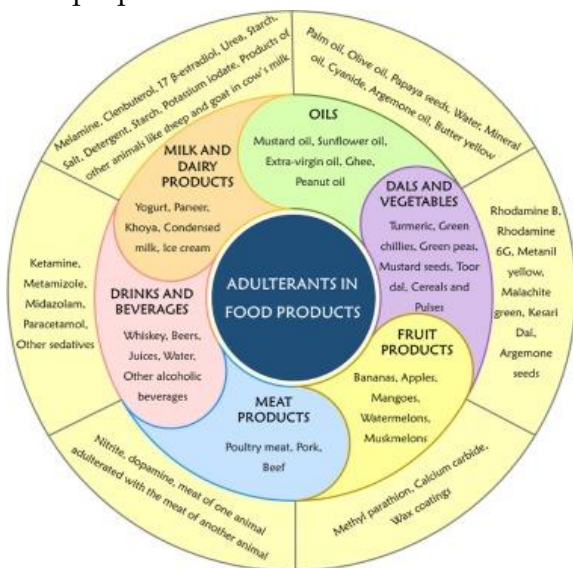


Fig. 1: Common adulterants present in different food products (Source: Ray et al., 2022)

Current Scenario of Food Adulteration

Food Adulteration is performed to achieve more quantity of the food in order to make more profit, following the addition of such chemical substances which should not be present legally or having unwanted status by the recipient. It is astonishing that impostors are at stride ahead of food safety organizations; their escalating technologies protect and allow them to become more refined in their work with each passing moment. Food fraud includes the substitution of an ingredient with a

cheaper alternative, miss description of the real nature of the product or one of its ingredients, incorrect quantitative ingredient declaration, and the utilization of non-acceptable processing practices such as irradiation, heating or freezing. There are various packaging techniques to protect food from external damage, but the question remains that, is the food itself safe? Or is it adulterated with contaminants/adulterants which ultimately pose a threat to human health? Hence, to address this issue, such techniques need to be developed through which time and cost-effective rapid analysis of adulteration can be performed.

Type of Methods

The recently developed analytical methods of food adulteration are non-destructive in nature based on experimental researches conducted with different food items. Based on their working principle and techniques, such methods can be divided broadly into:

- (i) Non-DNA based and (ii) DNA based techniques.

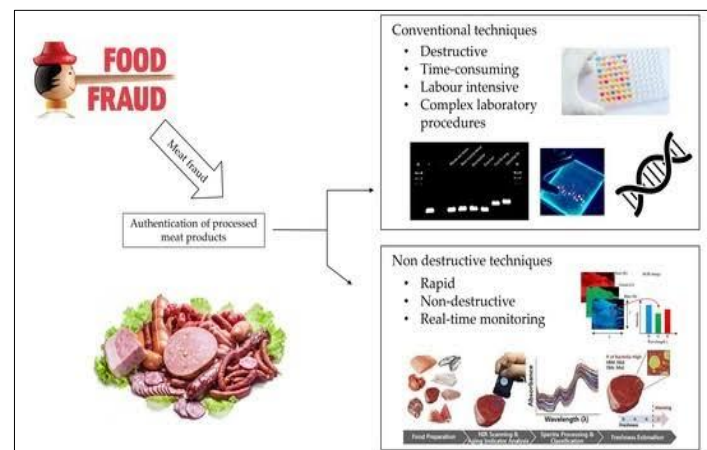


Fig 2. Comprehensive analytical techniques used to detect adulteration in food (Source: Edwards et al., 2021)

Non-DNA based Techniques

Analysis of adulteration by Mass Spectrometry (MS)

Mass spectrometry is an analytical technique for the separation of ionized atoms and molecules according to their mass-to-charge ratio using electrical and magnetic fields in a vacuum and identifying the composition and structure of the chemicals. There are

various methods which uses the principle of MS, such as:

Gas chromatography-mass spectrometry (GC-MS):

This combines gas chromatography and mass spectrometry to identify different substances within a sample. This method is effective in separating compounds into their various individual components and the identification of the specific substances. The GC-MS method combines the capabilities and advantages of both GC and MS analytical approaches. GC-MS combines high resolution separation of components, making it possible to achieve a high level of precision in the identification of unknown chemicals that cannot be achieved using GC or MS separately. GC-MS method has been developed for the detection of honey adulteration with high fructose inulin syrups.

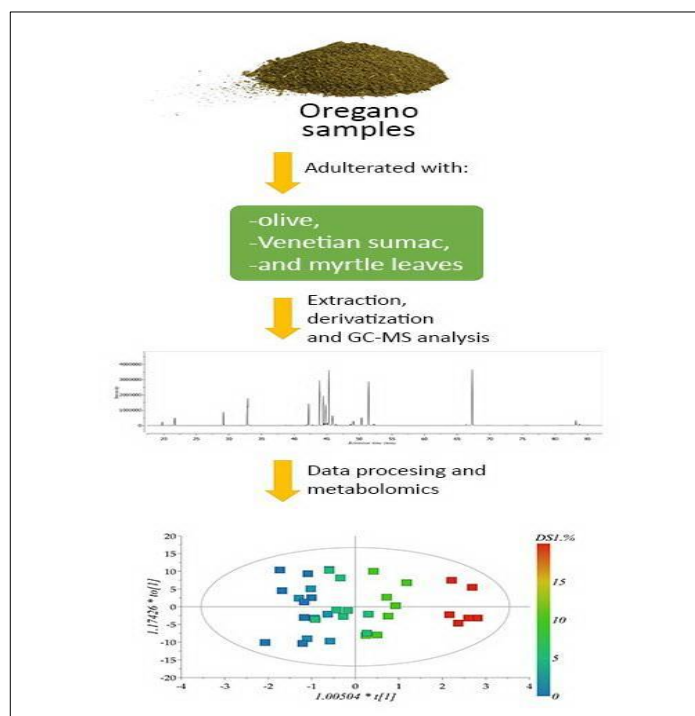


Fig 3. GC-MS-based metabolomics for the detection of adulteration in oregano leaves (Source: Ivanović et al., 2021)

Proton Transfer Reaction Mass: PTR-MS utilizes chemical ionization that is based on proton-transfer reactions; hydroxonium ions H_3O^+ are used as the reagent ions since the volatile compounds have a higher affinity for these ions. This analytical technique has been used for adulteration detection of individual cultivars of extra virgin olive oil through the analysis of volatile organic compounds, when the fraud

involves mixing valuable oil with cheaper oils or by mixing the oil of different cultivars. The instrument has a high sensitivity (i.e., pptv level), fast response time (~1 second) and a compact and robust setup. It is relatively inexpensive and can be fully automated.

Mass Spectrometry with Inductively Coupled Plasma (MS-ICP):

This method utilizes inductively coupled plasma as the ion source and a mass spectrometer for separation and detection. It is characterized by high sensitivity and the ability to identify metals and nonmetals, and in some instances at concentrations not exceeding 10–10 % or one part per 10¹² (trillion) parts. The MS-ICP method makes it possible to obtain isotopic information on the elements determined. Determination of the geographical origin of rice is an example of a practical use. This can prevent possible mislabeling and/or adulteration of rice products.

Isotope Ratio Mass Spectrometry:

The main elemental constituents (H, C, N, O, and S) of bio-organic material have different stable isotopes (^2H , ^1H ; ^{13}C , ^{12}C ; ^{15}N , ^{14}N ; ^{18}O , ^{17}O , ^{16}O ; ^{36}S , ^{34}S , ^{33}S , and ^{32}S). Isotopic ratios can be measured precisely and accurately using Isotope Ratio Mass Spectrometry (IRMS). Analysis of these ratios shows potential for assessing the authenticity of food of animal origin. Researchers have demonstrated that $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope values of fat and defatted fraction have different values between each other depending on if a cheese was produced with raw milk or with pasteurized milk thus allowing differentiation between these 2 kinds of product. Juice adulteration is achieved by either dilution of juice concentrate with water or addition of exogenous sugars. Such products can be detected by measuring ^{18}O , the measurement of the $^{13}\text{C}/^{12}\text{C}$ ratio, or the deuterium content D/H of sugars isolated from the juice, thus making it possible to identify adulterated juices.

High-Performance Liquid Chromatography:

It involves the application of high pressure (400 bar) and a fine-grained sorbent (a granular material made of solid particles 3-5 micrometers in size) to separate a complex mixture of substances quickly and completely (average analysis time is 3-30 min) with high resolution. HPLC effectively analyzes the presence of synthetic dyes in food and detects the

fraudulent addition of bergamot juice to lemon juice by identifying flavanones of bergamot fruit.

Analysis of adulteration by Spectroscopic techniques

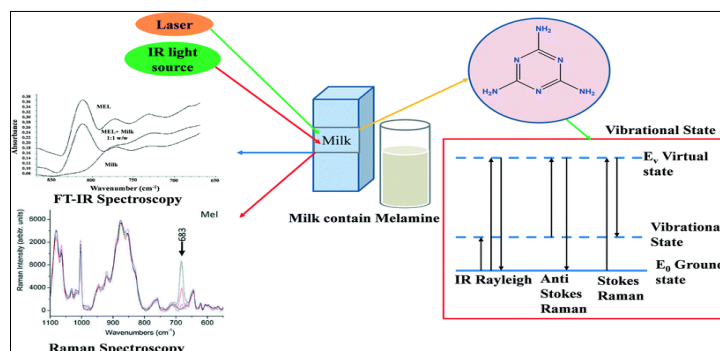
These are the most promising methods as they are quick, simple, require small quantities of the food/sample, and are usually non-invasive. Miniaturization of spectrophotometers and the manufacture of portable or hand-held instruments i.e. in-situ measurements have become a reality. There are many portable spectrophotometers on the market today. They can measure reflectance or transmittance of food/samples and can be used for direct measurement without sample pre-treatment. Some important spectroscopic methods include:

Fluorescence Spectroscopy: Fluorescence spectroscopy utilizes fluorescence emission and excitation spectra of electromagnetic radiation for qualitative and quantitative analysis of the structure and properties of a sample. It is an active process, which is why it is characterized by a high sensitivity. In addition, this technique is very rapid, low-cost and provides non-destructive interaction with the sample. Fluorescence spectroscopy has been utilized for the detection of adulteration of extra virgin olive oil with olive-pomace oil at a level of 5%.

Fourier Transform Infrared Spectroscopy (FTIR): This method works on the principle of interaction of electromagnetic radiations with the molecules of specific food with defined energy. The sensitivity of FTIR ranges from very low parts per million (ppm) to high percent (%) levels. FTIR has been successfully applied to detect grape juice in pure pomegranate juice concentrate and determine the presence of industrial grade glycerol in four brands of red wine at a detection limit of 1%.

Nuclear Magnetic Resonance Spectroscopy: NMR spectroscopy is a technique based on the analysis of the magnetic properties of atomic nuclei that possess spin. NMR spectroscopy is able to qualitatively and quantitatively detect very fine structural components. The adulteration of virgin olive oil with a wide range of seed oils was detected at level as low as 5% by means of application of NMR spectroscopy.

Raman Spectroscopy (RS): This provides spectral information on fundamental vibrations of functional groups in a molecule. It is based on the inelastic scattering of incident radiation through its interaction with vibrating molecules. If a sample has Raman active substances, a small amount of radiation is scattered at different wavelengths due to interactions between the incident electromagnetic waves and the vibration levels of the Raman active molecules in the sample. Surface Active Raman Scattering (SERS) has been used to detect melamine in liquid milk with minimal sample preparation which yielded precise results. This is a simple, fast (only requires about 3



min), cost effective and sensitive method.

Fig 4. Identification of Melamine in Milk using Raman & FT-IR Spectroscopy (Source: Sen et al., 2022)

Analysis of adulteration by Sensor Technologies

Optic sensors: Electronic noses (e-noses) and electronic tongues (e-tongues) crudely mimic the human smell and taste sensors (gas and liquid sensors) and their communication with the human brain. The e-nose often consists of non-selective sensors that interact with volatile molecules that result in a physical or chemical change that sends a signal to a computer which makes a classification based on a calibration and training process leading to pattern recognition. The e-tongue uses a range of sensors that respond to salts, acids, sugars, bitter compounds, etc. and sends signals to a computer for interpretation. Fresh cherry/ tomato juice adulterated with different amounts of the juice from overripe tomatoes has been assessed using e-Nose and e-Tongue measurements, where the simultaneous utilization of both instruments indicated a better performance than when used individually.

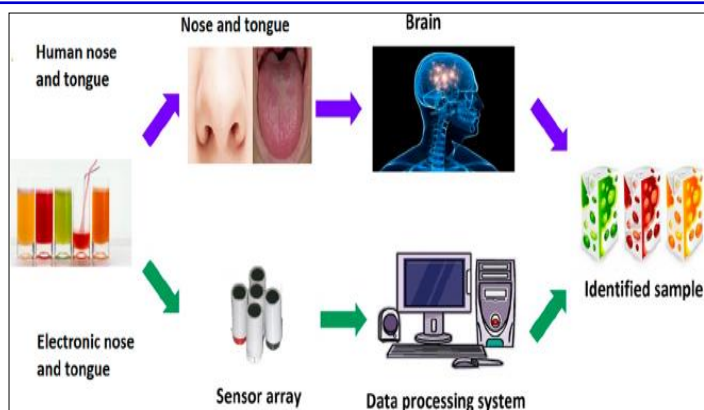


Fig 5. Application of Electronic Nose & Tongue
(Source: Sliwinska et al., 2014)

Nanobiosensors: Nanomaterials based biosensing holds great potential in designing highly sensitive and selective detection strategies necessary for food safety analysis. Several metal ions can be specifically identified by amino acid because of the functional side chain (such as cysteine).

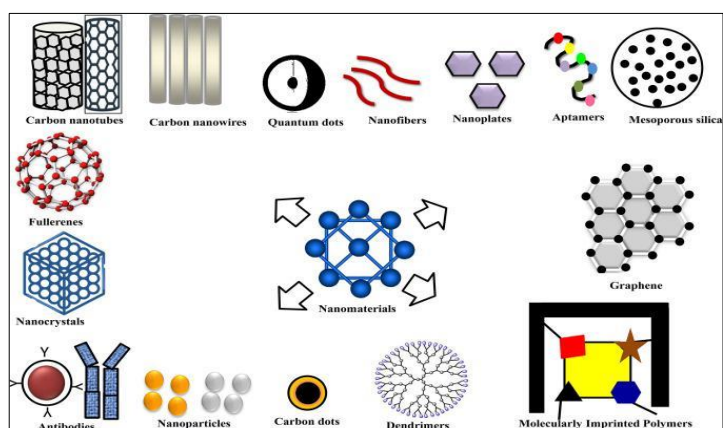


Fig 6. Nanomaterials applied in sensing of adulterants in food samples (Source: Singh, 2023)

DNA based Techniques

Utilization of DNA can be done as an effective tool to detect the adulteration and GMO content in various food products like oil, honey, beverages, baked products, animal feed, fried products, adulteration of milk and milk products. DNA based detection either complement the existing physical, sensory, or biochemical analytical methods or as a stand-alone tool due to its cost effectiveness, high sensitivity and reliability. Two commonly used methods are:

DNA Barcoding: DNA barcoding is a relatively simple technique that is based on the sequence variation in short nucleotide regions called barcodes that enables species identification and commodity authentication.

Efficiency of DNA barcoding in seafood traceability has resulted in its adoption as a method for authentication of fish based commercial products by the US Food and Drug Administration.

DNA Extraction: Extracted DNA can be used as a biomaterial for detecting adulterants. An investigation on adulteration of goat's milk with cow's milk in Taiwan, targeting the specific bovine mitochondrial DNA showed a 25% of adulteration in goat's milk and 50% of debasement in goat's milk powder.

Conclusion

Non-destructive methods play a crucial role in quality control and ensuring the authenticity of food products without compromising the product's physical integrity. Real-Time monitoring during different stages of food production and distribution helps prevent adulterated products from reaching consumers, enhancing overall food safety. The character and nature of the product and the adulterant are critical in selecting the most appropriate and effective analytical method. While the spectroscopic methods have proved to achieve robust results time and again, the emerging biosensing and DNA based technologies offer highly sensitive, accurate and precise identification of adulterants in a vast range of food items.

References

- He, Y., Bai, X., Xiao, Q., Liu, F., Zhou, L., & Zhang, C. (2021). Detection of adulteration in food based on nondestructive analysis techniques: A review. *Critical Reviews in Food Science and Nutrition*, 61(14), 2351-2371.
- Ali, M. M., & Hashim, N. (2022). Non-destructive methods for detection of food quality. In *Future Foods* (pp. 645-667). Academic Press.
- Sørensen, K. M., Khakimov, B., & Engelsen, S. B. (2016). The use of rapid spectroscopic screening methods to detect adulteration of food raw materials and ingredients. *Current Opinion in Food Science*, 10, 45-51.
- Khan, U., Afzaal, M., Arshad, MS., Imran, M. (2015), Non-destructive Analysis of Food Adulteration and Legitimacy by FTIR

- Technology, *Journal of Food and Industrial Microbiology*, 1(1), 103.
- Camin,F., Luana, B., Perini, M., Piasentier, E. (2016), Stable Isotope Ratio Analysis for Assessing the Authenticity of Food of Animal Origin, *Comprehensive Reviews in Food Science and Food Safety*, 15, 868-877.
- Ray, R., Prabhu, A., Prasad, D., kumar Garlapati, V., Aminabhavi, T. M., Mani, N. K., & Simal-Gandara, J. (2022). Paper based microfluidic devices for food adulterants: Cost-effective technological monitoring systems. *Food Chemistry*, 390, 133173.
- Edwards, K., Manley, M., Hoffman, L. C., & Williams, P. J. (2021). Non-destructive spectroscopic and imaging techniques for the detection of processed meat fraud. *Foods*, 10(2), 448.
- Ivanović, S., Mandrone, M., Simić, K., Ristić, M., Todosijević, M., Mandić, B., & Gođevac, D. (2021). GC-MS-based metabolomics for the detection of adulteration in oregano samples. *Journal of the Serbian Chemical Society*, (12), 1195-1203.
- Sen, R. K., Karthikeyan, K., Prabhakar, P., Vishwakarma, J., Gupta, G., Mishra, S. N., ... & Dwivedi, N. (2022). Fast tracking of adulterants and bacterial contamination in food via Raman and infrared spectroscopies: paving the way for a healthy and safe world. *Sensors & Diagnostics*, 1(4), 673-685.
- Sliwinska, M., Wisniewska, P., Dymerski, T., Namiesnik, J., & Wardencki, W. (2014). Food analysis using artificial senses. *Journal of agricultural and food chemistry*, 62(7), 1423-1448.
- Singh, M. (2023). Nanosensor Platforms for Detection of Milk Adulterants. *Sensors and Actuators Reports*, 100159.

* * * * *

Adulteration in Food

Rajeshwari N¹, Shweta Biradar² and Geeta Tamgale³

¹Professor and Head, Department of Extension and Communication Management, College of Community Science, University of Agricultural Sciences, Dharwad, Karnataka, India

²Scientist (Home Science), ICAR-KVK, University of Agricultural Sciences, Dharwad, Karnataka, India

³Assistant Professor, Department of Extension and Communication Management, College of Community Science, University of Agricultural Sciences, Dharwad, Karnataka, India

*Corresponding Author: rajeshwarinavaneeth@gmail.com

Good food is important for a healthy life. The food we eat should not only be balanced but also clean. Except for some vegetables and fruits most of the foods we consume are either processed or preserved. Post-harvest technology implemented to preserve food from spoilage makes lot of difference. Food and food products pass through many stages before reaching the hands of consumers. During processing technological interventions like addition of chemicals, artificial colors, thickening agents, stabilizers, additives and taste makers may be added or any other substance may be added. By the time food reaches the retail market, it loses its original shape, flavor and taste. Besides, any marketer measures a dish in terms of profit and not in the interest of consumer's health. Consumers also go for the price, packaging and advertisements while buying any food item more than for health reasons. Sometimes food is adulterated knowingly or unknowingly or undetected. It is essential for us to know about this as consumers we should be aware and protect ourselves and our children from the ill effects of consuming adulterated food.

So, what is food adulteration?

Food adulteration is the intentional addition of a substitute or the removal of a valuable ingredient from any food, thereby compromising the original taste and quality of the food. Adulteration can be deliberate or inadvertent as deliberate adulteration is done to maximize profits. When food becomes contaminated, it can happen at any stage of food processing, be it through inadvertence or lack of proper handling.

According to (Prevention of Food Adulteration Act. Food and Drug Administration Act 1954) the grounds for calling adulterated food are as follows.

1. If any food item is impure
2. If there is a poisonous substance in the food item
3. If inferior substitutes are added to the food item

4. If a valuable element is removed from the food
5. If the food is prepared in a contaminated environment
6. If there are lot of worms or insects in the food
7. If food is taken from diseased animals
8. If the food contains non-permissible dyes
9. If the container in which the food is stored is made of any toxic material
10. If adulterated preservatives are found in the food or permitted preservatives are present in excess
11. Violation of standards prescribed under the above Act

If any of the above grounds are found, we can lodge a complaint with the authorities concerned. This Act came into force on 1st June 1955. It was again amended in 1968 and 1973. Any such amendment shall be made by the Central Committee or Food Standards.

Similarly, we can categorize the harmful substances like this

1. Deliberate adulteration
2. Minerals found in food items
3. Finding worms
4. If pesticide residue remains
5. If toxic chemicals are added during packing

Health problems caused by deliberate mixing

1. Grains and spices - In grains and spices we find ash, pieces of iron and small stones. When these enter our stomach, they damage the delicate lining of the stomach.

2. Talc stone powder and lime powder -Wheat flour is mixed with talcum stone powder and lime powder. As talcum powder contains silicate, it damages the delicate lining of the stomach. Lime is added to dry ginger. Salt is added to pickles and spices to increase weight.

3. Starch flour i.e. starch is mixed with the ingredients prepared from khawa. Although it does not harm the human health, the quality of the sweets we buy decreases. Besides, color is often added to sweets. Paints and dyes contain lead chromate which is harmful to health.

4. Cyclamates and Additives - Sugar and sugar-like chemicals are added to honey. It does not harm health but reduces purity. Artificial sweeteners like Cyclamates and Additives are added. Too much of these are not good for health. Sometimes the fruit is injected with saccharin to sweeten it. Additives are also used to add color, flavor, processing, detoxification, foaming, to preserve food for a long time. These should be consumed in moderation. Excessive consumption is not good.

5. Asbestos - Asbestos fibers are used to purify soft drinks and fruit juices. If these particles are added excessively in the body, there is a possibility of cancer.

6. Mineral oil is mixed in cooking oil. Mineral oil is cheaper than cooking oil and is mixed in cooking oil. By consuming it, vitamin A is not available to the body.

7. Argemone seeds are mixed with mustard seeds and Argemon oil is added in cooking oil. Its regular consumption causes swelling and small fever blisters on the skin. A long-term effect is to invite cancer. Apart from this, cotton seed oil, used meter oil, linseed oil are mixed in coconut oil and sesame oil.

8. Kesari Dhal: Kesari Dal is similar to Tur Dhal. It is mostly used in Madhya Pradesh, Uttar Pradesh, Bihar and West Bengal. As it grows like a weed, it is a very cheap legume. It is added with chickpea flour. When it is consumed in excess, a disease called lathyrism occurs. It causes numbness in the legs when excessive.

9. Addition of foreign substances to the foodstuff. Seeds of a wild grass similar to cumin are added. Dried papaya seeds are added to the black pepper. Tamarind seed powder and date seed powder are added along with coffee powder. Casia flakes are added to cinnamon. Saw dust powder is added to tea powder and added. Glue is added to the asfoetida.

10. Toxic colors are commonly added in already made food items. Colors are added to attract children and enhance the taste of food items. Colours are mainly added to ice creams, milk products, biscuits, chocolates, candies, pastries, fruit products, processed vegetables, jellies, soups and soft drinks. Lead Chromate, Metanil Yellow, Rhodamine B, Orange 1&11. These colors are usually added to all the sweets available in the shops. Its excessive consumption can cause damage to bones, eyes, skin, lungs and cause mental retardation and anemia in children. Mixed colors found in various foods are Metanil Yellow - ice candy, phaluda, ice cream and pulses.

Orange 11- Halwa

Rodamine B - Red chilli powder

Blue VR S - Churan Sweets

Armine -Fennel seeds and Supari

Melachite Green - sweet snacks and peas

Small tests that can be done to detect adulteration in food

1. Pulses: 5 grams of pulses are mixed with 5 ml of water to test presence of metanil yellow content in pulses. A couple of drops of hydrochloric acid should be added to the water, if metanil yellow is present the solution will turn pink.
2. Kesari dal is mixed with tur dal and can be easily identified in Tur Dal as the shape is slightly different.
3. Iron filings in semolina When semolina is placed on a plate and a magnet is passed over semolina, the iron filings stick to the magnet.
4. Porridge flour is often added to milk and milk products. To check this, add a drop of iodine solution to milk or milk products. If there is starch the milk turns blue.
5. To know the addition of lime powder in wheat flour, wheat flour is mixed with dilute hydrochloric acid, if lime powder is present, it will foam.
6. To detect the inclusion of papaya seeds in the black pepper, immerse the seeds in Carbon Tetra Chloride. Papaya seeds will float and black pepper seeds will sink.

7. Dry dung is added to coriander seed powder or coriander powder. When coriander powder is added to water the dung floats on top and the coriander powder settles down.
8. To detect artificial color in tea powder, sprinkle tea powder on a piece of wet blotting paper, the blotting paper will get colour if tea is adulterated
9. If hydrochloric acid is added to jaggery and it turns red, it means metanil yellow is present
10. When hing is put in water if there is no impurity it melts and becomes like milk.

An important point emerges when examining the above issues. The food we eat should be clean and devoid of impurities and adulterants. But sometimes we cannot avoid eating impure food, so we should include foods which contain lot of fibre. Apart from that, we should process and consume food only when necessary. A clean diet should focus on maintaining good health. As our forefathers said, health is a blessing, it can be maintained only by eating clean and healthy food.

* * * * *

Guardians of Food Safety: Navigating Physical, Chemical and Biological Hazards in the Culinary Landscape

P. Jayamma¹, S. Pavana Deepthi², R. Aruna¹ and B. Manjula³

¹Assistant professor, Department of Food Safety and Quality Assurance, College of Food Science and Technology, ANGRAU, Pulivendula, A.P.

²Teaching Associate, Dept. of Food Processing Technology, College of Food Science and Technology, ANGRAU, Pulivendula, A.P.

³Assistant Professor, Dept. of Processing & Food Engg., College of Agricultural Engineering, ANGRAU, Madakasira.

*Corresponding Author: p.jayamma@angrau.ac.in

Food safety means assurance that food is acceptable for human consumption according to its intended use. An understanding of food safety is improved by defining two other concepts – toxicity and hazard.

Toxicity is the capacity of a substance to produce harm or injury of any kind under any conditions. Hazard is the relative probability that harm or injury will result when substance is not used in a prescribed manner and quantity. Hazards can be physical, chemical and biological causing harmful / adverse effects on the health of consumers.

Physical hazard is any physical material not normally found in food, which causes illness or injury and includes wood, stones, parts of pests, hair etc.

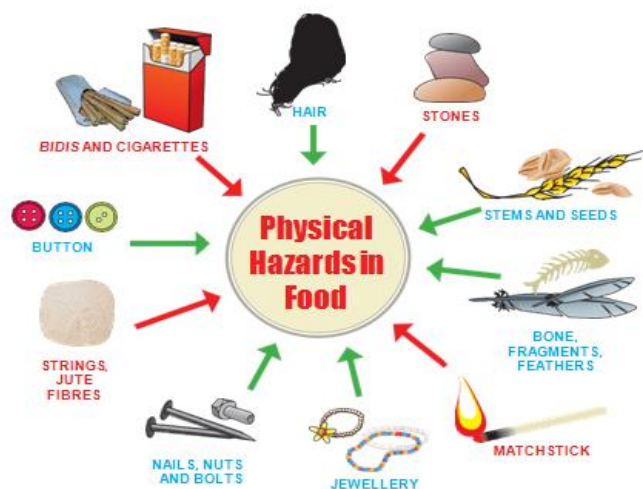


Fig.1: Physical hazards in foods

Chemical hazards are chemicals or deleterious substances which may be intentionally or unintentionally added to foods. This category of hazards includes pesticides, chemical residues, toxic metals, polychlorinated biphenyls, preservatives, food colors and other additives

Biological hazards are living organisms and include microbiological organisms (Fig.3 and Fig.4). Those micro-organisms which are associated with

food and cause diseases are termed food-borne pathogens. There are two types of food-borne diseases from microbial pathogens – infections and poisoning.

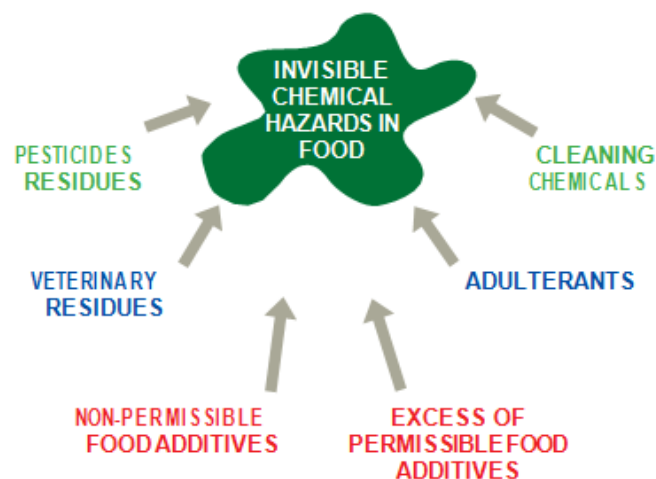


Fig.2: Chemical hazards in foods

Food infection /Food Poisoning results from ingestion of live pathogenic organisms which multiply in the body and cause disease. Salmonella is a classic example. This organism exists in the intestinal tract of animals. Raw milk and eggs are also sources. Heat destroys Salmonella; however, inadequate cooking allows some organisms to survive. Often Salmonella is spread through cross-contamination. This could happen when a cook cuts raw meat/poultry on a chopping board and without cleaning uses it for another food which does not involve any cooking, such as salad. Food may become infected by Salmonella if an infected food handler does not wash hands with soap after using bathroom and before touching food. Salmonella can reproduce very quickly and double their number every 20 minutes. The symptoms of Salmonella infection include diarrhea, fever and abdominal cramps.

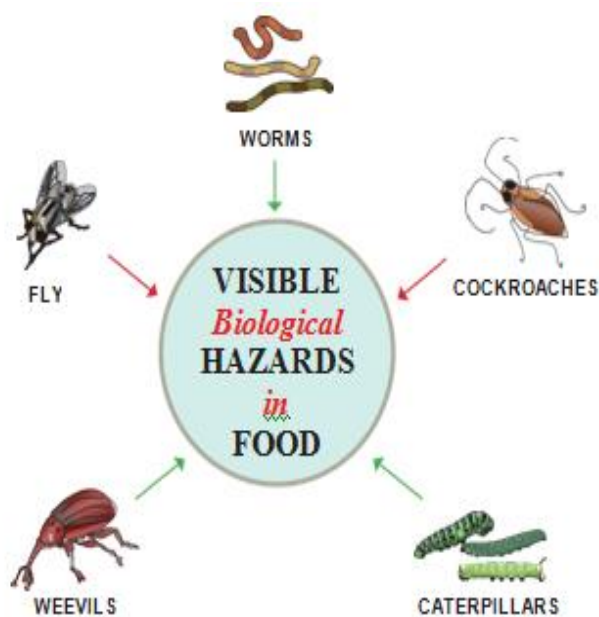


Fig.3: Visible biological hazards in foods

Food intoxication: Some bacteria produce harmful toxins which are present in food even if pathogen has been killed. Organisms produce toxins when the food has not been hot enough or cold enough. Toxins in food cannot be detected by smell, appearance or taste. Hence foods which smell and appear good are not necessarily safe. One example of

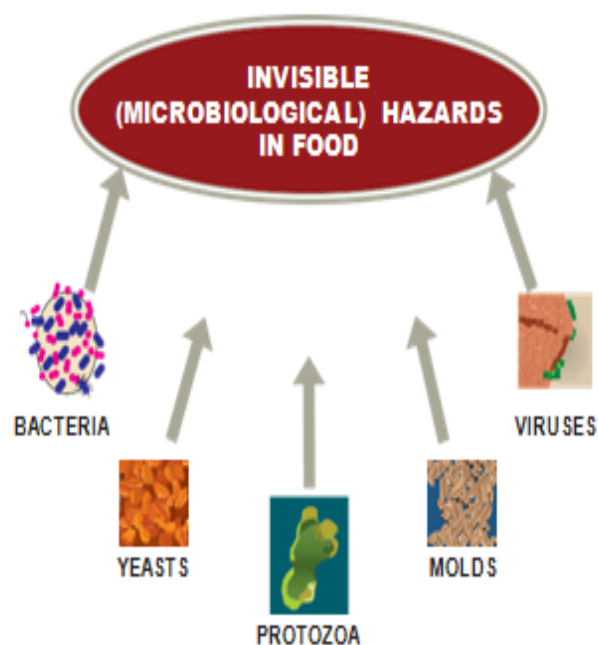


Fig.4: Invisible/microbiological hazards in foods such an organism is *Staphylococcus aureus*. Such organisms exist in air, dust, water. They are also present in the nasal passage, throat and on skin, hair of 50 per cent of healthy individuals. People who carry this organism, contaminate food if they touch these places on body while food handling. Diarrhea is also one of the symptoms of this contamination.

* * * * *

Antibiotic Residues in Milk-A Threat to Food Safety and Quality

Prince^{1*}, Somveer², Dimple³, Deshmukh R.R.⁴ and Nitish⁵

¹Ph. D. Scholar, Dairy Chemistry Division, ICAR-National Dairy Research Institute, Karnal

²Ph. D. Scholar, Dairy Engineering Division, ICAR-National Dairy Research Institute, Karnal

³M. Tech. Scholar, Department of Dairy Chemistry, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar

⁴Ph. D. Scholar, Dairy Microbiology Division, ICAR-National Dairy Research Institute, Karnal

⁵B. Tech. (Dairy Technology), Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar

*Corresponding Author: princendhanda29111998@gmail.com

Abstract

Across the world, the presence of antibiotic residues in animal-based food products is the major threat to the food safety and quality. The antibiotic residues in dairy products may lead to the occurrence of antimicrobial resistance among microorganisms or potent pathogens. The condition is more severe in developing countries like India due to lack of testing facilities, poor infrastructure at ground level, lack of education among the farmers and lack of awareness among the consumers. The consumption to milk and milk products contaminated by antibiotic residues should be stopped. Preventive measures should be taken to avoid the development of anti-microbial resistance among the pathogens.

Introduction

Food safety and quality is the matter of prime importance in recent times. Nowadays, the consumers are ready to pay more, for safe and high-quality food products. The food safety not only includes food free from adulterants but also from contaminants as well. Milk is the most consumed beverage across the globe. Milk is thought to be a complete food as it contains carbohydrates, fats, proteins, vitamins, and minerals in significant amount. Milk is consumed by people of all ages due to its pleasant taste, flavor, nutritional and therapeutic properties (Connie, 2010). Despite of huge nutritional availability the image of milk has been tainted in recent times because of presence of various adulterants and contaminants like antibiotics. India ranks first in milk production in the world but does not export the dairy products in significant amount because of not fulfilling the international food quality standards (Mohan, 2022). Food Safety and Standards Authority of India (FSSAI) has conducted a survey in 2019, showed that 77 samples (out of 6,432 samples) had antibiotics residues above the permissible limits (FSSAI, 2019), which means that the milk available throughout the country is largely safe with respect to

chemical adulterants, but the antibiotic residues in dairy products is a more serious problem than adulteration.

Antibiotics

Antibiotics are chemical substances naturally produced by microorganisms or synthetically, which at low concentration destroy or prohibit the proliferation of microorganisms resulting in minor or no host damage. In other words, antibiotics are chemical substances used to inhibit the growth of pathogens or diseases causing microorganisms. Antibiotics are the secondary metabolites of the microorganisms produced by the microorganisms to restrict the growth of other microorganisms.

Use of Antibiotics

In dairy animals antibiotics are mainly administered for the purpose of treatment of diseases, growth promotion and increased productivity. The use of antibiotics in animals has increased drastically. The use of antibiotics has transformed the dairy industry by offering several advantages including enhanced growth, increased production efficiency, obviating diseases, resulting in reduced prevalence of diseases, morbidity and mortality (Dafale *et al.*, 2016).

Antibiotic Residues in Milk

When any antibiotic is administered to the milch animal for treatment of disease or for prophylactic purpose the antibiotic residues gain entry in milk and get excreted out of the body of the animal through the route of milk. In this way the antibiotic residues gain entry into the milk. It is the one of the main reasons behind the entry of veterinary drug residues in the human food chain.

However, using antibiotics provides several advantages for the growth of dairy sector. On the other hand, indiscriminate use of antibiotics in farm animals leads to occurrence of antimicrobial residues in milk and thereby pose major food safety risk to consumers in terms of development of anti-microbial resistance

among the microorganisms and difficulties in processing of milk, like starter failure in fermented products.

Adverse Effects of Antibiotic Residues on Human Health

Antibiotic residues in milk and milk products poses various adverse health effects in humans which includes hypersensitivity reaction, carcinogenicity, teratogenicity, mutagenicity, nephropathy and disruption of normal intestinal flora. Antibiotic residues pose serious threats to human health as these residues may result in allergic reactions in hypersensitive individuals and may lead to emergence of anti-microbial resistance.

Maximum Residue Limit (MRL)

The maximum residue limit of antibiotic residue is the maximum concentration of residue legally permitted to occur in foods obtained from animals to which antibiotics are administered. In order to exert control on the problem antimicrobial residues in animal-based food products, the food safety authorities in many countries have established MRL. The food product containing antibiotic residues below MRL doesn't exert any significant effect on the health of the consumer. The problem arises when the MRL of the product is not followed due to lack of maintaining withdrawal time, poor infrastructure and lack of testing facilities at the ground level.

Economic loss to the Dairy Industry

The milk contaminated with antibiotic residues poses several problems to the dairy industry. The antibiotic residues containing milk shows more time in the MBRT test, which is used to estimate the microbial load of the milk. In this way the substandard milk may also pass the test. It also causes technical problems in dairy industry in the form of starter culture failures in case of fermented products (Kebede *et al.*, 2014), which leads to huge financial losses to the dairy industry. The antibiotic residues in milk are responsible for the slow fermentation process in dairy-based probiotic drinks. Microencapsulation is used to enhance the resistance of probiotics to unfavorable conditions (Kumari *et al.*, 2023).

Measures to Control Antibiotic Residues in Milk

Withdrawal Time- The withdrawal time is the necessary for the drug or antibiotic residues concentration to fall below the MRL. The withdrawal time of the antibiotics should be strictly followed in order to maintain food quality and safety.

Infrastructure Development- Proper infrastructure should be developed at the ground level to check the quality of the milk and ensure food safety, as shown in fig. 1. Testing of various products should be done regularly to prevent the sale of antibiotic residue containing products in the market.

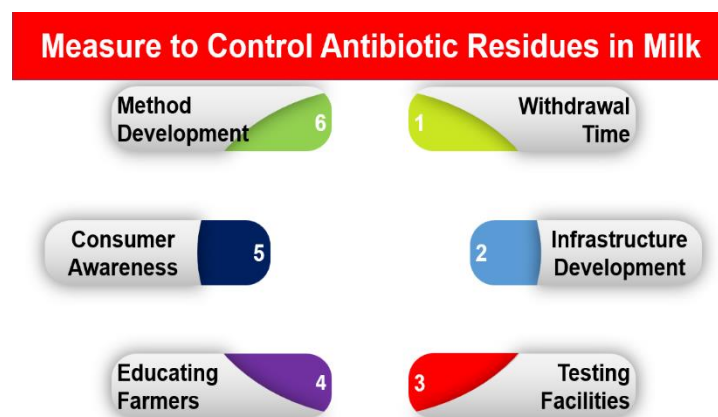


Fig. 1: Measures to control antibiotic residues in milk

Testing Facilities- There should be availability of testing facilities at grassroot level, so that the milk samples can be tested for antibiotic residues at the earliest stage.

Educating Farmers- There is lack of education among the farmers regarding the use of antibiotics as well as withdrawal time and MRL so in order to ensure production of antibiotic free milk the farmers/producers should be properly educated about the use and adverse health effects of antibiotic residues in milk.

Consumer Awareness - In developing countries like India there is lack of awareness among the consumers about the presence of contaminants in animal-based food products. Awareness among the consumers is necessary to prevent the use of milk containing antibiotic residues (Fig. 1).

Development of Rapid Methods- Some simple, inexpensive and rapid methods should be developed

to detect the antibiotic residues in raw milk at the time of procurement of milk so that the antibiotic residues containing milk is not pooled with safe milk.

Future Aspects

The problem of antibiotic residues in dairy products can lead to a global threat of anti-microbial resistance among some of the most potent pathogens, which may lead to some serious diseases with no cure at all. Also, the antibiotic residues in milk are responsible for huge monetary losses to the dairy processing industry. Considering these points, there should be more thrust on the research in this particular area to tackle the problem in a sustainable and effective manner.

Conclusion

With rapid increase in milk production, per capita availability and consumption, it is highly important to ensure that the milk supplied to consumers is of good quality to ensure the food safety. The milk should be free from adulterants as well as various contaminants like antibiotic residues. Antibiotic residues found in milk and milk products pose a significant threat to the safety of consumers and their detection in milk and milk products is essential to ensure compliance with the national and international regulatory standards. Some rapid strip-based test may be developed to check presence of antibiotic residues in milk in order to ensure the supply of milk having good quality to the consumers.

References

- Connie, M. W. 2010. Role of dairy beverages in the diet. *Physiology and Behavior* **100**: 63-66.
- Dafale, N. A., Semwal, U. P., Rajput, R. K., & Singh, G. N. 2016. Selection of appropriate analytical tools to determine the potency and bioactivity of antibiotics and antibiotic resistance. *Journal of Pharmaceutical Analysis*, **6**(4), 207-213. <https://doi.org/10.1016/j.jppha.2016.05.006>.
- FSSAI. 2019. FSSAI Survey: Your Milk is Largely Safe. Food Safety and Standards Authority of India, Ministry of Health and Family Welfare, Government of India, New Delhi, India.
- Kebede, G., Zenebe, T., Disassa, H. and Tolosa, T. 2014. Review on detection of antimicrobial residues in raw bulk milk in dairy farms. *African Journal of Basic and Applied Sciences*. **6**(4):87-97.
- Kumari M., Somveer, Chopde S. S., Pramanik A. and Bakeeru L. 2023. Encapsulation of probiotic cultures for dahi using spray and freeze drying. *AgriTech Today*, 1(Special Issue), 66-69.
- Mohan, V. 2022. World Dairy Summit in India to take up export issue of liquid milk. Times of India 17. May 2022. Available at <https://timesofindia.indiatimes.com/india/world-dairy-summit-in-india-to-take-up-export-issue-of-liquid-milk/articleshow/91624229.cms>. Accessed on 24.5.2022.

* * * * *

Conjugated Linoleic Acid (CLA)

***Sneha Shende¹, Gajanan Narnaware² and Prashant Wasnik³**

¹Assistant Professor, Dairy Chemistry Department, College of Dairy Technology, Warud (Pusad, Yavatmal, Maharashtra)

²Assistant Professor, Dairy Business Management, College of Dairy Technology, Warud (Pusad, Yavatmal, Maharashtra)

³Professor and Head, Dairy Engg. Department, College of Dairy Technology, Warud (Pusad, Yavatmal, Maharashtra)

*Corresponding Author: snehashende@mafsu.in

Abstract

CLA, also known as bovinic acid or rumenic acid, is a type of fatty acid. It is a mixture of positional and geometric isomers of linoleic acid that the rumen bacteria convert from linoleic acid. It is the only naturally occurring substance that has been proven to prevent cancer. It is considered as a healthy fat that occurs naturally in many foods, particularly milk and meat from ruminants such as cows, sheep, and goats. It is a powerful cancer fighter along with numerous other health benefits such as prevents obesity, atherosclerosis, and type 2 diabetes.

Chemistry and Definition

Conjugated linoleic acid (CLA) is a group of polyunsaturated fatty acids that are positional and geometric isomers of linoleic acid (C18:2), molecular formula C18 H32 O2. It contains 18 carbon atoms and two double bonds holding the chain together, similar to Linoleic Acid (LA). The main distinction is in the placement of those bonds. Its precursor i.e trans vaccenic acid, are naturally produced during bacterial fermentation in the rumen of ruminant animals.

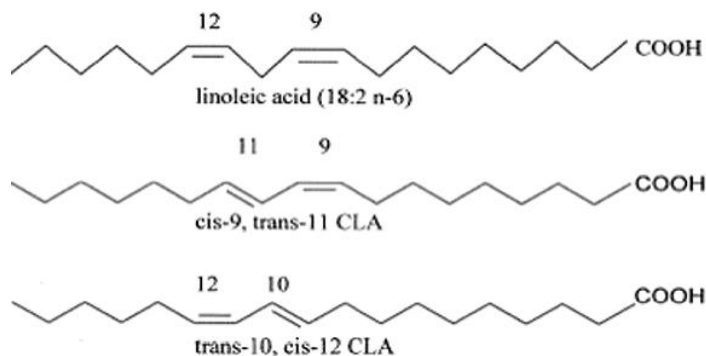


Fig 1: structure of linoleic acid, CLA (c-9, t-11) & (t-10, c-12)

Natural Conjugated Linoleic Acid Sources

Conjugated linoleic acid content is higher in grass-fed animals and their products than in animals fed grains or other types of fodder. CLA levels in grass-fed meats can range between 300 and 500 times higher. CLA levels in grass-fed milk products such as whole milk, cream, butter, cheese, and yogurt

were extremely high. Fermented dairy products are incredibly high in CLA due to lactic acid bacteria, and fermentation increases the CLA content. Furthermore, beneficial bacteria found in the digestive tract can produce CLA, which aids in maintaining healthy gut flora. Dairy products are the richest source of CLA, accounting for roughly 70% of total dietary CLA, compared to 25% from beef and smaller amounts from other ruminants. Organic milk contains the most CLA. As a result, non-vegetarians, ova-vegetarians, and lacto-vegetarians can quickly meet their conjugated linoleic acid needs. Due to a restricted diet, vegans struggle to get their daily dose of CLA. It can be found in cooking oils such as sunflower and safflower. Cooking foods may raise CLA levels.

Meat from grass-fed cows, sheep, bison, goats, and other ruminant animals is also high in CLA. It is naturally produced in the digestive tracts of ruminants such as cattle, goats, sheep, buffalo, and, to a lesser extent, pigs, chickens, and turkeys, and the synthesis occurs via fermentative bacteria, *Butyrivibrio fibrisolvens*, which isomerize the linoleic acid in CLA, or via 9-desaturase of 11-trans octadecanoic acid. Beef fat has 9-cis and 11-trans isomers of CLA and contains between 1.7 and 10.8 mg of CLA per gram of fat. Organically raised grass-grazed breeds have additional advantages such as being hormone- and antibiotic-free, having lean protein, and having a lower fat content.

Artificial Conjugated Linoleic Acid Sources

Commercial supplements containing CLA are also available. Commercially, CLA can be produced by modifying the chemical structure of vegetable oils. During this artificial modification, the original structure of the CLA is completely compromised. Thus, the health benefits of CLA from natural foods cannot be met by the synthetic form of CLA.

Process Influence on Conjugated Linoleic Acid

During processing and storage, the lipids in milk and milk products undergo structural, chemical, and physical changes. Nutraceuticals such as CLA,

sphingomyelin, and butyric acid are found in milk lipids. Trans fats are formed in the lipids of cattle's rumen during biohydrogenation. However, they can also form during high-temperature cooking methods such as baking or frying. A study concluded that, with the exception of microwave heating, heat treatments and refrigerated storage of milk and dairy products, did not result in significant changes in the

fatty acid composition of meat and milk. The microbiology of biohydrogenation in the rumen has received a lot of attention, but similar research on the human intestinal microbiota has yet to be done.

Roseburia species were found to be among the most active in metabolizing linoleic acid (cis-9, cis-12-18:2) in a survey of 30 representative strains of human gram-positive intestinal bacteria. Various Roseburia spp. In human tissues and the intestine, these compounds are precursors of the health-promoting conjugated linoleic acid cis-9, trans-11-18:2. CLA is simply a rumen bacterial excretory metabolite or metabolic intermediate. It is typically produced in ruminants for symbiotic purposes, promoting the animals' health and longevity.

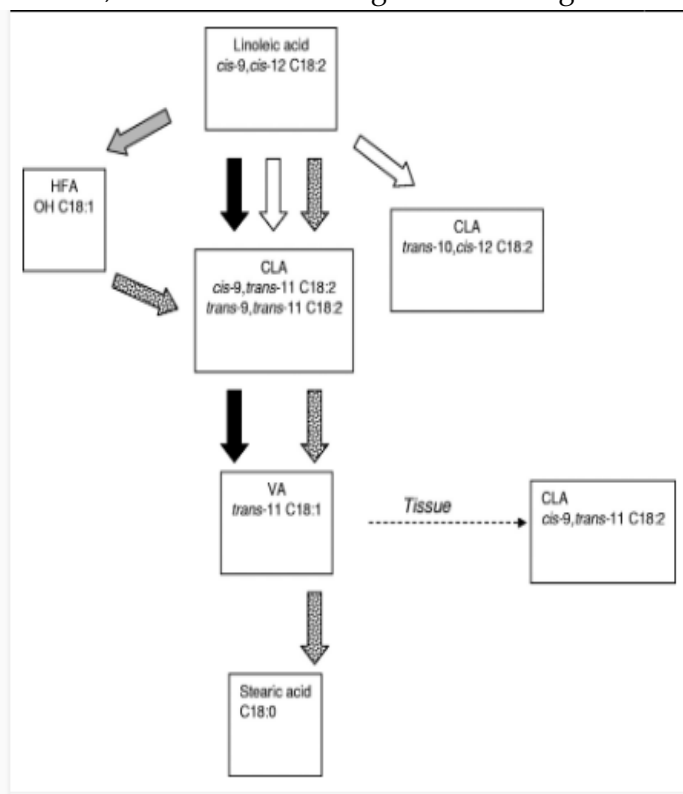
Animal studies and clinical trials have indicated that CLA may be useful in improving human health. The uptake of CLA formed in the intestine seems to be minor. However, local effects on gut tissue might be anticipated. It is now well established that CLA have antiproliferative and anti-inflammatory effects on colonocytes, so provision of CLA in the intestinal lumen could be considered beneficial, particularly for inflammatory bowel diseases, such as ulcerative colitis and Crohn's disease. Bacteria from other ecosystems and from food products which are also found in the human gut, including strains of *Lactobacillus*, *Propionibacterium*, and *Bifidobacterium*, have been known for some time to possess the ability to generate CLA.

Conjugated Linoleic Acid's Physiological Effects and Health Benefits

CLA is gaining popularity due to its purported weight-loss, anti-atherosclerotic, anti-diabetic, and hypotensive properties. Some studies have found that CLA supplementation improves insulin resistance and influences osteoarthritis pathogenesis by modulating inflammatory factors. CLA has been shown to have health benefits in the prevention and management of various conditions, including cardiovascular disease, cancer, and obesity, and it may change body composition by lowering body fat percentage.

Reduction in Body Fat Percent

The possible mechanism by which CLA can alter body composition involves metabolic changes



trans fatty acid isomer and CLA contents.

Fig. 2 Pathway Linoleic Acid metabolism by bacterial Species isolated from human gut

Conjugated Linoleic Acid Metabolism and Bioavailability

CLA is a trans-fatty acid, but it is a natural trans-fat found in various healthy foods and has health benefits. Much research indicates that industrially produced trans-fat has adverse health effects. Naturally occurring trans fats differ from the previous type and may benefit consumers' health. Linoleic acid (LA) (cis-9, cis-12-18:2) is metabolized in the human colon by conjugated linoleic acids (CLA) (primarily cis-9, trans-11-18:2) to vaccenic acid (VA) (trans-11-18:1) (both of which are beneficial to health) and then to stearic acid (18:0). A similar pathway occurs in the rumen, where this process, known as biohydrogenation, has significant implications for the

that favor the reduction of lipogenesis and the potentiation of lipolysis, accompanied by fatty acid oxidation in skeletal muscle, due to increased carnitine palmitoyl-transferase-1 activity and action, or possibly because of adipocyte differentiation inhibition. Therefore, researchers studied the effect of CLA supplementation on the lipid and hormone profiles, as well as the activity of the enzymes involved in the oxidation process. According to research, CLA isomers 10-trans and 12-cis, as opposed to 9-cis 11-trans, significantly increase lipolysis in human adipocytes while decreasing fatty acid synthesis. This would explain some of the possible CLA action mechanisms on body composition.

Even though the research was done in vitro, the metabolic hypotheses to explain CLA's body fat-lowering action began with the control of the expression of genes involved in the differentiation of pre-adipocytes into mature adipocytes; in other words, the expression of these genes would result in reduced lipogenesis. CLA appears to interact with the PPAR Co-activator complex, increasing gene transcription related to adipocyte differentiation, lipolysis (-oxidation), mitochondrial biogenesis, and insulin sensitivity, all associated with weight loss.

CLA's fat-lowering properties were discovered in rodents first, and the debate over whether they can be extrapolated to humans continues. Several mechanisms of action have been proposed, including decreased energy intake, increased energy expenditure, reduced adipocyte size, inhibition of preadipocyte differentiation, increased adipocyte apoptosis, inhibition of lipogenesis in the liver and adipose tissue, and increased fat oxidation in the liver and adipose tissue. Several recent reviews have focused on these issues.

Obesity and Body Fat Loss

CLA supplementation has been shown to improve weight loss. CLA supplementation increased energy expenditure while decreasing body fat in animal studies. CLA stimulates the activity of carnitine palmitoyl transferase, an enzyme that transports fat into mitochondria for oxidation. CLA improves fat storage utilization while increasing the basal metabolic rate. The naturally occurring CLA can

also improve the subjects' overall metabolic health. CLA may also increase bone density in animals, according to some studies.

Cardiovascular Disease Prevention

Natural CLA protects the heart by acting as an antioxidant and lowering blood pressure. It may prevent plaque formation and atherosclerosis by promoting the oxidation and utilization of body fat.

Cancer Avoidance

CLA has anti-carcinogenic properties and helps to prevent cancer formation. CLA is thought to influence prostaglandin synthesis and the fat-soluble vitamin pathway. It improves cellular function and thus helps to prevent neoplasia.

Conjugated Linoleic Acid in Food Applications

The increased interest in increasing CLA content in food products is attributed to its potential anti-carcinogenic, anti-diabetic, anti-atherogenic, and immunomodulatory functions in animals and humans. The health benefits of high-CLA milk and its products provide a niche market opportunity.

Dairy products and beverages concentrate on incorporating additional CLA as a functional food into diets because they naturally contain CLA. Aside from regular dairy products, milk-based beverages used in sports nutrition can improve athletes' endurance and positive weight regulatory mechanisms. CLA can be added to a variety of foods. Its potential market remains in meal replacement drinks, juices, smoothies, shakes, sports bars, cookies, and biscuits, where dairy products are freely used.

In this sense, consuming foods naturally enriched with CLA (rather than supplementation) over a lifetime would be an alternative to reducing excess adiposity. Furthermore, it may reduce the risk of other obesity-related diseases by ensuring beneficial effects on body composition without adding adverse health effects. Evidence suggests that CLA isomers affect blood lipids, tissue metabolism, cell functions, and transcription factors, which may improve health. However, studies with dietary supplements of various CLA isomers, either alone or in combination, have negatively affected human nutrition and health.

Concerns about the safety of CLA supplementation

CLA supplements may not be as beneficial as the natural form. They may also cause stomach aches, constipation, diarrhea, and nausea. Excessive CLA consumption can result in fatty liver, metabolic abnormalities, inflammation, and insulin resistance. As a result, dietary CLA may be considered a better option than artificial supplementation. However, the American FDA allows CLA to be added to foods and has granted it GRAS (Generally Regarded as Safe) status.

Despite studies on CLA supplementation in animals and humans to investigate changes in body composition and other benefits, they should be more discordant. CLA's ability to positively alter body composition by reducing fat mass has been demonstrated in experimental models and some human studies. Few studies have been conducted in humans to assess the effects of CLA alone or in combination with physical exercise on changes in

body composition. As a result, the clinical evidence regarding the effects on body fat reduction needs to be more comprehensive, and significant side effects have already been described.

Conclusion

Conjugated Linoleic Acid is found in many foods, particularly milk and meat from ruminants such as cows, sheep, and goats. It is the only naturally occurring substance that has been shown to prevent cancer unequivocally. CLA's functional properties included increased energy expenditure, reduced body fat, and heart-friendly and anti-carcinogenic properties. It is also known to significantly reduce body weight by increasing lipolysis and fat oxidation. CLA can be fortified or enriched in a variety of foods. Aside from regular dairy products, sports nutrition products can also be aimed at incorporating CLA into diets. However, dietary CLA is preferable to artificial supplementation.

* * * * *

Edible Coatings for Fruits and Vegetables- A New Opportunity for Farmers

Sandeep Bhardwaj^{1*} and Rupali Sharma²

¹Department of Basic Engineering, COAE&T CCSHAU Hisar Haryana-125004, India

² Department of Horticulture, COA, CCSHAU Hisar Haryana-125004, India

*Corresponding Author: bsandeep@hau.ac.in

The herbal extracts such as rosemary, oregano, thyme, and cinnamon are being used in active edible coatings for fruits and vegetables. These extracts contain natural antioxidants and antimicrobial compounds that can extend the shelf life and prevent spoilage. Studies have shown that coatings made with rosemary extract significantly reduced the decay of strawberries during storage, while coatings made with cinnamon extract effectively inhibited bacterial growth on apple slices. These findings suggest that herbal extracts can serve as natural alternatives to synthetic preservatives in edible coatings. This emphasizes that these extracts contain natural antioxidants and antimicrobial compounds that can help to preserve the quality of fruits and vegetables.

Edible coatings or films are a combination of polysaccharides, proteins, lipids, and plasticizers, used to enhance the functional properties and the general quality parameters of fruits and vegetables, such as texture, colour, acidity, total soluble solids, thus preventing their browning and oxidation. Casting (wet process) and extrusion (dry process) are two prominent methods used to fabricate edible thin films. General techniques for applying edible coatings are dipping, spraying, coating, panning, using a fluidized bed, and film wrapping. Active edible coatings or films are developed with herbal extracts to improve the functional properties, i.e., antioxidant and antimicrobial quoted from (Murugan et al., 2022).

Methodology

Some examples of foods that commonly use edible coatings include fresh produce such as strawberries, grapes, and apples, as well as meat and poultry products. The use of edible coatings has been shown to extend the shelf life of these foods by reducing spoilage and preventing contamination. For instance, a chitosan-based coating significantly reduced the decay rate of strawberries during storage (Pham et al., 2022). A whey protein isolate-based coating effectively reduced the weight loss and spoilage of chicken breasts during refrigerated storage (Pham et al., 2022). Overall, edible coatings offer a

sustainable and eco-friendly alternative to traditional packaging materials, as they are biodegradable and can be consumed along with the food. However, further research is needed to optimize the formulation and application of edible coatings for different types of foods and to ensure their safety for human consumption and poultry products. The use of edible coatings has been shown to extend the shelf life of these foods by reducing spoilage and preventing contamination. However, further research is needed to optimize the formulation and application of edible coatings for different types of foods and to ensure their safety for human consumption.

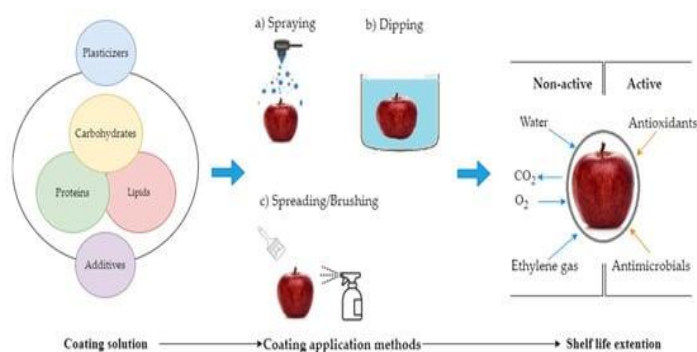


Fig 1. Process of Coating in the Fruits and vegetables

However, the effectiveness of these coatings may depend on factors such as the type of fruit, the concentration of antimicrobial compounds, and the application method. A chitosan-based coating with added essential oils significantly reduced the microbial load and spoilage of strawberries during storage (Pham et al., 2022). A coating containing a combination of chitosan and grapefruit seed extract effectively controlled the decay of kiwifruit during storage (Pham et al., 2012). Overall, the use of antimicrobial compounds in edible coatings has the potential to significantly reduce the microbial load and diseases in fruits, which can result in improved quality and safety for consumers. However, further research is needed to optimize the formulation and application of these coatings for different types of fruits and to ensure their safety for human consumption and the application method.

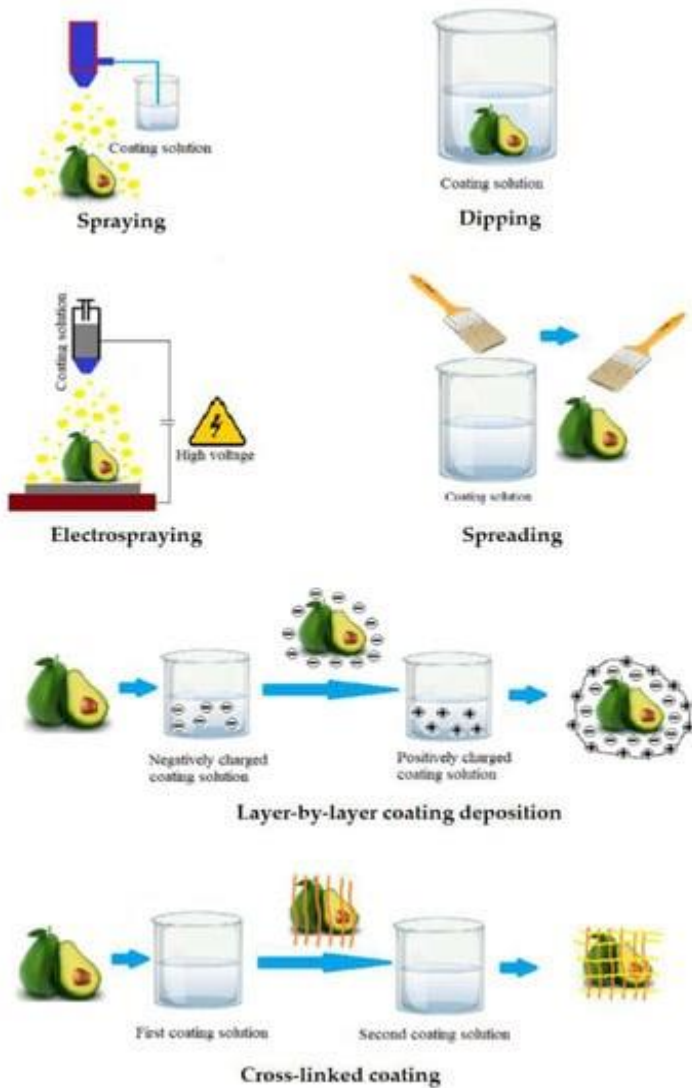


Fig 2. Classification and types of coating process for farmers (Pham et al., 2023)

Edible coatings to replace and decrease the usage of chemicals and synthetic compounds. An edible coating is a covering sheet composed of biological or chemical ingredients and utilized as a monolayer film or multilayer films on the surface of the product (Pham et al., 2022). Edible coatings maintaining the phytonutrients (antioxidants, phenolics, pigments) and controlling physicochemical qualities (inhalation and exhalation rate, weight loss, total dissolved matters, pH) of fruits for longer time. Due to this fruit deterioration is delayed, fruit quality is improved, and fruit shelf life is extended. To be effective, edible coatings must meet several functional requirements (Fig. 2), including (i) being free of toxic materials and harmless for human beings; (ii) having superb boundary capabilities regarding water, humidity, O_2 , CO_2 , and C_2H_4 ; and (iii) improving the

visual as well as textural properties of the coated products.

Dipping is the simplest method consisting of three steps: (i) immersion and dwelling, (ii) deposition and (iii) evaporation of solvents (Pham et al., 2022). After the excess solution has been drained away, the food is typically dried at ambient condition or treated with a dryer. Previous studies showed that the density and morphology of coatings precipitated by dipping are significantly affected by several factors including time for immersion, speed of withdrawal, number of cycles for dip-coating, coating solution parameters such as density, viscosity, surface tension, substrate surface characteristics, and drying conditions. Satisfactory results are not attained due to thickness of coatings causing respiration rate of the fruit and vegetables affected severely, density of the fruit and vegetables are also affected etc.

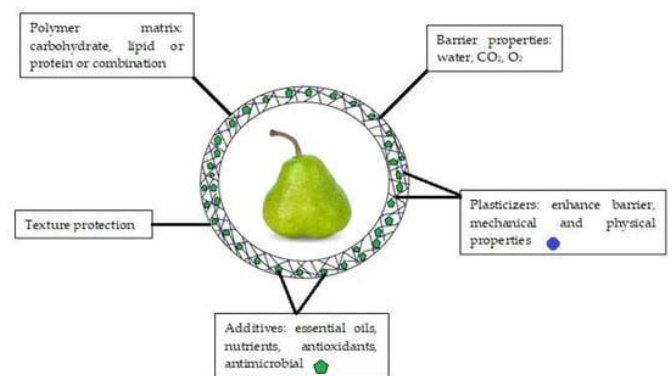


Fig 3. Outcome of Coating on Fruits and Vegetables (Pham et al., 2023)

Latest Advancements

A biodegradable, edible coating solution can extend the shelf-life of fresh produce, such as green chillies and tomatoes. The coating can reduce the load of food-borne pathogens, retain firmness, and prevent the weight loss of fruits and vegetables when stored for a month. This coating will reduce post-harvest loss significantly. The coating solution by mixing de-oiled crude ethanolic extract of a marine green alga with a chitosan-based solution. They made dried, edible films from the coating solution and found that this film was thermally stable, blocked ultraviolet and visible light, and showed antioxidant properties. (Excerpts from the Nature India magazine)



Fig 4. Mechanism and benefits of coating
(Gianfranco and Marwa, 2022)

The material was tested on potato, tomato, green chili, strawberry, Khasi Mandarin, apple, pineapple and kiwifruit and was found to keep these vegetables fresh for nearly two months. And a mix of an extract of a marine microalga called *Dunaliella tertiolecta* and polysaccharides to produce it. The microalga is known for its antioxidant properties and has various bioactive compounds such as carotenoids and proteins. It is also used to produce algal oil, a non-animal source of omega-3 fatty acid and is considered a good source of biofuel. After the oil is extracted, the residue is usually discarded. And extracts from this residue used in formulating their film, in combination with chitosan, which is a carbohydrate. It also has antimicrobial and antifungal properties and can be made into an edible film. (Excerpts from the down-to-earth magazine)

However, the development and application of edible coatings are not without challenges. Some of the limitations and drawbacks of edible coatings include:

- 1. High production costs:** The use of natural biopolymers and other ingredients in edible coatings can result in higher production costs compared to synthetic coatings.
- 2. Limited shelf life:** While edible coatings can extend the shelf life of fruits, they may also have a limited shelf life themselves, requiring careful storage and handling to prevent spoilage.
- 3. Variability in effectiveness:** The effectiveness of edible coatings may vary depending on factors such as the type of fruit, the coating formulation, and the application method.

4. Potential for allergic reactions: Some biopolymers used in edible coatings, such as chitosan, may cause allergic reactions in some individuals.

5. Impact on sensory properties: Edible coatings may affect the sensory properties of fruits, such as texture and flavor, which could impact consumer preferences.

6. Environmental impact: While edible coatings are biodegradable, their production and disposal could still have an environmental impact, particularly if large quantities are used.

Overall, while edible coatings offer many benefits for preserving fruits and reducing the use of synthetic chemicals, further research is needed to address these limitations and ensure their safety and effectiveness for consumers.

References:

- Edible coating solution increases shelf-life of fruits and vegetables (nature.com)
- Gianfranco Romanazzi, Marwa Moumni. (2022) Chitosan and other edible coatings to extend shelf life, manage postharvest decay, and reduce loss and waste of fresh fruits and vegetables, *Current Opinion in Biotechnology*, Volume 78, 2022, 102834, ISSN 0958-1669.
- Hazarika T.K., Lalhriatpuia C., Ngurthankhumi Rody, Lalruatsangi Esther, Lalmachhuani H. (2023). Edible Coatings in Extending the Shelf Life of Fruits: A Review. *Indian Journal of Agricultural Research*. 57(5): 555-558.
- Murugan, Aswini and Banu, Azeez Thahira and Lakshmi, Duraikkannu Shanthana,(2022). Edible Coatings to Enhance Shelf Life of Fruits and Vegetables: A Mini-Review (January 12, 2022). *Current Nutrition & Food Science*, 2022, 18, 525-538.
- New edible coating to prolong shelf life of fruits and vegetables (downtoearth.org.in)
- Pham, Thanh Tung, Lien Le Phuong Nguyen, Mai Sao Dam, and Laszlo Banyai. (2023). Application of Edible Coating in Extension of Fruit Shelf Life: Review. *AgriEngineering* 5, no. 1: 520-536.

Ensuring Food Safety and Quality: A Comprehensive Approach

Pooja M. Eranna¹ and Madhusudhan Nayak C.²

¹Ph.D Scholar, Department of food Technology, Faculty of Life and Allied Health Sciences

² Assistant Professor, Department of Food Technology, Faculty of Life and Allied Health Sciences,
M S Ramaiah University of Applied Sciences - Bangalore, Karnataka, India.

*Corresponding Author: poojaeranna27@gmail.com

In an era marked by globalization and diverse culinary preferences, the importance of ensuring food safety and quality has never been more crucial. The implications of compromised food safety can range from mild discomfort to severe health issues, making it imperative for individuals, businesses, and regulatory bodies to collaborate in upholding rigorous standards.

Regulatory Framework

Government agencies play a pivotal role in establishing and enforcing regulations to safeguard food safety and quality. These regulations cover various aspects of the food supply chain, including production, processing, distribution, and retail. Compliance with these standards is essential for all stakeholders to ensure the well-being of consumers.

Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Points (HACCP)

Adhering to GMP is fundamental in maintaining the hygiene and cleanliness of food production facilities. HACCP, on the other hand, involves a systematic approach to identifying and controlling potential hazards at critical points in the production process. These methodologies help prevent contamination and ensure the production of safe and high-quality food products.

Supply Chain Traceability

The modern food supply chain is intricate and global, making traceability a key component of ensuring food safety. Tracking the origin and movement of food products allows for swift identification and recall of contaminated items in the event of a safety concern, safeguarding consumers and maintaining public trust.

Quality Assurance and Testing

Stringent quality assurance measures involve continuous testing for contaminants, additives, and adherence to nutritional specifications. Advanced technologies, such as DNA testing and spectroscopy, contribute to accurate and rapid analysis, enhancing

the ability to detect potential hazards and maintain quality standards.

Education and Training

Ensuring a culture of food safety requires educating and training all individuals involved in the food industry. This includes farmers, food processors, distributors, and food service providers. Awareness programs and training sessions can empower these stakeholders to implement best practices and stay abreast of evolving safety standards.

Consumer Awareness

Empowering consumers with knowledge about safe food practices is equally important. Labels, nutritional information, and guidelines on proper food handling and storage enable consumers to make informed choices, reducing the risk of foodborne illnesses.

Technological Innovations

Embracing technological advancements is essential for improving food safety and quality. Blockchain technology, for instance, can enhance transparency in the supply chain, while IoT devices can monitor and ensure the proper storage conditions of perishable goods.

Collaboration and Global Cooperation

Given the global nature of the food supply chain, collaboration between countries, businesses, and organizations is vital. Sharing best practices, research findings, and technological innovations on an international scale contributes to a collective effort in enhancing food safety and quality worldwide.

In conclusion, safeguarding food safety and quality is a multifaceted endeavour that requires the commitment of governments, businesses, and consumers alike. By integrating regulatory compliance, technological advancements, and a commitment to education, the global community can work together to ensure that the food we consume is not only delicious but also safe and of the highest quality.

Certainly! Let's delve deeper into specific aspects of food safety and quality to provide a more comprehensive understanding:

Risk Assessment and Management

- **Risk Analysis:** This involves evaluating potential hazards associated with specific foods and processes. It includes risk assessment, risk management, and risk communication.
- **Allergen Management:** Identification and control of allergens are crucial, given the rise in food allergies. Proper labeling and segregation of allergens are essential in preventing adverse reactions.

Microbiological Safety

- **Pathogen Control:** Preventing the growth and spread of harmful microorganisms, such as Salmonella, E. coli, and Listeria, is critical. Adequate cooking, proper storage, and sanitation measures are essential in minimizing the risk of foodborne illnesses.
- **Food Preservation:** Techniques like pasteurization, canning, and refrigeration contribute to preserving food and inhibiting the growth of spoilage and pathogenic microorganisms.

Chemical Safety

- **Pesticide Residue Management:** Ensuring that the use of pesticides in agriculture adheres to safety standards is vital in preventing harmful chemical residues in foods.
- **Food Additives:** Proper regulation and monitoring of food additives, such as preservatives and colorants, are essential to prevent excessive or unsafe levels in food products.

Physical Contaminants

- **Foreign Object Control:** Strict measures to prevent physical contaminants, such as glass, metal, or plastic, from entering the food supply chain. This includes robust quality control processes during food processing and packaging.

Supply Chain Integrity

- **Cold Chain Management:** Maintaining proper temperature controls throughout the supply chain is crucial for preserving the quality and safety of perishable goods.
- **Supplier Audits:** Regular audits of suppliers and third-party vendors ensure that they adhere to the same high standards of food safety and quality.

Quality Attributes

- **Sensory Evaluation:** Beyond safety, ensuring the sensory attributes like taste, aroma, texture, and appearance meet consumer expectations is integral to overall food quality.
- **Nutritional Integrity:** Monitoring and labeling nutritional content is essential for consumers to make informed choices about their diet.

Emerging Technologies

- **Blockchain in Food Traceability:** Blockchain technology enhances traceability by providing an immutable ledger of a product's journey from farm to table.
- **Artificial Intelligence (AI) in Quality Control:** AI applications, such as computer vision, can automate quality control processes, identifying defects or irregularities in food products.

Regulatory Compliance

- **Global Harmonization:** Efforts to harmonize food safety standards globally ensure consistency in regulations, facilitating international trade while maintaining high standards.
- **Adaptation to New Challenges:** Regulatory bodies continually adapt to emerging challenges, such as the introduction of novel foods or evolving production methods.

Consumer Education and Engagement

- **Label Reading:** Educating consumers on how to interpret food labels enables them to make healthier and safer choices.
- **Community Outreach:** Engaging with communities to raise awareness about food

safety practices, particularly in regions with limited resources.

Crisis Management

- **Recall Protocols:** Establishing clear protocols for product recalls ensures swift action in the event of contamination or safety concerns, minimizing the impact on consumers.

By understanding and addressing these various facets of food safety and quality, stakeholders can collectively contribute to a robust and resilient food system that prioritizes both the pleasure and safety of the dining experience. Continuous improvement, innovation, and collaboration remain central to the ongoing enhancement of food safety and quality standards globally.

Reference

Kotsanopoulos, K. V., & Arvanitoyannis, I. S. (2017). The role of auditing, food safety, and food quality standards in the food industry: A review. *Comprehensive reviews in food science and food safety*, 16(5), 760-775.

Morales-de la Peña, M., Welti-Chanes, J., & Martín-Belloso, O. (2019). Novel technologies to improve food safety and quality. *Current opinion in food science*, 30, 1-7.

Burlingame, B., & Pineiro, M. (2007). The essential balance: Risks and benefits in food safety and quality. *Journal of Food Composition and Analysis*, 20(3-4), 139-146.

* * * * *

Food Toxins: A Comprehensive Exploration

Abhishek Chitranashi¹, Aditi Mathur², Nandini GA¹, Mallesh Gampa¹ and Ashok Kumar¹

¹Division of Biochemistry, ICAR-IARI, New Delhi

²Division of Pathology, Agriculture College Kota

*Corresponding Author: chitranashiabhishek@gmail.com

Food toxins encompass a diverse range of substances that can pose health risks to humans upon consumption. These toxins may be naturally occurring or introduced during various stages of food production, processing, and storage. Understanding the types, sources, and effects of food toxins is crucial for maintaining food safety and preventing adverse health outcomes. Different types of food toxins are bacterial toxin, fungal toxin, marine toxins, plant toxins and chemical toxins.

Bacterial Toxins

Bacterial toxins represent a significant category of foodborne hazards. Among the most notorious is Botulinum toxin, produced by *Clostridium botulinum*. This potent neurotoxin can cause botulism, a severe and potentially fatal illness. Improperly canned or preserved foods, particularly low-acid vegetables and meats, are common sources of contamination. The toxin inhibits neurotransmitter release, leading to paralysis and respiratory failure.

Salmonella and *Escherichia coli* (*E. coli*) are other bacterial culprits. Salmonella infections often result from the consumption of contaminated eggs, poultry, and unpasteurized dairy products. *E. coli*, particularly the strain O157:H7, can lead to serious illness, causing symptoms such as bloody diarrhea and kidney failure. Contaminated water, undercooked meat, and unwashed vegetables are common sources.

Fungal Toxins

Mycotoxins are toxic compounds produced by molds, and they can contaminate a variety of crops. Aflatoxins, produced by *Aspergillus flavus* and *Aspergillus parasiticus*, are known carcinogens. Found in peanuts, corn, and grains, chronic exposure can result in liver damage and an increased risk of liver cancer. Rigorous quality control measures in food production are crucial to minimize aflatoxin contamination.

Ochratoxin, another mycotoxin, is associated with kidney damage. It can contaminate cereals, coffee, and other agricultural products. Strategies such

as proper storage and monitoring are essential to prevent ochratoxin accumulation in the food supply chain.

Plant Toxins

Certain plants contain toxins that can be harmful if not properly processed or prepared. Cyanogenic glycosides, found in plants like cassava, almonds, and stone fruit pits, can release cyanide when metabolized. Adequate processing methods, such as soaking and cooking, are crucial to detoxify these compounds and reduce the risk of cyanide poisoning.

Solanine and chaconine are glycoalkaloids present in green potatoes and related plants. When consumed in large quantities, these compounds can cause nausea, vomiting, and neurological symptoms. Proper storage and cooking practices, including avoiding green or sprouted potatoes, help mitigate the risk of solanine and chaconine poisoning.

Cyanogenic glycosides (CNGlcs) are bioactive plant products derived from amino acids. Structurally, these specialized plant compounds are characterized as α -hydroxynitriles (cyanohydrins) that are stabilized by glucosylation. Notably, cassava, sorghum, stone fruits, bamboo roots, and almonds are significant dietary sources of cyanogenic glycosides. The potential toxicity of a plant containing cyanogenic glycosides primarily depends on the likelihood of its consumption leading to a concentration of cyanide that proves toxic to humans. In the case of human exposure, acute cyanide intoxication may manifest as rapid respiration, a decrease in blood pressure, dizziness, headaches, stomach pains, vomiting, diarrhea, mental confusion, cyanosis accompanied by twitching, convulsions, and ultimately, terminal coma. Fatality resulting from cyanide poisoning occurs when the cyanide level surpasses an individual's detoxification capacity.

Furocoumarins, stress toxins found in various plants like parsnips, celery roots, and citrus plants. Furocoumarins exhibit phototoxicity, leading to

severe skin reactions upon exposure to sunlight (UVA). Although primarily associated with dermal exposure, reports suggest similar reactions can occur after consuming substantial quantities of specific vegetables containing elevated furocoumarin levels.

Lectins are proteins found in many foods, particularly in legumes, grains, and certain vegetables. Lectins are part of plants' natural defense mechanisms, serving to protect them against predators, including insects and fungi. These proteins can interfere with the digestive processes of these organisms. Foods rich in lectins include legumes (such as beans and lentils), grains, and nightshade vegetables. Cooking methods, such as boiling or soaking, can help reduce lectin levels, making these foods more digestible.

Mushrooms, while often enjoyed as a culinary delicacy, can pose serious health risks due to the presence of various toxins. Some mushrooms contain toxic compounds that, when ingested, can lead to a range of adverse effects, including gastrointestinal distress, organ failure, and even death. Amanita mushrooms, such as the infamous Amanita phalloides (death cap), contain potent toxins known as amatoxins. These toxins can cause severe liver and kidney damage, often leading to fatalities. Certain mushrooms, like those belonging to the Inocybe and Clitocybe genera, can contain muscarine. Muscarine toxicity primarily affects the parasympathetic nervous system, leading to symptoms such as excessive salivation, sweating, and gastrointestinal distress.

Marine Toxins

Seafood, while a valuable source of nutrition, can also harbor toxins. Ciguatera toxin, produced by certain dinoflagellates, accumulates in predatory fish like barracuda and snapper. Consumption of contaminated fish can lead to gastrointestinal and neurological symptoms. Awareness and monitoring of fish sources are crucial to prevent ciguatera poisoning.

Saxitoxin is associated with paralytic shellfish poisoning. Produced by certain algae, this toxin accumulates in shellfish, posing a risk to consumers. Strict monitoring of shellfish harvesting areas and prompt public advisories are essential measures for preventing saxitoxin-related illnesses.

Chemical Toxins

Chemical toxins in food can originate from various sources, including pesticide residues and heavy metals. Pesticide residues can result from the improper use of pesticides during cultivation. Chronic exposure to these residues may have adverse health effects, emphasizing the importance of adhering to recommended agricultural practices and implementing effective regulatory measures.

Heavy metals such as mercury and lead can accumulate in certain foods, especially fish and shellfish. Long-term exposure to elevated levels of these metals can lead to serious health issues, particularly affecting the nervous system. Regular monitoring of food products, especially those prone to metal accumulation, is essential to ensure consumer safety.

Regulatory Measures and Preventive Strategies

Ensuring food safety requires a multifaceted approach, involving regulatory measures, industry practices, and consumer awareness. Government agencies set standards and regulations to limit the permissible levels of various toxins in food. Rigorous testing and inspection protocols are implemented to detect and prevent contaminated products from reaching consumers.

Industry stakeholders play a vital role in adopting good manufacturing practices, adhering to quality control standards, and implementing proper storage and transportation procedures. Comprehensive training programs for food handlers contribute to reducing the risk of contamination during various stages of the food supply chain.

Consumer awareness and education are fundamental aspects of preventing foodborne illnesses. Understanding proper food handling, storage, and cooking techniques empowers individuals to minimize the risk of toxin exposure in their households. Additionally, prompt reporting of suspected cases of foodborne illnesses facilitates timely investigations and interventions.

Conclusion

In conclusion, the realm of food toxins is intricate and diverse, encompassing bacterial, fungal,

plant, and chemical hazards. Vigilance at every stage of the food supply chain, from cultivation to consumption, is essential to mitigate risks and safeguard public health. Regulatory frameworks, industry diligence, and informed consumer practices collectively contribute to a safer and more secure food landscape.

Understanding the specific characteristics of various toxins, their sources, and the associated health risks is crucial for informed decision-making. By fostering a collaborative approach among regulators, industry stakeholders, and consumers, we can strive to minimize the incidence of foodborne illnesses and ensure that the food we consume nourishes without compromising our well-being.

References

- Baatouche, S., Cheriet, T., Sarri, D., Mekkiou, R., Boumaza, O., Benayache, S., & Seghiri, R. (2019). *Centaurea microcarpa* Coss. & Dur. (Asteraceae) extracts: New cyanogenic glucoside and other constituents. *Natural product research*, 33(21), 3070-3076.
- Metcalf, J. S., Banack, S. A., Wessel, R. A., Lester, M., Pim, J. G., Cassani, J. R., & Cox, P. A. (2021). Toxin analysis of freshwater cyanobacterial and marine harmful algal blooms on the west coast of Florida and implications for estuarine environments. *Neurotoxicity Research*, 39(1), 27-35.
- Wang, H., Peng, H., Li, W., Cheng, P., & Gong, M. (2021). The toxins of *Beauveria bassiana* and the strategies to improve their virulence to insects. *Frontiers in Microbiology*, 12, 705343.
- Rajkovic, A., Jovanovic, J., Monteiro, S., Decleer, M., Andjelkovic, M., Foubert, A., ... & Uyttendaele, M. (2020). Detection of toxins involved in foodborne diseases caused by Gram-positive bacteria. *Comprehensive reviews in food science and food safety*, 19(4), 1605-1657.
- Baatouche, S., Cheriet, T., Sarri, D., Mekkiou, R., Boumaza, O., Benayache, S., & Seghiri, R. (2019). *Centaurea microcarpa* Coss. & Dur. (Asteraceae) extracts: New cyanogenic

* * * * *

Quality Standards of Ghee

B.P. Pushpa

Assistant Professor, Department of Dairy Chemistry, Dairy Science College, KVAFSU, Hebbal, Bengaluru, Karnataka

*Corresponding Author: pushpadc819@gmail.com

Ghee is a high value food having unique flavour which increase the acceptability of the product as compared to any other fat rich products or vegetable oils. Ghee is a clarified butter accounts for about 45% of the total milk produced in India. Ghee is primarily used for cooking and frying and as dressing or toppings for various foods. It is also used in the manufacture of snacks and sweets often mixed with vegetables, cereals, fruits, and nuts. In some parts of the world, ghee is considered as a sacred product and is used in religious rites. Ghee is used in Ayurveda, which is a system of traditional medicine developed in India several thousand years ago as an alternative medicine.

Chemically ghee is a complex mixture of glycerides, free fatty acids, phospholipids, sterols, sterol esters, fat soluble vitamins (A, D, E, K), tocopherol, carbonyls, hydrocarbons, carotenoids (only in ghee derived from cow milk), small amounts of charred casein and traces of calcium, phosphorus, iron etc. It contains not more than 0.5 % of moisture and glycerides constitute about 98-99 % of the total material. Remaining 1-2 % comprises of phospholipids (0.2-1.0 %), sterols (major cholesterol; 0.25-0.40 %) and traces of free fatty acids, waxes, squalene, fat soluble vitamins etc.

Quality Standards of Ghee

Competition in the organized ghee production sector leads to create brand value to the product, which comes with quality and special features. Quality of ghee in consumer's point of view may possess pleasing flavour, granular texture, attractive colour and freshness including clean packaging material. Quality of ghee is mainly affected by its source of raw material, processing, season, species, feed of animal, region, storage and adulteration. Ghee quality can be assessed by determining the fat constants such as Butyro refractometer reading, Reichert Meissl value, Polenske value, Iodine value, Saponification value and Fatty acid profile. Moisture content of ghee and free fatty acid content important in controlling the quality of ghee. To assess the quality

and to check adulteration of ghee FSSAI has brought some new regulations by adding additional parameters (Fig. 1).

According to literature, ghee is a lipophilic product with 99-99.5% lipids from which 46-47.8% is saturated fat, 36% monounsaturated and 18% polyunsaturated fatty acids. The classification for fatty acid includes saturated fatty acids including Butyric acid 1 -5%, Hexanoic acid (Caproic acid) 0.5 - 2.2%, Octanoic acid (Caprylic acid) 0.4 - 1.5%, Decanoic acid (Capric acid) 0.8- 5%, Dodecanoic acid (Lauric acid) 1.5 - 4%, Tetradecanoic acid (Myristic acid) 6- 13%, Hexadecanoic acid (Palmitic acid) 22-38%, and Octadecanoic acid (Stearic acid) 8-19% (FSSR, 2021).

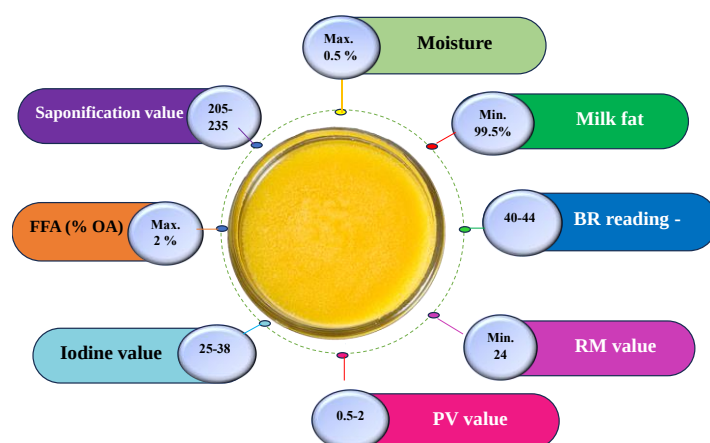


Fig. 1: FSSAI (2022) Standards for GHEE.

AGMARK is a certification mark of Government of India to ensure the purity and quality of Agricultural and allied products in India. Under Agmark, ghee is graded into three categories; differ in free fatty acid content (% Oleic acid); 'Special' (Agmark Red Label; Max.1.4 % OA), 'General' (Green Label; Max. 2.5 % OA) and 'Standard' (Chocolate Label; Max. 3.0 % OA) (Fig. 2) with moisture content of not more than 0.3 %, Butyro Refractometer reading of 40-43 at 40°C, RM value not less than 28.0, Poleske value between 1.0-2.0 and Boudoin test should be negative. Adulteration of ghee in India is more prevalent especially in unorganized sector, with Vanaspati (Hydrogenated vegetable oil), Refined (de-odourized) vegetable oil and Animal body fat.

Government has made it compulsory that all Vanaspati must contain a maximum of 5% of Sesame oil which can be identified in ghee by a simple colour test known as Baudouin test, which can be detected upto 3 % level.



Fig. 2 Different Grades (Free fatty acids %OA) of Ghee under AGMARK

Storage Changes in Ghee: Quality of ghee may be affected due to the production of off flavour in ghee as a result of different chemical reactions viz. hydrolysis of tri acyl glycerols (fats) to produce free fatty acids; and oxidation of fat to produce saturated and unsaturated aldehyde, ketones, alcohols and hydrocarbons.

Free Fatty Acid (FFA) content

The FFA is defined as the percentage by weight of free acid groups in the oil or fat. Free fatty acids (FFA) are an indication of hydrolytic rancidity, but other lipid oxidation processes can also produce acids. The value is a measure of the number of fatty acids (%)

Oleic acid) which have been liberated by hydrolysis from the glycerides due to the action of moisture, temperature and/or lipolytic enzyme lipase. Free fatty acids are significant for the quality of the milk fat because they increase the fat's susceptibility to oxidation and can contribute to bitter or soapy flavours. Rancid flavour developed due to fat hydrolysis due to lipase action in milk, cream, curd, butter and ghee may deteriorate the quality of ghee. This problem can be overcome by inactivating the lipase by proper heat treatment and clarify fat at optimum temperature which ensures minimum moisture content in ghee.

Peroxide Value

The peroxide value is used to determine the oxidative rancidity in ghee is the milli equivalents of oxygen per kilogram of sample. The higher peroxide value determines the age of ghee with rancid flavour production. Flavour defect of ghee is mainly due to fat oxidation by direct contact of milk, curd, cream, butter and ghee with copper or iron, exposure of these products to sunlight lead to oxidized, oily or metallic flavour. Oxidized flavour can be prevented by storage of fat products in properly tinned or aluminium alloy or stainless-steel vessels, filling ghee upto the brim to minimize the headspace and using opaque containers and avoiding ghee storage at high temperature (>21°C) for long time.

Conclusion

Chemical composition of ghee as determined by fat constants is helpful in assessing the quality of ghee. Knowledge of fatty acid profile of different fats or oils is helpful to analyse the quality differences due to species, breed, region, and adulteration. Use of some advanced techniques is helpful in quick determination of ghee quality and a greater number of samples can be screened to reduce the malpractices.

* * * * *

Antinutritional Factors in Cereals

Abhishek Chitranashi¹, Aditi Mathur², Nandini GA¹, Mallesh Gampa¹, Ashok Kumar¹ and Diksha Srivastava³

¹Division of Biochemistry, ICAR-IARI, New Delhi

²Division of Pathology, Agriculture College Kota

³Division of extension education and communication management, RPCAU, Bihar

*Corresponding Author: chitranashiabhishek@gmail.com

Cereals like rice, wheat, and maize belong to the Graminae grass family, playing a crucial role as staple food crops globally. These cereal foods are vital components of daily diets, providing essential nutrients such as carbohydrates, proteins, dietary fibers, and vitamins. Epidemiological studies have highlighted the protective impact of whole grain foods against various diseases prevalent in westernized societies, including type 2 diabetes, cardiovascular diseases, and certain cancer.

Antinutrients encompass both naturally occurring and synthetic compounds that impede the bioavailability and absorption of essential nutrients. Research in nutrition predominantly investigates antinutrients prevalent in dietary sources and beverages. These entities can manifest as pharmaceutical agents, endogenous food-derived chemicals, proteins, or excessive intake of specific nutrients. Mechanistically, antinutrients operate by sequestering vitamins and minerals, thereby thwarting their assimilation, or by inhibiting enzymatic activities critical for nutrient metabolism.

Different types of antinutritional factors and strategies for its removal

Antinutritional factors (ANFs) represent a diverse group of naturally occurring compounds in various foods that can exert adverse effects on nutrient absorption and utilization in the human body. Understanding these factors is essential for developing dietary strategies that optimize nutritional intake and promote overall health. This comprehensive exploration will delve into the major antinutritional factors, their sources, effects, and potential mitigation strategies.

Phytic acid, identified as an antinutrient, diminishes mineral bioavailability, forming insoluble complexes with divalent cations. High polyphenol content in plant-based grains may also impede mineral absorption. Commonly found in grains, pulses, and seeds, phytic acid is concentrated in the

outer layers of cereals, comprising 1-2% of seed weight, reaching 3-6% in some cases. In maize, 90% is in the germ, while in wheat and rice, it is mainly in the pericarp and aleurone layer.

Folates, vital cofactors in enzymatic reactions, are pivotal for DNA integrity. Their deficiency heightens mutation and DNA breakdown risks, potentially leading to cancers. Adequate folate intake also lowers elevated serum homocysteine, a recognized coronary heart disease risk. Despite phenolic compounds' antioxidant properties, their complex formation with minerals reduces bioavailability, impacting iron and zinc absorption in cereal-based foods. This contributes to prevalent deficiencies, especially in infants, children, and women of childbearing age. Mineral absorption complexities extend to dietary content, influencing their bioavailability. The inefficiency of mineral absorption, particularly iron (below 1-30%), underscores the risk of malnutrition disorders due to dietary deficiencies.

Phytates, prevalent in cereals and legumes, serve as the main storage form of phosphorus. They chelate essential minerals, diminishing their bioavailability and posing a challenge to human nutrient absorption. Germination proves effective in reducing antinutritional factors like phytates, crucial for seedling development. However, the limited hydrolysis ability in humans results in an adverse impact on mineral bioavailability. Various factors, including genetics, environment, and soil conditions, influence the levels of phytic acid and phosphorus availability in cereal grains. Despite its role as a phosphate reserve during seed germination, phytic acid's complexation with metal ions, especially Zn (II), Ca (II), and Fe (III), categorizes it as an antinutrient, potentially leading to mineral absorption deficits with high consumption.

Strategies such as controlling phytic acid intake and germination have shown promise in reducing its levels and enhancing nutritional value.

Fermentation led to a significant reduction in total polyphenols and phytic acid content. Enhancing the nutritional quality of cereals requires the removal of undesirable components, a task achieved through traditional processing methods like fermentation and germination. Household techniques such as soaking, cooking, and fermentation significantly reduce levels of phytate and tannin, improving nutrient bioavailability. These processes, notably in fermented cereal products, lead to increased protein content and digestibility. In particular, finger millet benefits from germination and fermentation, reducing antinutrients and enhancing nutrient absorption. The reduction of phytic acid in pearl millet through fermentation highlights its nutritional potential.

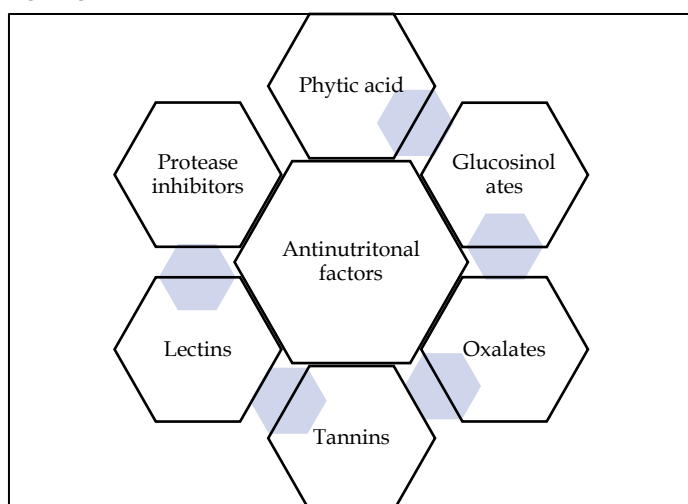


Fig 1. Different types of antinutritional factors present in plants

Phytic Acid

Phytic acid, or phytate, is a major antinutritional factor in wheat. Primarily concentrated in the bran and germ layers, phytic acid is the storage form of phosphorus in plants. Its strong chelating properties render phosphorus largely unavailable for human absorption, leading to reduced bioavailability of essential minerals like iron, zinc, and calcium. Source: Found in seeds, grains, and legumes.

Mitigation Strategies: Traditional food processing methods such as soaking, fermentation, and germination can effectively reduce phytic acid levels. These processes break down phytic acid,

releasing bound minerals and improving their absorption.

Protease Inhibitors

Wheat contains protease inhibitors that interfere with protein digestion. These compounds inhibit the activity of digestive enzymes involved in breaking down proteins, resulting in incomplete protein digestion and reduced availability of essential amino acids. Source: Present in various legumes and seeds.

Mitigation Strategies: Cooking and heat treatment are effective in reducing protease inhibitor activity. Proper processing of wheat products can minimize the negative impact on protein digestion.

Lectins

Lectins are carbohydrate-binding proteins in wheat that can interfere with nutrient absorption. They may bind to the lining of the gut, affecting the absorption of nutrients, and have been associated with inflammatory responses and autoimmune conditions. Source: Found in many plant foods, especially in grains and legumes.

Mitigation Strategies: Cooking and processing can partially reduce lectin levels. However, complete elimination is challenging, and individuals with specific sensitivities may explore alternative grains.

Tannins

Tannins, polyphenolic compounds present in the bran layers of wheat, can bind to proteins and minerals. This binding forms complexes that are less digestible and absorbable in the gastrointestinal tract. Source: Present in tea, coffee, some fruits, and grains.

Mitigation Strategies: Soaking, fermenting, and cooking can help reduce tannin levels in wheat-based foods, improving the bioavailability of nutrients.

Oxalates

While not as abundant, oxalates in wheat can bind with minerals, forming insoluble complexes. High oxalate intake may contribute to the formation of kidney stones in susceptible individuals. Source: Found in foods like spinach, rhubarb, and beet greens.

Mitigation Strategies: Cooking and boiling effectively reduce oxalate content in wheat products.

Adequate hydration and a balanced diet further help mitigate the risk of kidney stone formation.

Gluten

Gluten, a complex mixture of proteins in wheat, can trigger immune responses and damage the intestinal lining in individuals with celiac disease or non-celiac gluten sensitivity.

Mitigation Strategies: For those with gluten-related disorders, adopting a gluten-free diet is essential. This involves substituting wheat with alternative grains and carefully managing food choices to avoid gluten-containing products.

Alkaloids

Alkaloids, present in various plants, including potatoes, tomatoes, and certain spices, can be toxic and interfere with nervous system function. While some alkaloids, like caffeine, are well-tolerated, others may pose health risks in excessive amounts. Proper cooking and preparation methods are essential to minimize alkaloid content and potential toxicity.

Glycosides

Glycosides, found in certain plants like cassava, release toxic compounds upon ingestion, impacting digestion and nutrient absorption. For example, cyanogenic glycosides can release cyanide. Proper processing methods, such as thorough cooking, are crucial to reduce glycoside content and eliminate potential health risks.

Amylase Inhibitors

Amylase inhibitors, found in certain grains and legumes, interfere with the activity of amylase, the enzyme responsible for starch digestion. This interference may affect carbohydrate metabolism. Cooking and heat treatment are effective in reducing amylase inhibitor activity, ensuring better starch digestion.

Glucosinolates

Abundant in cruciferous vegetables like broccoli and cabbage, glucosinolates can interfere with iodine uptake by the thyroid gland and may have goitrogenic effects, potentially impacting thyroid function. However, these compounds also exhibit anticancer properties. Cooking and processing can reduce glucosinolate levels, making the balance

between potential benefits and risks an important consideration.

In addition to these individual antinutritional factors, it's crucial to consider their cumulative effects in a varied diet. The goal is not to eliminate these compounds entirely, as many also have beneficial properties, such as antioxidant and anticancer effects. Striking a balance between the potential risks and benefits requires an understanding of the specific dietary context, individual sensitivities, and appropriate food processing techniques.

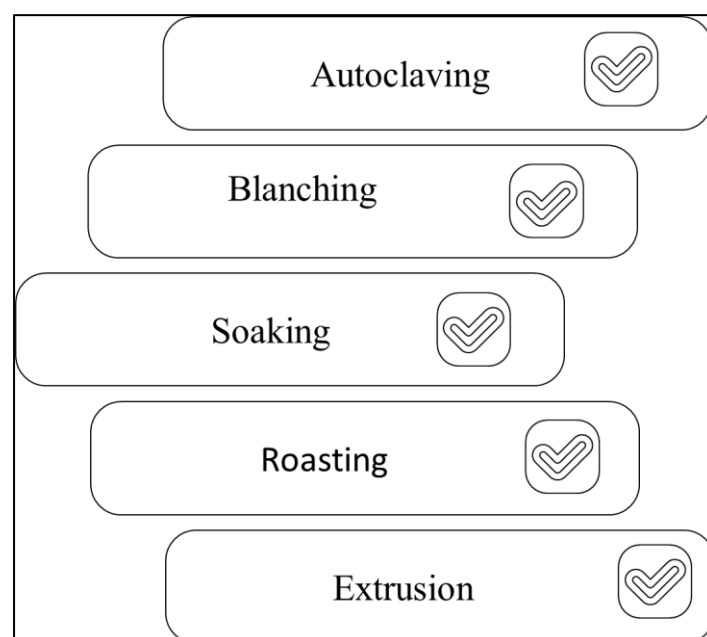


Fig 2. Different methods of Antinutritional factor removal

Furthermore, the nutritional quality of foods can be influenced by the interactions between antinutritional factors and the overall composition of the diet. For example, the presence of certain nutrients in the diet may mitigate the impact of antinutritional factors, emphasizing the importance of diverse and well-balanced dietary patterns. Research continues to advance our understanding of these factors, exploring innovative approaches to minimize their negative effects while preserving the nutritional value of foods. Additionally, individual tolerance and sensitivity to specific antinutritional factors can vary, highlighting the need for personalized dietary recommendations.

Conclusion

In conclusion, while antinutritional factors are inherent in many plant-based foods, their impact on health is complex and context-dependent. Proper food

processing, cooking techniques, and a diversified diet are crucial for minimizing the adverse effects of these compounds while ensuring the overall nutritional quality of the diet. Ongoing research and a nuanced understanding of the interplay between antinutritional factors and dietary components will contribute to the development of effective strategies for optimizing nutrition and promoting human health.

References

- 1) Adeyemo, S. M., & Onilude, A. A. (2013). Enzymatic reduction of anti-nutritional factors in fermenting soybeans by *Lactobacillus plantarum* isolates from fermenting cereals. *Nigerian Food Journal*, 31(2), 84-90.
- 2) Camargo, A. C., Favero, B. T., Morzelle, M. C., Franchin, M., Alvarez-Parrilla, E., de la Rosa, L. A., & Schwember, A. R. (2019). Is chickpea a potential substitute for soybean? Phenolic bioactives and potential health benefits. *International journal of molecular sciences*, 20(11), 2644.
- 3) Al Hasan, S. M., Hassan, M., Saha, S., Islam, M., Billah, M., & Islam, S. (2016). Dietary phytate intake inhibits the bioavailability of iron and calcium in the diets of pregnant women in rural Bangladesh: a cross-sectional study. *BMC Nutrition*, 2, 1-10.

* * * * *

Non-Thermal Processing Methods for Food Safety and Shelf-Life Enhancement

Kumari M.^{1*}, Somveer², Ravikant V. Vinchurkar³, Soniya Mor⁴ and Deshmukh RR³

¹Teaching Associate, Dairy Engineering Division, CoDST, RAJUVAS, Bikaner

²Ph.D. Scholar, Dairy Engineering Division, National Dairy Research Institute, Karnal

³Ph.D. Scholar, Dairy Microbiology Division, National Dairy Research Institute, Karnal

⁴Assistant Professor, Dairy Chemistry Division, CoDST, RAJUVAS, Bikaner

*Corresponding Author: mishameena7@gmail.com

The manufacturing sector which includes the production of food and beverages is one of the largest in the world. Food processors face ongoing challenges in creating consumer-driven products that meet their needs while maintaining food safety in an economical and consumer-driven market. Foods that taste better, are fresher-tasting, and contain few or no preservatives are preferred by consumers who lead health and wellness-conscious lifestyles. To maintain the health and welfare of society at large, food safety management has gained prominence on a global scale. Novel techniques have enhanced the shelf life of food products without impacting their functional properties, freshness, or quality. Traditional thermal processing methods that are believed to utilize the most energy in the food industry include pasteurization, evaporation, drying, sterilization, chilling, and freezing process. To reduce the growth of microbes, which will improve food goods' safety and shelf life. (Putnik *et al.*, 2017) reported that conventional methods are used to prevent the formation of enzymes that cause spoiling, including lipo-oxygenase, peroxidase, polyphenol oxidase, and pectin methyl esterase. Bhattacharjee *et al.*, (2019) reported that novel thermal techniques have been widely used to increase food safety with less of an impact on the nutritional quality of food products. Having applications in the field of nutraceuticals, it is used to reduce the microbial load that contaminates fresh produce before and after harvest, dehydrate it and enhance its physico-chemical properties. Delorme *et al.*, (2020) reported that milk retains its nutrients, which include lipids, carbohydrates, proteins, enzymes, essential amino acids, minerals, and vitamins.

Due to increased consumer awareness of food safety, customers nowadays have higher expectations for wholesome, premium foods with excellent nutritional qualities and mouthfeel. Foods that are natural and fresh are in great demand after because

they are free from any chemicals. Therefore, scientists are working hard to develop appropriate technologies that will reduce the need for chemical additives without impacting the natural flavors and quality of the final product. These techniques are used to produce high-quality food with a reduced microbial load. In terms of destroying microbes and harmful bacteria in the food as well as denaturing, inhibiting, and gelatinizing protein, enzymes, and starch. It was reported that compared to heat treatment technique and non-thermal processing technologies cause less damage to food quality (Liu *et al.*, 2020). This is because non-thermal processing techniques typically have an impact on the food molecules' non-covalent bindings, including ionic, hydrophobic, and electrovalent bonds.

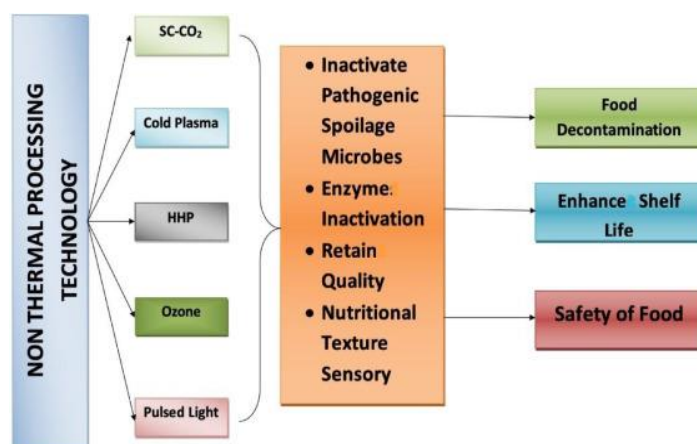


Fig. 1. Novel technologies for reducing contamination and enhancing food safety

Non-Thermal Processing Methods

High-Pressure Processing (HPP)

High-Pressure Processing is a non-thermal technique that involves subjecting packaged foods to elevated pressures, usually between 100 to 1000 MPa. This process effectively inactivates microorganisms, enzymes, and pathogens without the use of high temperatures. HPP is particularly beneficial for beverages, deli meats, and ready-to-eat meals, as it preserves the nutritional content and sensory qualities of the food.

Pulsed Electric Field (PEF)

PEF is a non-thermal method that applies short bursts of electrical energy to food products. These pulses create pores in microbial cell membranes, leading to microbial inactivation. PEF is effective in preserving the color, flavor, and nutritional quality of fruits, juices, and liquid foods. Its ability to target specific microorganisms makes it a valuable tool in the food industry.

Ultrasound Technology

Ultrasound technology involves the use of high-frequency sound waves for microbial inactivation and food preservation. This non-thermal method is particularly useful for liquids and semi-liquids. Ultrasound helps to disrupt cell structures of microorganisms, thereby extending the shelf life of products such as fruit juices, sauces, and purees.

Ionizing Radiation

Ionizing radiation, including gamma radiation and electron beam irradiation, is employed to control microbial growth and enhance the shelf life of various food products. It is a highly effective method for eliminating pathogens and parasites in spices, dried fruits, and some types of seafood. Despite initial concerns, extensive research has demonstrated the safety of irradiated foods within established dosage limits.

Ozone Treatment

Ozone, a powerful oxidizing agent, is gaining popularity for its ability to eliminate microorganisms and enhance food safety. Ozone treatment is applied in gaseous or aqueous forms to fruits, vegetables, and even water. It helps in controlling spoilage organisms, extending shelf life, and reducing the need for chemical preservatives.

Cold Plasma Technology

Cold plasma involves the use of ionized gases to inactivate microorganisms on the surface of food products. This non-thermal method has shown promise in enhancing the safety of fruits, vegetables, and even packaging materials. Cold plasma technology also has the advantage of being environmentally friendly, as it does not leave chemical residues.

Advantages of Non-Thermal Processing Methods

Preservation of Nutritional Quality:

Non-thermal methods such as high-pressure processing (HPP) and pulsed electric fields (PEF) are known for their ability to preserve the nutritional content of food products. Unlike thermal methods that can lead to nutrient degradation, non-thermal techniques maintain the integrity of vitamins, enzymes, and other essential nutrients.

Improved Retention of Flavor and Texture

Non-thermal processing helps retain the natural flavors and textures of food products. Minimal heat exposure prevents undesirable changes in taste and texture, ensuring that the final products closely resemble their fresh counterparts.

Reduced Risk of Pathogen Contamination

Non-thermal methods effectively reduce the risk of pathogen contamination in food. Techniques such as ultraviolet (UV) light treatment and high-pressure processing can eliminate harmful microorganisms, contributing to enhanced food safety without the need for excessive heat.

Extended Shelf Life

Non-thermal processing methods contribute to the extension of shelf life by minimizing the impact on the quality of food products. This allows for longer storage periods, reducing food waste and providing consumers with products that maintain their sensory attributes over an extended period.

Energy Efficiency and Sustainability

Unlike traditional thermal processing methods that often require significant energy input, many non-thermal techniques are more energy-efficient. This increased efficiency aligns with the growing emphasis on sustainability in the food industry, reducing both energy consumption and greenhouse gas emissions.

Minimal Impact on Colour and Appearance

Non-thermal methods help preserve the natural colour and appearance of food products. Traditional heat-based processing can lead to colour changes and visual alterations, while non-thermal methods maintain the appealing visual characteristics of the original products.

Flexibility in Packaging

Non-thermal processing allows for greater flexibility in packaging options. The reduced impact on food quality enables the use of various packaging materials, including those that may not withstand traditional thermal treatments, expanding the possibilities for eco-friendly packaging solutions.

Compliance with Consumer Preferences

With an increasing focus on minimally processed and fresh-like foods, non-thermal methods align well with consumer preferences. These techniques allow manufacturers to meet the demand for products with natural flavors, textures, and nutritional profiles while ensuring safety and extended shelf life.

Conclusion

- ❖ Emerging non-thermal technologies for enhancing food safety and shelf life have completely changed the food processing industry.
- ❖ By lowering spoilage and waste, the use of various non-thermal techniques such as cold plasma and high hydrostatic pressure technologies can extend the shelf life of food and improve its quality.
- ❖ Examine shows that these innovative techniques and novel approaches preserve the nutritional value of heat-sensitive components in food while also assuring its freshness.

References

Bhattacharjee, C., Saxena, V. K., & Dutta, S. (2019). Novel thermal and non-thermal processing of

watermelon juice. *Trends in Food Science & Technology*, 93, 234-243

Delorme, M. M., Guimarães, J. T., Coutinho, N. M., Balthazar, C. F., Rocha, R. S., Silva, R., ... & Cruz, A. G. (2020). Ultraviolet radiation: An interesting technology to preserve the quality and safety of milk and dairy foods. *Trends in food science & technology*, 102, 146-154.

Liu, J., Bi, J., McClements, D. J., Liu, X., Yi, J., Lyu, J., ... & Liu, D. (2020). Impacts of thermal and non-thermal processing on structure and functionality of pectin in fruit-and vegetable-based products: A review. *Carbohydrate Polymers*, 250, 116890.

Kumari M., Somveer, RR Deshmukh, RV Vinchurkar and P.L. Parameswari (2023). Computer vision driven precision dairy farming for efficient cattle management. *REST Journal on Data Analytics and Artificial Intelligence*, 2(3), 47-54.

Putnik, P., Bursać Kovačević, D., Herceg, K., Pavkov, I., Zorić, Z., & Levaj, B. (2017). Effects of modified atmosphere, anti-browning treatments and ultrasound on the polyphenolic stability, antioxidant capacity and microbial growth in fresh-cut apples. *Journal of Food Process Engineering*, 40(5), e12539.

Somveer, Kumari M., A. Pramanik, B. Lakshmaiah, B. Godara, and P.L. Parameswari (2023). A predictive approach for evaluating thermo-physical properties of nano fluids using artificial intelligence algorithms. *REST Journal on Data Analytics and Artificial Intelligence*, 2(3), 55-61.

Exploring the Application of Radio Frequency (RF) Heating in Food Commodities: Eco-Friendly Disinfestation

C Indumathi., P Krishnakumar, S Chittibabu and S Shanmugasundaram*

National Institute of Food Technology, Entrepreneurship and Management - Thanjavur (NIFTEM-T), Tamil Nadu

*Corresponding Author: sasu@iifpt.edu.in

India, a significant global food producer, is actively addressing the challenge of minimizing food waste at different stages, including production, processing, retail, and consumption. This involves investing in local initiatives and partnering with international investors to adopt best practices and advanced technology. The production of sustenance, approximately 10% of it is being lost amid postharvest operations between the field and the consumers. This results in about 15 million tons of wasted food grains annually, valued at approximately 2400 million Indian rupees. Insects significantly contribute to post-harvest losses in legumes and grains, occurring during the storage phase before reaching the end user in the market. Infestations in stored grains can lead to weight loss, reduced viability, loss of nutritional quality and financial losses, making the grains unsuitable for consumption.

Disinfestation of insects in warehouses during storage is a critical unit operation for extending the shelf life of agricultural commodities. Traditional thermal methods are slow and may harm food quality through prolonged heating. Chemical treatments, while effective, are discouraged due to environmental concerns, residual effects and studies have shown increasing insect tolerance to pesticides in recent years. Hence, it is imperative to adopt eco-friendly disinfestation methods to safeguard the safety and quality of food products. In this context, the introduction of radio-frequency heating technology emerges as a viable alternative to the current chemical practices employed in warehouses and industries.

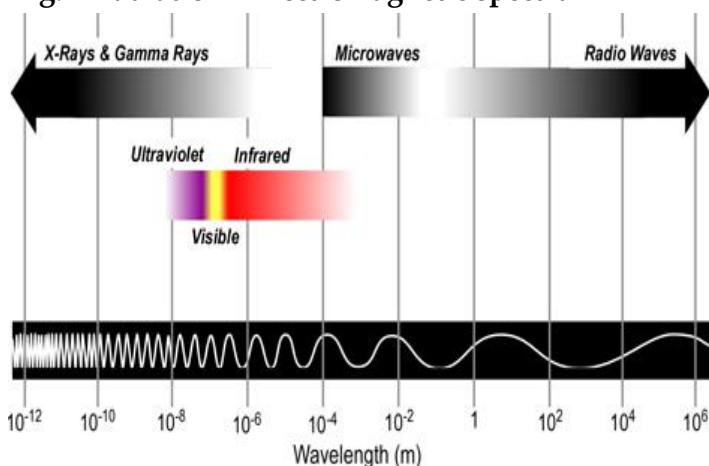
RF Heating Technology

Radiofrequency waves

Radiofrequency waves are a type of electromagnetic radiation that constitutes distinct frequencies and wavelengths as shown in Fig.1. It has longer wavelengths but lesser frequency than microwaves which are situated in the range of radar which are used in communication fields. Novel electromagnetic wave techniques are enticing the

researchers as they leave no toxic substances in the food product and for not induce insect resistance. Radiofrequency waves range from 1-300 MHz, whereas 13.56, 27.12 and 40.68 MHz are reserved for commercial, technological and medical purposes, to prevent possible interference with other spectrum users.

Fig. 1 Radiation – Electromagnetic spectrum



Higher penetrative intensity, heating efficiency, minimized thermal impact on product quality, shortened treatment time, easy to apply, no environmental contaminants and low energy consumption addresses RF heating as an advanced technology. In RF heating, water molecules present in the insects are continuously spinning and develop friction with cell organelles, which contributes to cell disruption resulting in death. Thus, all stages of insects can be killed without any adverse effects on quality of the product with the application of optimized RF electrode current and product exposure time concerning the lethal temperature of insects.

RF Heating – Working Principle in disinfestation

Radio Frequency heating involves the application of electromagnetic energy to generate heat within the targeted material. In this system, the RF generator establishes an alternate electric field between the electrodes and the material, consisting of atoms and molecules. While some molecules are electrically neutral, the majority are bipolar. The substance to be heated is positioned between the electrodes. The alternating electric field, oscillating at

40.68 MHz (equivalent to 40,680,000 cycles per second), induces polarization, causing molecules to reorient themselves in the opposite direction. When the electric field is applied, the bipolar molecules act like miniature magnets, aligning with the field. This phenomenon occurs due to the presence of water molecules in both, serving as dielectric materials. In insects, these water molecules undergo continuous spinning, generating friction with cell organelles. This friction leads to cell disruption and, ultimately, the death of the insects. Consequently, employing optimized RF electrode current and product exposure time in alignment with the lethal temperature of insects ensures the eradication of all insect stages without compromising the quality of the product.

During RF treatments, heat is generated within the product due to molecular friction resulting from the movement of oscillating dipole molecules, space charge displacement, and the migration of ions triggered by the applied alternate electric field, as illustrated in Fig. 2.

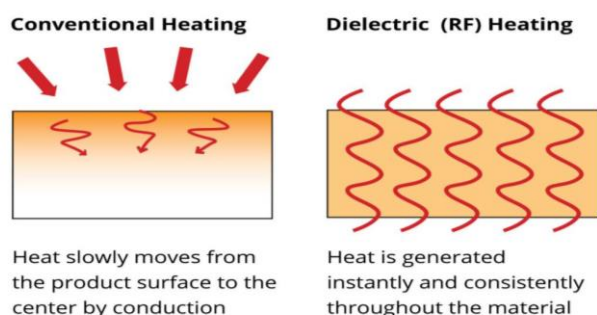


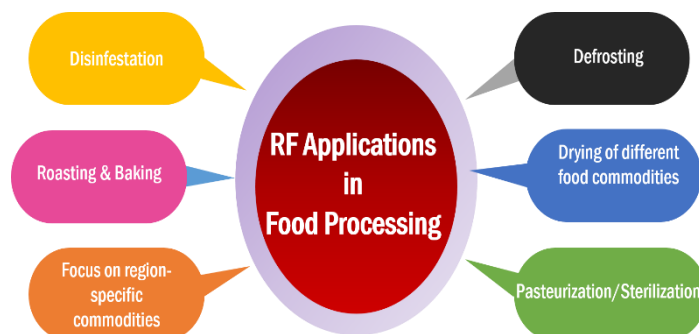
Fig. 2 Mechanism involved in Conventional heating and RF heating

RF Heating System

Two types of RF heating systems are widely applied in the food industry and research, which include free-running oscillators and 50 Ω RF systems. Among these, free running oscillator parallel-plate system is the most applied in the food grains and their products processing research. RF energy in this system is generated by the standard oscillator circuit formed by the triode tubes. Two electrodes and the loaded products between them could form a tuning circuit and be inductively coupled with the output circuit, which results in heat generation. The energy coupled within the product is adjusted by the moveable top electrode and the products can be moved through the

RF electromagnetic field by a conveyor belt to achieve a continuous heating processing. The advantages of free free-running oscillator system include high efficiency, simple structure and low cost. However, the capacitance of the working circuit could be changed during RF heating due to the changes in electrode gaps and DPs of products, which would lead to a change in the system frequency.

Fig. 3. Applications of RF treatment in food grains and their product processing



RF Disinfestation Applications in the Food Industry

Numerous research studies have focused on RF heating to suppress the proliferation of insects in farm produce. RF heating has been extensively studied in research laboratories and a few studies are 100% disinfested in-shell walnuts with *Amyelois transitella*, navel orange worm, complete disinfestation of *Cydia pomonella*, codling moth in in-shell walnuts and *Rhyzopertha dominica*, lesser grain borers present in rough rice. Disinfestation of *Plodia interpunctella*, Indian meal moth and *Callasobruchus maculatus*, cow pea weevil using RF heating with a treatment temperature of 55-58 °C for 5-10 min resulted in 100% mortality and no detrimental consequences on legume germination and quality was reported. An efficient treatment approach has been developed to manage *sitophilus oryzae* in milled, rough and brown rice without significant degradation of quality. Radiofrequency energy provides the prospect of rapidly rising temperature in bulk materials such as rice and wheat flour. Experimental studies on stored rapeseeds revealed that 100 % mortality of *T. castaneum* could be achieved at 80 °C for adults and 60 °C for larva phases at different moisture content levels, without significant degradation in seed quality with appropriate RF heating parameters. The red flour beetle, *T. castaneum* is the most strongly connected

insect with the post-harvest infestation, worldwide and the major insect that is present in wheat flour.

Disinfestation of all life stages of grain borers and *Angoumois* grain moths by establishing a correlation between temperature and disinfestation effects. This correlation was instrumental in optimizing the Radio Frequency (RF) protocols for rough rice. Notably, a 100% mortality rate was observed after a 2-hour treatment for grain moths and a 1-hour treatment for *Angoumois* grain moths, with no emergence of insects during a 120-day storage period. RF disinfestation of wheat flour achieved a 100% disinfestation of *T. castaneum* by employing optimized RF parameters.

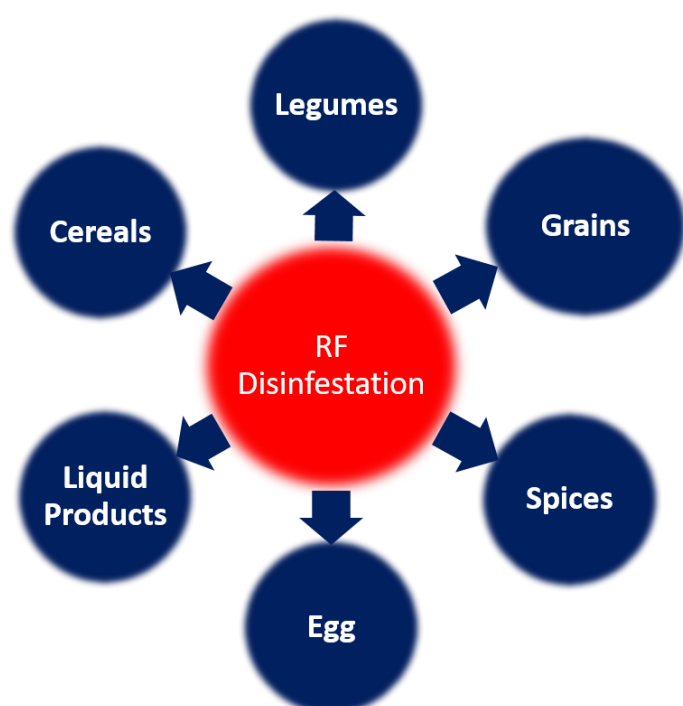


Fig. 4. Applications of RF treatment in various product processing

Conclusion

The advantages of Radio Frequency (RF) Disinfestation lie in its notable benefits for food production. RF heating provides a chemical-free solution, ensuring cleanliness and safety. It enables precise temperature control, preserving the nutritional quality and characteristics of food. The method's energy efficiency reduces overall energy consumption compared to conventional approaches. RF disinfestation also contributes to environmental

sustainability by eliminating the need for chemical pesticides. Despite requiring an initial investment, the long-term advantages, such as reduced reliance on pesticides and improved energy efficiency, result in cost savings. The promising future of RF heating aligns with sustainability goals, making it an eco-friendly and high-quality processing method. In conclusion, the exploration of RF heating signifies a significant step towards innovative and sustainable solutions in the food industry, with the potential to reshape practices and contribute to an environmentally conscious and resilient food supply chain.

References

- Landi, a. 1995. "Durum Wheat, Semolina and Pasta Quality Characteristics for an Italian Food Company." *Durum Wheat Quality in the Mediterranean Region* 42: 33–42. http://ressources.ciheam.org/util/search/detail_article.php?id=95605351&langue=fr.
- Indumathi, C., Manoj, D., Loganathan, M., & Shanmugasundaram, S. Radio frequency disinfestation of *Tribolium castaneum* (Herbst) in semolina: An emerging thermal technique. *Journal of Food Process Engineering*, e14443.
- Jiao, S., J. Tang, J. A. Johnson, G. Tiwari, and S. Wang. 2011. "Determining Radio Frequency Heating Uniformity of Mixed Beans for Disinfestation Treatments." *Transactions of the ASABE* 54 (5): 1847–55.
- Altemimi, Ammar, Salah Naji Aziz, Asaad R S Al-hiiphy, Naoufal Lakhssassi, Dennis G Watson, and Salam A Ibrahim. 2019. "Critical Review of Radio-Frequency (RF) Heating Applications in Food Processing," 1–11.
- Hassan, Amro B., Elke Pawelzik, and Dieter von Hoersten. 2016. "Effect of Radio Frequency Heating on Nutritional Quality and Protein Solubility of Corn." *Food Science and Nutrition* 4 (5): 686–89.

Stable Isotope Ratio Analysis (Sira): A Tool for Isotopic Analysis for Food Authentication and Traceability in Dairy Industry

Ashritha B¹, N. Veena², Avinash C. Gautham¹ and Somveer³

¹PhD scholar, Department of Dairy Technology, ICAR-NDRI, Karnal

²Associate Professor, Department of Food Safety and Quality, DSLD College of Horticultural Engineering and Food Technology, UHSB, Devihosur, Haveri

³PhD scholar, Department of Dairy Engineering, ICAR-NDRI, Karnal

*Corresponding Author: veena.ndri@gmail.com

The area of food authentication is experiencing tremendous growth as a result of the growing public awareness regarding food quality and safety. Consumers have been showing a growing preference for food labels that provide detailed information on the origin and authenticity of the product. Typically, the food label or description includes information on the ingredients, geographical origin, processing methods, manufacturing dates, and genetic characteristics. An authentic food is defined as one that conforms precisely to the specifications set forth by the producer. The food label description provides vital information for consumers to make informed judgments on their dietary choices and food purchases.

Authenticating food involves identifying instances of mislabeling, where food have been falsely labeled with a specific name, as well as the use of cheaper but similar ingredients, undisclosed processes, or the addition of adulterants to increase the quantity of food. It also entails verifying the accuracy of information regarding the food's origin, species, and production method. Currently, the accurate evaluation of food authenticity is crucial due to consumers' frequent exposure to a diverse range of food products. Undoubtedly, globalization entails the increasing exchange of food products around the globe. Traceability has become a fundamental aspect of food safety policy. It serves as a risk-management tool that allows the food sector or authorities to remove or recall items that have been identified as dangerous. The growing intricacy and elongation of the food chain, in addition to recent food-related concerns, have increased public awareness about the source of food and emphasized the necessity of implementing measures to guarantee that foods are of superior quality and free from harm when they are consumed by individuals (Mania et al., 2018).

Developing a proficient food traceability system offers a method for safeguarding the reputation of a specific region's brand, guaranteeing fair competitiveness in trade, and enhancing consumer trust. Various analytical techniques employed in the determination of food authenticity. Stable isotope ratio analysis (SIRA) is one of the highly accepted approaches for providing information on the traceability of food. This method often encompasses multiple aspects of food production. SIRA is an analytical technique that fulfills these requirements and has been employed to verify the geographical origin of various food items, such as wine (Christoph et al., 2015), meat (Bontempo et al., 2023), milk, and dairy products (Gregorcic et al., 2020). It is also used to compare isotopic results with typical samples from official wine databases, such as the one established by the European Commission in Regulation (EC) No 479/2008. It is possible to create a comparable database to support assertions of geographical origin found on dairy product labels. Isotope analysis offers the benefits of exceptional precision and efficiency and has broad relevance in various domains, including food authenticity, medical sciences, geology, and biology, resulting in its widespread use (Schauble, 2004).

Stable isotope ratios

Isotopes are atoms that possess different numbers of neutrons while maintaining an identical number of protons. Isotopes of a specific element hold the identical position on the periodic table, thereby exhibiting identical chemical properties but varying in mass. In general, isotopes can be categorized into two types: stable isotopes and radioactive isotopes (also known as unstable isotopes). In contrast to unstable isotopes, which decay and lose mass over predictable time periods, stable isotopes' nucleus properties remain constant throughout time. (Vanhaecke & Degryse, 2012).

Stable isotope ratios show the relationship between heavy and light isotopes. Isotopic data are reported in two ways: absolute ratios and relative to standard (delta notation) (Laursen et al., 2016).

$$\alpha_B^A = \alpha_{A-B} = \frac{R_A}{R_B}$$

' α ' is the factor used to report isotope differences between two phases fraction.

In order to determine the ratio reliably, the actual ratio measured in research samples are compared to a standard isotope ratio, and are given as permil (‰)

$$\delta_{Sample} = \left(\frac{R_{sample}}{R_{standard}} - 1 \right) \times 1000$$

Table 1. Isotopic composition of the primary reference standard

Primary reference material	Isotope ratio	Accepted value (x 10 ⁶ ppm) (with 95% confidence interval)
VSMOW	² H/ ¹ H	155.76 ± 0.10
	¹⁸ O/ ¹⁶ O	2005.20 ± 0.43
	¹⁷ O/ ¹⁶ O	373 ± 15
VPDB	¹³ C/ ¹² C	11237 ± 9.0
	¹⁸ O/ ¹⁶ O	2067.1 ± 2.1
	¹⁷ O/ ¹⁶ O	379 ± 15
AIR	¹⁵ N/ ¹⁴ N	3676.5 ± 8.1
VCDT	³⁴ S/ ³² S	45004.5
	³³ S/ ³² S	8100.0

Different isotopes for food authenticity and traceability

Carbon

The primary and largest natural source of carbon is atmospheric carbon dioxide (CO₂), which is utilized by plants for the process of photosynthesis. During the process of photosynthesis, carbon isotopes undergo fractionation. Plants exhibit a preference for the lighter ¹²C over the heavier ¹³C in enzymatic and transport reactions (Marshall et al., 2007). However, the extent of this preference differs among plants that

employ different photosynthetic routes. Due to the uniqueness of enzymes associated with the three primary photosynthetic pathways (Calvin cycle, Hatch Slack cycle, and Crassulacean acid metabolism), which exhibit varying preferences for ¹³C and ¹²C isotopes, the isotopic characteristics of different plant groupings may be reliably differentiated. C₃ plants, such as temperate grasses, barley, and sugarbeet, exhibit $\delta^{13}\text{C}$ values that fall within the range of -35 to -21‰. On the other hand, C₄ plants, including tropical grasses, maize, and sugarcane, display $\delta^{13}\text{C}$ values that are less negative, ranging from -14 to -10‰. Hence, the impact of grazed feedstuffs on $\delta^{13}\text{C}$ values of animal derived foods, like milk, is significantly influenced by geographical factors. This is because C₃ plants are predominantly found in regions with temperate climates and abundant rainfall, while C₄ plants are more prevalent in equatorial regions with less rainfall and greater sunlight exposure (Still et al., 2003)

Nitrogen

Atmospheric dinitrogen (N₂) is the primary natural source of nitrogen. Nevertheless, herbivores obtain their nitrogen from the plants they consume, and the $\delta^{15}\text{N}$ values vary among different plant functional groups. Legumes have the ability to form a symbiotic relationship with certain bacteria that allows them to convert atmospheric nitrogen into a usable form. This process is associated with a $\delta^{15}\text{N}$ value of 0‰ (Molkentin & Giesemann, 2010). In contrast, other plants reflect the nitrogen composition of the soil they grow in, which is influenced by agricultural practices such as the application of fertilizers. Additionally, the nitrogen in the soil gradually becomes enriched with ¹⁵N due to the preferential loss of ¹⁴N as nitrate or nitrous oxide. In general, $\delta^{15}\text{N}$ values tend to be elevated (reaching up to 30‰) in organic fertilizers such as slurry, as a result of selective loss of ¹⁴N during their production. On the other hand, synthetic fertilizers typically exhibit lower values (ranging from 4‰ to 4‰), which is indicative of their origin from N₂ (defined as 0‰) (Gautam & Iqbal, 2010)

Hydrogen and oxygen

According to Marshall et al. (2007), water serves as the primary reservoir of hydrogen and oxygen atoms in plant and animal systems. Dairy cows typically obtain water through drinking and consuming plant water, both of which are predominantly influenced by precipitation water. Consuming groundwater directly can affect the $\delta^2\text{H}$ and $\delta^{18}\text{O}$ levels of cows' drinking water, serving as a reliable diagnostic of their geographic origin. Due to the irregular replacement of groundwater compared to precipitation water, dairy products from places where deep groundwater is the primary source of drinking water for dairy cows do not experience the same impact on their isotope ratios as products from animals ingesting precipitation water. The reference standard (V-SMOW) utilized in the computation of hydrogen ($\delta^2\text{H}$) and oxygen ($\delta^{18}\text{O}$) reading has a precisely defined value of 0‰ for both ratios (Gonfiantini, 1978). As ocean water evaporates, it loses the heavier isotopes (^{18}O and ^2H). So when the vapor condenses to form clouds, the isotopic composition of the cloud is lighter (with more of the lighter isotopes ^{16}O and ^1H) compared to the ocean water. This means that the cloud has more negative $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values (Bowen, 2010). Consequently, when water condenses from rain clouds, the heavier isotopes precipitate at a somewhat faster rate. Nevertheless, the seasonal variation significantly influences the $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values of precipitation water. Hence, it is imperative to take into account seasonality while interpreting data.

Principle of stable isotopes analysis

Isotope fractionation is the primary mechanism that influences the proportional distribution of isotopes in natural substances. The chemical behavior of two isotopes of an element is comparable due to their same electronic configuration. However, the variation in mass between the isotopes leads to differences in chemical effects, such as reaction rates and binding strength. The variation in the strength of chemical bonds and the rate at which chemical reactions occur between different isotopes results in a modification of the distribution of heavy and light isotopes (Kendall and Caldwell, 1998). Plant-

based food products frequently exhibit distinct isotopic fingerprints as a result of fractionation processes. Furthermore, researchers have explored isotopic signals as a means of evaluating the nutritional history in animal ecology and thereby for authenticating animal products such as meat, eggs, and dairy products.

Isotope ratio mass spectrometry (IRMS) is a valuable technique for quantifying the relative proportions of isotopes in natural substances. The device consists of three fundamental components: an ion source, a magnetic analyzer, and an ion collector. The light isotope in IRMS exclusively analyzes gases, so the analytes must be converted into a gaseous state (such as H_2 , N_2 , CO , CO_2 , and SO_2) that is suitable for ionization. In this scenario, carbon dioxide is generated from organic components by undergoing oxidation with copper oxide. Hydrogen is produced through the reductive conversion of water by reacting it with a metal such as zinc. The ions are spatially segregated by either a fixed magnet or an electromagnet (Kelly, 2003). The radius of deflection is determined by the mass and charge. Ions with identical mass-to-charge ratios exhibit equivalent deflection radii, with heavier ions experiencing less deflection compared to lighter ions. The deflection of ions concentrates them into many beams that subsequently reach the ion collectors. The quantification of each beam is performed using Faraday cups in ion collectors. The ion currents generate the voltage within the cup, which is then converted into a digital signal.

In the Continuous flow-IRMS technique (shown in figure 1), a solid or liquid biological sample is inserted into a high-temperature combustion chamber of an elemental analyzer, where it undergoes conversion into a gaseous state. The gaseous byproducts of combustion, such as CO_2 , N_2 , and H_2O , are transported by a continuous flow of helium gas, passing through a purification process, and then analyzed using a gas chromatography-isotope ratio mass spectrometry apparatus. The gases are separated using gas chromatography and then directed to an ion source, where individual ion beams are created for each combustion gas. Within the magnetic sector of the

mass spectrometer, the beam is divided into many beams based on the molecular weights of the different isotopes present in the gas (Brenna et al., 1997). IRMS has been applied to authenticate numerous food products, including honey, fruit juices, wine, and milk.

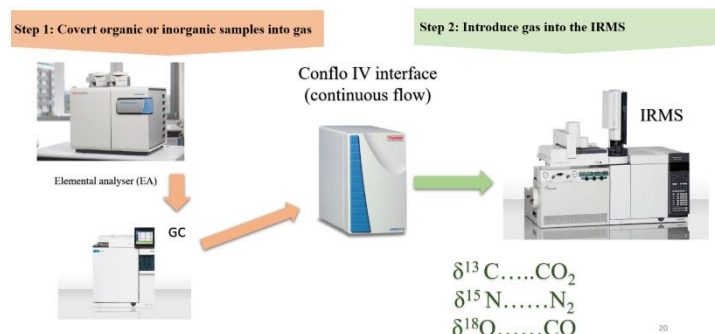


Fig 1: Continuous flow-IRMS working principle
Applications in dairy industry

Isotope analysis is frequently employed to ascertain the origin of dairy output. The effectiveness of SIRA as an authentication tool for milk and dairy products stems from the inherent characteristic that isotope ratios undergo predictable and replicable changes in response to various factors, such as: (i) the animal's diet, (ii) the geographic origin of the animal (which affects its diet), (iii) the seasonal variations in milk production, and (iv) the manufacturing procedures employed in product production (O'Sullivan et al., 2022).

Conclusions

SIRA is an independent, reproducible method of authenticating dairy products providing specific information of value to regulators, dairy producers and ultimately consumers. The techniques of isotope analysis have advantages such as high precision, small sample size and same technique can be used for almost any type of food productions. Future food authentications will be increasingly based on multivariate datasets generated by several analytical techniques (SIRA, NMR, metabolomics, elemental fingerprinting, etc.).

References

Bontempo, L., Perini, M., Pianezze, S., Horacek, M., Roßmann, A., Kelly, S. D., ... & Camin, F. (2023). Characterization of Beef Coming from Different European Countries through Stable

Isotope (H, C, N, and S) Ratio Analysis. *Molecules*, 28(6), 2856.

Bowen, G. J. (2010). Statistical and geostatistical mapping of precipitation water isotope ratios. *Isoscapes: understanding movement, pattern, and process on Earth through isotope mapping*, 139-160.

Brenna, J. T., Corso, T. N., Tobias, H. J., & Caimi, R. J. (1997). High-precision continuous-flow isotope ratio mass spectrometry. *Mass spectrometry reviews*, 16(5), 227-258.

Brescia, M. A., Caldarola, V., Buccolieri, G., Dell Atti, A., & Sacco, A. (2003). Chemometric determination of the geographical origin of cow milk using ICP-OES data and isotopic ratios: A preliminary study. *Italian Journal of Food Science*, 15(3), 329-336.

Camin, F., Wietzerbin, K., Cortes, A. B., Haberhauer, G., Lees, M., & Versini, G. (2004). Application of multielement stable isotope ratio analysis to the characterization of French, Italian, and Spanish cheeses. *Journal of agricultural and food chemistry*, 52(21), 6592-6601.

Christoph, N., Hermann, A., & Wachter, H. (2015). 25 Years authentication of wine with stable isotope analysis in the European union-review and outlook. In *BIO Web of Conferences* (Vol. 5, p. 02020). EDP Sciences.

Erich, S., Schill, S., Annweiler, E., Waiblinger, H. U., Kuballa, T., Lachenmeier, D. W., & Monakhova, Y. B. (2015). Combined chemometric analysis of ¹H NMR, ¹³C NMR and stable isotope data to differentiate organic and conventional milk. *Food Chemistry*, 188, 1-7.

Gautam, S., & Iqbal, M. Z. (2010). Using stable isotopes of nitrogen to study its source and transformation in a heavily farmed watershed. *Environmental Earth Sciences*, 60, 11-20.

Gonfiantini, R. (1978). Standards for stable isotope measurements in natural compounds. *Nature*, 271(5645), 534-536.

- Hamzić Gregorčič, S., Potočnik, D., Camin, F., & Ogrinc, N. (2020). Milk authentication: Stable isotope composition of hydrogen and oxygen in milks and their constituents. *Molecules*, 25(17), 4000.
- Kelly, S. D. (2003). Using stable isotope ratio mass spectrometry (IRMS) in food authentication and traceability. *Food authenticity and traceability*, 156-183.
- Kendall, C., & Caldwell, E. A. (1998). Fundamentals of isotope geochemistry. In *Isotope tracers in catchment hydrology* (pp. 51-86). Elsevier.
- Laursen, K. H., Bontempo, L., Camin, F., & Rossmann, A. (2016). Advances in isotopic analysis for food authenticity testing. In *Advances in food authenticity testing* (pp. 227-252). Woodhead Publishing.
- Mania, I., Delgado, A. M., Barone, C., Parisi, S., Mania, I., Delgado, A. M., ... & Parisi, S. (2018). Food traceability system in Europe: basic and regulatory requirements. *Traceability in the Dairy Industry in Europe: Theory and Practice*, 3-14.
- Marshall, J. D., Brooks, J. R., & Lajtha, K. (2007). Sources of variation in the stable isotopic composition of plants. *Stable isotopes in ecology and environmental science*, 22-60.
- McLeod, R. J., Prosser, C. G., & Wakefield, J. W. (2016). Identification of goat milk powder by manufacturer using multiple chemical parameters. *Journal of Dairy Science*, 99(2), 982-993.
- Molkentin, J., & Giesemann, A. (2010). Follow-up of stable isotope analysis of organic versus conventional milk. *Analytical and Bioanalytical Chemistry*, 398, 1493-1500.
- O'Sullivan, R., Schmidt, O., & Monahan, F. J. (2022). Stable isotope ratio analysis for the authentication of milk and dairy ingredients: A review. *International Dairy Journal*, 126, 105268.
- Pianezze, S., Bontempo, L., Perini, M., Tonon, A., Ziller, L., Franceschi, P., & Camin, F. (2020). $\delta^{34}\text{S}$ for tracing the origin of cheese and detecting its authenticity. *Journal of Mass Spectrometry*, 55(7), e4451.
- Schauble, E. A. (2004). Applying stable isotope fractionation theory to new systems. *Reviews in mineralogy and geochemistry*, 55(1), 65-111.
- Still, C. J., Berry, J. A., Ribas-Carbo, M., & Helliker, B. R. (2003). The contribution of C 3 and C 4 plants to the carbon cycle of a tallgrass prairie: An isotopic approach. *Oecologia*, 136, 347-359.
- Vanhaecke, F., & Degryse, P. (Eds.). (2012). Isotopic analysis: fundamentals and applications using ICP-MS. John Wiley & Sons.

Table 2. Different isotopes and their fractionation process

Elements	Isotopes	Natural Abundance	Delta Notation	Fractionation Process	Information
Hydrogen	^1H ^2H	99.98 0.02	$\delta^2\text{H}$	Evaporation, condensation, precipitation, transpiration	Geography, water usage, fertilization rate
Carbon	^{12}C ^{13}C	98.9 1.1	$\delta^{13}\text{C}$	CO_2 assimilation, stomatal conductance	Water use efficiency, fertilization rate
Nitrogen	^{14}N ^{15}N	99.6 0.4	$\delta^{15}\text{N}$	N transformation processes, atmospheric loss	Fertilizer type and rate
Oxygen	^{16}O ^{17}O ^{18}O	99.76 0.04 0.2	$\delta^{18}\text{O}$	Evaporation, condensation, precipitation, transpiration	Geography, water usage, fertilization rate

Table 3. Applications of SIRA in dairy foods

Sl. No.	Applications	Isotopes involved	References
1	Distinguish milk between 2 different geographical areas in southern Italy	$\delta^{13}\text{C}$ and $\delta^{15}\text{N}$	Brescia et al., 2003
2.	Characterization of French, Italian, and Spanish Cheeses	$\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ of casein and $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ of glycerol (obtained from lipid hydrolysis)	Camin et al., 2005
3.	Discrimination of organic milk from conventional milk in Korea	$\delta^{13}\text{C}$ of protein in combination $\delta^{15}\text{N}$	Chung et al., 2014
4.	Differentiation of organic and conventional milk (raw, pasteurized, and ultraheat treated).	$\delta^{13}\text{C}$	Erich et al., 2015
5.	Concentrations of some trace elements in goat milk powder	$\delta^{13}\text{C}$, $\delta^{15}\text{N}$	McLeod et al., 2015
6.	Detection of water addition (>15%)	$\delta^{18}\text{O}$	Gregorcic et al., 2020
7.	Italian cheese (Grana Padano PDO and Parmigiano Reggiano PDO) characterized for the different regions and zones	$\delta^{34}\text{S}$	Pianezze et al., 2020

* * * * *

FSSAI's Pioneering Role in Enhancing Food Safety and Quality in the Indian Subcontinent

Somveer^{1*}, Kumari M², Ravikant V. Vinchurkar³, Deshmukh RR³ and Bakeeru L³

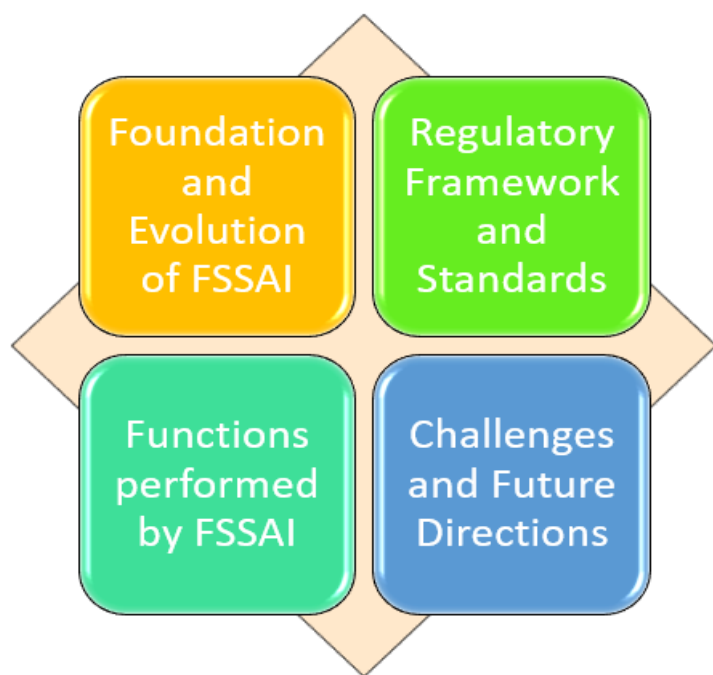
¹PhD Scholar, Dairy Engineering Division, National Dairy Research Institute, Karnal

²Teaching Associate, Dairy Engineering Division, CoDST, RAJUVAS, Bikaner

³PhD Scholar, Dairy Microbiology Division, National Dairy Research Institute, Karnal

*Corresponding Author: somveer.berwal20@gmail.com

In the rich tapestry of the Indian subcontinent, where diverse cultures, traditions, and flavours converge, the significance of food cannot be overstated. However, ensuring the safety and quality of the food supply is a formidable challenge, given the vastness and complexity of the region. The Food Safety and Standards Authority of India (FSSAI) has emerged as a crucial player in this landscape, working tirelessly to uphold the highest standards of food safety and quality. In this article, we delve into the pivotal role played by FSSAI in improving the overall food safety scenario in the Indian subcontinent.



Foundation and Evolution of FSSAI

Established in 2006 under the Food Safety and Standards Act, FSSAI operates as an autonomous body under the Ministry of Health and Family Welfare, Government of India (FSSAI, 2011). Its primary mandate is to regulate and monitor the manufacture, storage, distribution, sale, and import of food products to ensure they meet the prescribed safety and quality standards (Ajay, 2018). The journey of FSSAI has been marked by a commitment to continuous improvement and adaptability. Over the years, the authority has evolved to address emerging

challenges and incorporate international best practices into the Indian food regulatory framework. This evolution has played a pivotal role in enhancing the food safety and quality landscape in the subcontinent.

Regulatory Framework and Standards

A cornerstone of FSSAI's efforts lies in the establishment of a robust regulatory framework and the formulation of comprehensive standards for various food products. The Food Safety and Standards (Food Products Standards and Food Additives) Regulations, 2011, provide a detailed set of guidelines covering a wide spectrum of food items. This includes provisions for permissible limits of contaminants, food additives, and labeling requirements, among other critical aspects. By setting and regularly updating these standards, FSSAI not only ensures the safety of consumers but also fosters a culture of compliance within the food industry. The standards are designed to align with global benchmarks, promoting trade and assuring consumers that the food they consume adheres to international quality norms (Somveer *et al.* 2023).

Functions performed by FSSAI

Enhanced Surveillance and Enforcement

FSSAI has significantly bolstered its surveillance and enforcement mechanisms to monitor the food supply chain effectively. The authority conducts regular inspections, sampling, and testing of food products to verify compliance with established standards. Rigorous enforcement actions are taken against entities found violating regulations, including fines, product recalls, and, in severe cases, license cancellations. The use of technology has been instrumental in these endeavours. FSSAI has implemented initiatives such as the Food Safety Compliance System (FoSCoS) to streamline regulatory processes, enhance transparency, and facilitate real-time monitoring. This digital platform allows food businesses to obtain licenses, submit compliance reports, and undergo inspections seamlessly,

contributing to a more efficient and accountable regulatory ecosystem.

Capacity Building and Training

Recognizing that a well-informed and skilled workforce is essential for effective implementation of food safety measures, FSSAI has placed a strong emphasis on capacity building and training programs. These initiatives target various stakeholders, including food businesses, regulatory officials, and consumers. For food businesses, FSSAI conducts training sessions to enhance awareness about regulatory requirements and good manufacturing practices. This not only empowers businesses to operate within the legal framework but also promotes a culture of self-regulation.

Regulatory officials are provided with specialized training to stay abreast of the latest developments in food safety and quality management. This ensures that inspections are conducted with precision, and regulatory decisions are based on a deep understanding of the evolving challenges in the food industry. Consumer education is another vital component of FSSAI's outreach efforts. Through campaigns, workshops, and digital platforms, the authority disseminates information about safe food practices, reading labels, and reporting concerns. Empowering consumers with knowledge makes them active participants in the broader mission of food safety.

International Collaboration and Best Practices

FSSAI recognizes the global nature of the food supply chain and actively collaborates with international agencies and organizations to stay informed about best practices and emerging trends. This collaborative approach helps in benchmarking India's food safety standards against global norms, fostering a culture of continuous improvement.

Participation in international forums and adherence to Codex Alimentarius, the international food standards body, further aligns India with global expectations. By adopting internationally accepted practices, FSSAI contributes not only to the safety of domestically consumed food but also facilitates exports by ensuring compliance with destination country requirements.

Addressing Emerging Challenges

The dynamic nature of the food industry presents new challenges regularly, including the rise of novel food products, changing consumption patterns, and evolving technologies. FSSAI remains vigilant in adapting its regulatory framework to address these challenges effectively.

One such example is the regulation of genetically modified (GM) foods. FSSAI has established guidelines for the safety assessment of GM foods and derived products, ensuring a cautious and science-based approach to their introduction into the market. This reflects the authority's commitment to balancing technological advancements with safety considerations.

Contaminant Management and Risk Assessment

FSSAI places significant emphasis on managing contaminants in the food supply chain. Regular monitoring and assessment of contaminants such as pesticides, heavy metals, and mycotoxins are conducted to ensure that food products remain within permissible limits.

The authority employs a risk-based approach to prioritize and address potential hazards. This involves assessing the level of risk associated with specific contaminants and tailoring regulatory measures accordingly (Nair *et al.*, 2023). By focusing resources on high-risk areas, FSSAI optimizes its efforts to safeguard public health.

Issuing Licencing Number

The FSSAI number is a 14-digit unique code assigned to food businesses in India. Each digit carries specific information:

- Digit 1: Indicates registration status (1 for registered, 0 for unregistered)
- Digits 2-3: State code
- Digits 4-5: Year of registration
- Digits 6-9: Serial number in that state and year
- Digits 10-14: Check digit for verification

Types: Different types of licenses exist based on the nature and size of the business, each with its own FSSAI number format and eligibility criteria. These include:

- Basic Registration
- State License
- Central License
- Import License
- Manufacturing/Processing License
- Hotel/Restaurant License

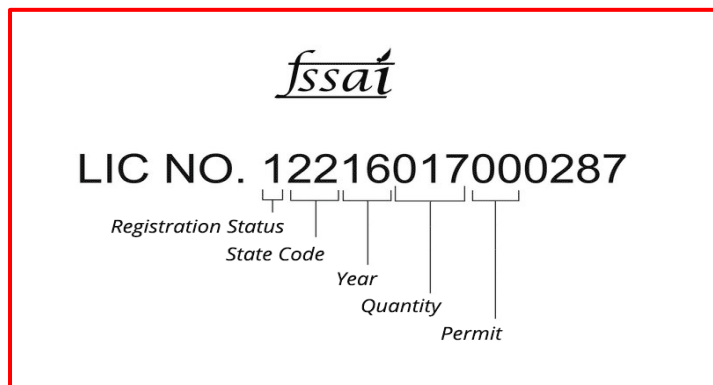


Figure 1. FSSAI Licence Number

Validity: License validity depends on the type, ranging from 1 year (Basic Registration) to 5 years (Central License). Renewal is required before expiry.

Validation: The FSSAI number can be verified online through the FoSCoS portal (Food Safety Compliance System) using the search features.

Obtaining the FSSAI Number

Application Process: The application process is online through FoSCoS, with varying document requirements based on the license type. It involves fees, self-declaration forms, and inspections.

Online Portal: FoSCoS provides a streamlined platform for applicants to submit details, track progress, and receive the license electronically.

Professional Assistance: Consultants and food safety experts can assist with understanding regulations, preparing documents, and navigating the application process.

Significance of the FSSAI Number

- Mandatory Requirement:** For any food business operating in India, obtaining the FSSAI license and displaying the number is mandatory by law.
- Consumer Confidence:** The FSSAI number assures consumers that the business adheres to food safety standards and regulations, promoting trust and brand reputation.

- Legal Compliance:** Possessing a valid FSSAI number protects businesses from legal penalties and ensures smooth operations.
- Market Access:** Many retailers and distributors require suppliers to have a valid FSSAI number for product listing and distribution, making it crucial for market access.
- Public Database:** The FSSAI number is listed in a public database, allowing consumers to verify the business's registration status and hygiene ratings.

Promoting Innovation and Research

FSSAI recognizes the role of innovation in the food industry and supports research initiatives that contribute to the development of safer and higher-quality food products. The authority collaborates with research institutions, academia, and industry stakeholders to stay abreast of technological advancements and scientific developments.

Encouraging the development of food safety technologies, novel food products, and sustainable practices is essential for the long-term improvement of the food safety landscape. FSSAI's proactive approach in this regard not only fosters innovation but also ensures that advancements are aligned with safety and quality considerations.

Challenges and Future Directions

While FSSAI has made remarkable strides in enhancing food safety and quality in the Indian subcontinent, challenges persist. The vastness and diversity of the region, coupled with varying levels of infrastructure and awareness, pose ongoing hurdles. To address these challenges, FSSAI is focused on expanding its outreach, leveraging technology, and strengthening collaborations with state and local authorities.

The future trajectory of FSSAI involves continued vigilance in the face of emerging risks, harnessing technology for more efficient regulatory processes, and promoting a culture of self-regulation within the food industry. The authority's commitment to staying abreast of global best practices and fostering international collaborations will remain central to its mission.

Conclusion

In conclusion, FSSAI stands as a beacon of progress in the realm of food safety and quality in the Indian subcontinent. From formulating stringent standards to leveraging technology for efficient monitoring, the authority has played a pivotal role in transforming the regulatory landscape. Through capacity building, international collaborations, and a commitment to addressing emerging challenges, FSSAI is not only safeguarding sustenance but also contributing to the overall well-being of millions across the subcontinent. As the journey continues, the authority's dedication to excellence will undoubtedly shape the future of food safety and quality in this diverse and vibrant region.

References

Ajay, V. (2018). Food Safety Standards and its Growing Role in Recent Times in India.

IMPACT: International Journal of Research in Humanities, Arts and Literature, 6(2), 135-140.

Retrieved from:
<https://www.fssai.gov.in/upload/uploadfiles/files/Chapter2.pdf>

Sasikumar Nair, S., Mazurek-Kusiak, A. K., Trafialek, J., and Kolanowski, W. (2023). Assessing Food Safety Compliance in a Small-Scale Indian Food Manufacturer: Before and after Certification of the Food Safety Management System and Foreign Supplier Verification Program. *Applied Sciences*, 13(22), 12190.

Somveer, Kumari M., Deshmukh R. R., Vinchurkar R. V., A. Pramanik and Avinash Chandra Gautam (2023). Role of water activity in food stability. *AgriTech Today*, 1(Special Issue), 93-98.

* * * * *

Surveillance and Impact of Antibiotic Resistance in Emerging Food Borne Pathogens

Ravikant V. Vinchurkar^{1*}, Kumari M.², Somveer³, Deshmukh RR¹ and B. Lakshmaiah¹

¹Ph.D. Scholar, Dairy Microbiology Division, National Dairy Research Institute, Karnal

²Teaching Associate, Dairy Engineering Division, CoDST, RAJUVAS, Bikaner

³Ph.D. Scholar, Dairy Engineering Division, National Dairy Research Institute, Karnal

*Corresponding Author: ravikantvinchurkar97@gmail.com

Recent research conducted in various regions of India has discovered traces of antibiotics in livestock products such as chicken meat and dairy. This finding indicates widespread antibiotic use in the production of food animals (Boeckel et al., 2015). Gandra et al.'s study in 2016 revealed that *Pseudomonas aeruginosa* exhibited an antibiotic resistance rate exceeding 50%, while *E. coli* and *Klebsiella pneumonia* demonstrated resistance rates of over 70% to the broad-spectrum antibiotics fluoroquinolones and third-generation cephalosporin. In 2010, Kumarasamy et al. investigated Enterobacteriaceae isolates from two significant Indian centers, Chennai (South India) and Haryana (North India). Furthermore, Dixit and other co-authors (2011) highlighted a concerning trend of resistance to novel antimicrobial medicines like carbapenems across various Gram-positive and Gram-negative microorganisms since their release in 2010. They predicted that by 2050, antimicrobial resistance (AMR) would lead to 2 million fatalities annually in India (Laxminarayan et al., 2012). Additionally, their research found that 70-80% of India's Enterobacteriaceae harbored extended-spectrum beta-lactamases (ESBLs). Collectively, these studies underscore the rapid expansion of the antimicrobial resistance issue in India, emphasizing the urgent need for decisive action by various organizations to control AMR.

Epidemiology

Antimicrobial-resistant bacteria are found across the globe, posing a growing challenge in the treatment of common infections. An illustrative case is the increased difficulty in managing urinary tract infections (UTIs) due to the prevalence of resistant *E. coli*, compromising the effectiveness of the Fluoroquinolones on a global scale. Treatment failures for gonorrhea, using 3rd generation Cephalosporins, have been documented in at least 10 countries. In the US alone, over 2.8 million cases of antibiotic resistant infections have been emerging annually, resulting in

more than 35,000 deaths. Moreover, the incidence of resistant pathogens directly correlates with sepsis related outcomes, as demonstrated in a current investigation analyzing hospitalized patients from 2011 to 2014. This study identified the highest sepsis rates against Fluoroquinolone resistant *E. coli*, 3rd generation Cephalosporins, Carbapenem resistant *Klebsiella* species, and Vancomycin-resistant *Enterococcus* (VRE).

Mechanisms of Resistance

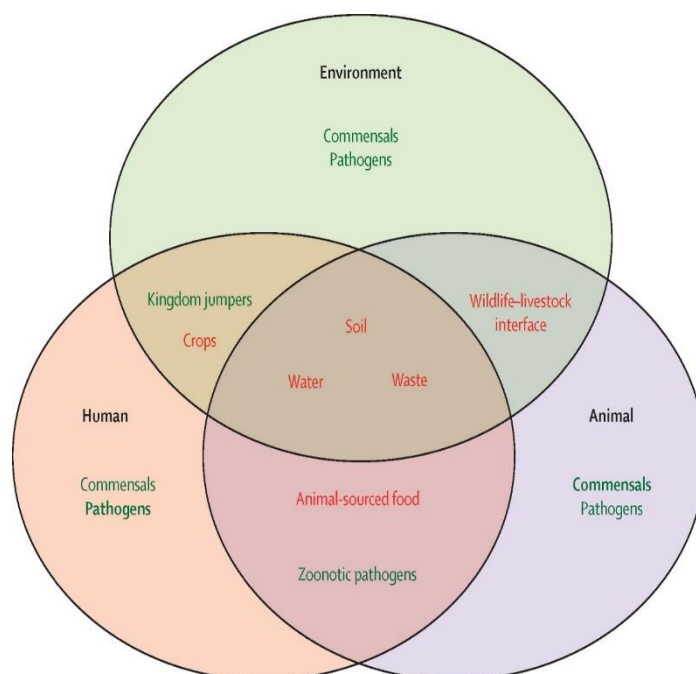


Fig. 1 Different sources of AMR pathogens

There are two types of bacterial resistance: intrinsic and acquired. Intrinsic resistance occurs when the antibiotic has no impact on the pathogen from the beginning. Acquired resistance is gained through the transmission of genetic material that imparts resistance. Specific bacterial genes are situated on plasmids, which are small, circular, double-stranded DNA molecules distinct from chromosomal DNA. These plasmids are transferred from one bacterium to another through a process known as conjugation, and this transfer can occur between bacteria of different species. The mechanisms that

bacteria utilize to develop acquired resistance are encoded on plasmids and can be categorized into four groups.

- 1) reduced permeability of the cell wall to antibiotics;
- 2) modification of enzymes to deactivate antibiotics;
- 3) changes in the drug target site; and
- 4) efflux pumps that eliminate antibiotics from the cell.

The primary mechanism used by bacteria is drug inactivation through enzymes, and the genes responsible for encoding these types of enzymes might be persuaded by specific medications or constantly expressed.

Multidrug-Resistant *Enterococcus*

Enterococci, which are primarily benign bacteria found in the gut, are a widely recognized group of microorganisms that demonstrate both inherent and acquired resistance to antibiotics. Particularly concerning are *E faecium* and *Enterococcus faecalis*, as they may possess various acquired resistance mechanisms, leading to multidrug resistance (Kumari et al., 2023). These organisms can display a significant level of resistance to beta-lactams (through beta-lactamase enzymes and modified binding proteins), vancomycin (involving alterations in peptidoglycan synthesis, known as VRE), and aminoglycosides (via enzymatic degradation). Ampicillin remains the preferred treatment for susceptible *Enterococcus* infections; however, options for addressing systemic infections caused by multidrug-resistant *Enterococcus* are limited, with drugs like linezolid, daptomycin, and tigecycline being among the available alternatives.

Methicillin-Resistant *Staphylococcus aureus* (MRSA)

MRSA first appeared in the early 1960s, shortly after the introduction of methicillin. Like most gram-positive organisms, the cell wall serves as a primary target for antimicrobial agents, leading to the development of acquired antimicrobial resistance. For a bacterium to be categorized as MRSA, it must harbor the *mecA* gene, responsible for a structural alteration in penicillin-binding protein 2a (PBP2a). This modification hinders the binding of beta-lactam antibiotics to the cell wall. Although laboratory testing

for methicillin susceptibility in *S aureus* is infrequent due to the instability of methicillin plates, MRSA is identified using a similar beta-lactam, oxacillin. According to the Clinical Laboratory Standards Institute, methicillin resistance is defined as an oxacillin mean inhibitory concentration of at least 4 mcg/mL, and oxacillin-resistant isolates also exhibit resistance to all beta-lactams, with a few exceptions such as ceftaroline.

Table 1: List of pathogens and their intrinsic resistance

Organism	Intrinsic resistance
<i>Bacteroides</i> (anaerobes)	aminoglycosides, many β -lactams, quinolones
All gram positives	aztreonam
<i>Enterococci</i>	aminoglycosides, cephalosporins, lincosamides
<i>Listeria monocytogenes</i>	cephalosporins
All gram negatives	glycopeptides, lipopeptides
<i>Escherichia coli</i>	macrolides
<i>Klebsiella</i> spp.	ampicillin
<i>Serratia marcescens</i>	macrolides
<i>Pseudomonas aeruginosa</i>	sulfonamides, ampicillin, 1 st and 2 nd generation cephalosporins, chloramphenicol, tetracycline
<i>Stenotrophomonas maltophilia</i>	aminoglycosides, β -lactams, carbapenems, quinolones
<i>Acinetobacter</i> spp.	ampicillin, glycopeptides

Extended-Spectrum Beta-Lactamase (ESBL)-Producing Organisms

Many gram-negative bacterial species have developed acquired resistance to beta-lactam antibiotics through the production of beta-lactamase. This enzyme works by deactivating the antimicrobial properties of the antibiotic, specifically by hydrolyzing its beta-lactam ring. The first beta-lactamase identified was a penicillinase found in *E. coli* in 1940, predating the medical use of penicillin. Over time, new antibiotics were created to counteract this enzyme, such as broad-spectrum cephalosporins. However, the introduction of these antibiotics led to resistance against even broader-spectrum agents, resulting in the emergence of the ESBL enzyme. Currently, more than 150 ESBLs have been identified in various species of Enterobacteriaceae and in *Pseudomonas aeruginosa*.

Pseudomonas aeruginosa

Pseudomonas aeruginosa, a gram-negative opportunistic pathogen, is a common cause of nosocomial infections. Treatment typically involves the use of beta-lactams, fluoroquinolones, and aminoglycosides. However, *Pseudomonas* often exhibits various mechanisms of resistance. Inherently, *Pseudomonas* has a lower membrane permeability

compared to *E. coli*, making it less susceptible to certain antimicrobials. The resistance mechanisms in *Pseudomonas* include mutations in genes encoding enzymes targeted by fluoroquinolones and the production of aminoglycoside-modifying enzymes for aminoglycoside resistance. Beta-lactam resistance is attributed to modifications in penicillin-binding proteins, efflux pump overexpression, and enzymatic drug inactivation. Exposure to antipseudomonal beta-lactam antibiotics increases the risk of resistance development. A retrospective study with 7,118 patients revealed a 4% increased risk of new resistance for each additional day of antipseudomonal beta-lactam therapy. To mitigate resistance, it is crucial to limit the duration of beta-lactam exposure effectively.

Enterobacteriaceae and ampC Enzyme

Enterobacteriaceae comprise over 100 species, with certain pathogens like *Serratia marcescens*, *Morganella morganii*, *Proteus vulgaris*, *Citrobacter species*, and *Enterobacter* species possessing the inducible beta-lactamase enzyme ampC. While not initially expressed, ampC can activate in response to certain antibiotics, leading to resistance. Culture and sensitivity reports may not detect ampC, but if resistance to cefoxitin is observed, it can serve as a surrogate marker for ampC. In such cases, avoiding penicillins and narrow-spectrum cephalosporins is advisable to prevent further resistance development.

Impact of Antibiotic Resistance in Food Borne Pathogens

Antibiotic resistance poses a significant threat to public health, particularly when it comes to foodborne pathogens. The widespread use of antibiotics in agriculture, including in livestock for growth promotion and disease prevention, has contributed to the emergence of antibiotic-resistant strains of bacteria. This phenomenon is alarming, as it diminishes the effectiveness of commonly used antibiotics in treating infections caused by these pathogens. When antibiotic-resistant strains of foodborne bacteria, such as *Salmonella* or *E. coli*, proliferate, it not only complicates the treatment of infections in humans but also raises the risk of severe and potentially life-threatening illnesses. Moreover, the transmission of antibiotic-resistant genes from

foodborne pathogens to other bacteria further exacerbates the problem. Addressing antibiotic resistance in foodborne pathogens requires a multifaceted approach, including prudent antibiotic use in agriculture, surveillance of resistant strains, and the development of alternative strategies for disease control in both humans and animals. Failure to address this issue comprehensively could lead to a future where treating common infections becomes increasingly challenging and may have dire consequences for global public health.

Conclusion

This article focuses on pathogens and mechanisms directly related to the global challenge of antimicrobial resistance. Bacteria, being ancient organisms, possess inherent survival skills within their environment, including the host undergoing antibiotic treatment. The widening gap between escalating resistance and the development of effective drugs emphasizes the crucial need for enhanced Antimicrobial Stewardship (AMS) and a comprehensive understanding of how bacteria can elude even the most potent antibiotics. Despite efforts to create new antibiotics capable of countering the latest resistance mechanisms, such endeavors have proven futile. The active participation of pharmacists in drug selection and AMS can significantly enhance patient outcomes and curb the further advancement of bacterial resistance. It is imperative to recognize that developing new medications alone does not offer a solution to this crisis; instead, the preservation of existing agents is paramount.

Reference

Kumarasamy, K. K., Toleman, M. A., Walsh, T. R., Bagaria, J., Butt, F., Balakrishnan, R., Chaudhary, U., Doumith, M., Giske, C. G., Irfan, S., Krishnan, P., Kumar, A. V., Maharjan, S., Mushtaq, S., Noorie, T., Paterson, D. L., Pearson, A., Perry, C., Pike, R., Rao, B., Woodford, N. (2010). Emergence of a new antibiotic resistance mechanism in India, Pakistan, and the UK: a molecular, biological, and epidemiological study. *The Lancet. Infectious diseases*, 10(9), 597–602.

- Kumari M, Vinchurkar RV, Somveer and Deshmukh RR (2023). Mathematical model-based comparative storage study of dahi at refrigeration and room conditions. *International Journal of Statistics and Applied Mathematics*, 8(3), 603-605.
- Muloi, D. M., Jauneikaite, E., Anjum, M. F., Essack, S. Y., Singleton, D. A., Kasudi, M. R., ... & Zadoks, R. N. (2023). Exploiting genomics for antimicrobial resistance surveillance at One Health interfaces. *The Lancet Microbe*, 4(12), e1056-e1062.
- Reygaert W. C. (2018). An overview of the antimicrobial resistance mechanisms of bacteria. *AIMS microbiology*, 4(3), 482-501.
- Van Boeckel, T. P., Brower, C., Gilbert, M., Grenfell, B. T., Levin, S. A., Robinson, T. P., & Laxminarayan, R. (2015). Global trends in antimicrobial use in food animals. *Proceedings of the National Academy of Sciences*, 112(18), 5649-5654.

* * * * *

Revolutionizing Food Safety in Food Supply Chain: A Comprehensive Survey of Modern Technologies

Suneel Subray Hegde

Ph. D scholar, Division of Postharvest Technology, ICAR- Indian Institute of Horticultural Research, Bengaluru

*Corresponding Author: suneelhegde111@gmail.com

Food safety is of vital importance, as it directly impacts the health and well-being of the public. Ensuring that the food we consume is free from contaminants, pathogens and harmful substances is crucial to prevent foodborne illnesses and outbreaks. Traditional methods of ensuring food safety often face limitations in terms of accuracy and efficiency. Manual record-keeping and paper-based tracking systems are prone to human errors, leading to delay in identifying and responding to potential hazards. Also, the lack of real-time monitoring and data analytics in traditional methods may cause difficulties in identifying the exact stage of contamination during a foodborne disease outbreak. Inadequate technological integration in traditional practices can delay the rapid identification and management of food safety risks, emphasizing the importance of embracing technological advancements for a more robust and effective food safety system.

In this era of technological advancement, it is essential to leverage the power of technology to enhance food safety. Cutting-edge technologies, such as blockchain, artificial intelligence and sensors, offer more efficient and transparent ways to track and trace the entire food supply chain. These innovations enable faster identification of potential hazards, better monitoring of food handling and transportation, and rapid response to any safety concerns. As the global food supply chain becomes increasingly complex, the need for continuous advancements in technology is essential to ensure that our food is safe, thereby safeguarding public health and maintaining consumers' confidence in the food industry.

Blockchain Technology

Blockchain technology has emerged as a revolutionary innovation in ensuring food safety by providing an irreversible and transparent ledger throughout the entire food supply chain. This is a decentralized, distributed ledger technology which employs cryptographic algorithms to secure transactions, ensuring secure and transparent record of all interactions. The unique characteristics of

blockchain enables it to address the challenges faced by the food industry, particularly in the areas of traceability and food safety. The decentralized nature of the technology allows for the creation of a tamper-resistant record of every transaction and movement within the supply chain, from the farm to processing, packaging and distribution. This creates a complete and transparent view of the product's journey, providing stakeholders with real-time information. The implementation of blockchain technology in food safety can be seen in enterprises such as the IBM Food Trust Network, where major players in the food industry collaborate to create a shared platform for end-to-end traceability. This platform enables consumers to access the information about the product's origin, processing methods and transportation through the scanning of QR codes on food products. This enhanced traceability imparts confidence in the safety and authenticity of the food we consume.

In the event of a food safety issue, blockchain technology facilitates rapid identification and removal of contaminated products from the supply chain. Traditional methods of tracing the source of contamination are often time-consuming and lack precision. However, with blockchain, the exact origin and distribution of affected products can be pinpointed within minutes, minimizing the potential impact on consumer health and reducing economic losses for the industry. Blockchain technology has the potential to revolutionize the food industry by providing a secure, transparent and tamper-resistant record of transactions throughout the supply chain. Its applications in enhancing traceability and food safety make it an ideal solution for addressing the challenges faced by the industry, ensuring the safety and authenticity of food products, and protecting consumers from potential health risks.

The integration of blockchain technology into the food industry has shown promise in enhancing food safety, but it faces significant challenges that must be addressed for widespread adoption to occur.

The development of unified interface standard is a crucial step towards integrating blockchain into existing systems, which ensures nonstop communication between different blockchain platforms used by various supply chain participants. Standardization of protocols and practices facilitates a more consistent and efficient implementation of blockchain technology across the food industry, ultimately leading to a more secure and transparent global food supply chain.

Artificial Intelligence in Predictive Analytics

Artificial Intelligence (AI) has emerged as a powerful tool in predictive analytics, revolutionizing the way the food industry approaches safety. AI, a branch of computer science that simulates human intelligence, plays a crucial role in predictive analytics by analysing vast datasets to forecast future outcomes. In the context of food safety, predictive analytics involves using AI algorithms to identify potential risks, allowing for preventive actions to mitigate those risks before they occur.

Machine learning, a subset of AI, enables computers to learn patterns from data and make predictions. In the food industry, machine learning algorithms analyse historical data related to food safety incidents, helping to identify trends and potential risks. By analysing vast amounts of data, AI algorithms can identify patterns and trends that may not be apparent to human analysts, allowing for more accurate predictions and better decision-making. This predictive capability is helpful in preventing foodborne illnesses and ensuring the safety of the food supply. Real-world applications of AI in predictive analytics for food safety abound. For instance, AI algorithms can analyse sensor data from the food supply chain to predict potential spoilage or contamination. By identifying deviations from optimal conditions in real-time, AI allows for immediate corrective actions, minimizing the risk of compromised food safety.

Challenges in the implementation of AI for food safety include the need for large and diverse datasets, ensuring algorithmic fairness and addressing complexity issues. Ongoing research focuses on refining algorithms, improving their accuracy and

developing explainable AI models that provide insights into the decision-making process. In inference, AI-driven predictive analytics represents a game-changer in ensuring food safety. By leveraging machine learning algorithms to analyse data and forecast potential risks, the food industry can take precautionary measures to prevent contamination and protect the consumers. While ethical considerations and challenges persist, ongoing research and developments position AI as a cornerstone in the continuous improvement of food safety standards.

Sensor Technologies for Real-time Monitoring

Sensor technologies have become very essential in real-time monitoring of the food industry, offering insights into critical factors that affects the food. Sensor technologies encompass a variety of devices designed to measure and monitor physical conditions. In the food industry, sensors are employed to track parameters such as temperature, humidity, gas composition and the presence of contaminants. These technologies provide a real-time understanding of environmental conditions throughout the food supply chain.

Continuous monitoring of temperature is crucial for preventing spoilage in perishable goods. Sensors placed in storage facilities, transportation vehicles and retail environments enable real-time tracking of temperature variations. In the event of deviations from optimal conditions, immediate corrective actions can be taken to preserve the quality and safety of the products. One of the primary applications of sensor technologies is in monitoring the cold chain, ensuring that temperature-sensitive products like dairy products, meat products and frozen foods, which are transported and stored under cold conditions. Real-time data from sensors allows for the identification of any breaches in the cold chain, reducing the risk of contamination and ensuring product quality upon reaching consumers. Beyond temperature and humidity, sensors play a crucial role in detecting contaminants. Environmental monitoring systems equipped with sensors can identify the presence of pathogens, allergens or other harmful substances in real-time. Early detection allows for

swift intervention, preventing contaminated products from reaching consumers.

The advantages of sensor technologies include rapid detection of deviations from ideal conditions, reduced waste through preventive measures and improved resource efficiency. However, challenges such as calibration, maintenance and data interpretation must be addressed to fully harness the potential of these technologies. Calibration ensures accuracy, regular maintenance prevents sensor malfunctions and effective data interpretation allows for good decision-making. Future developments should focus on refining sensor accuracy, exploring novel applications and establishing industry-wide standards to promote compatibility. Addressing these challenges and embracing technological advancements will further unlock the full potential of sensor technologies, establishing them as essential components of a proactive and comprehensive food safety strategy.

Challenges and Future Directions

The integration of emerging technologies in food safety faces challenges, including regulatory hurdles struggling to keep pace with advancements in blockchain, AI and sensors. Establishing standardized regulations considering these innovations is crucial. Industry resistance, driven by concerns about integration costs and data sharing, poses another obstacle, requires efforts to showcase technology benefits. Collaboration among stakeholders, ongoing

research refining AI algorithms, improving sensor affordability and enhancing blockchain interoperability are key to overcoming challenges and promoting sustainable technology-driven food safety.

Future directions for technology-driven food safety involves integration of efforts to refine, integrate and educate. Industry leaders and researchers must work collaboratively to develop standardized protocols, ensuring seamless collaboration and addressing regulatory concerns. Public awareness campaigns are crucial for building trust and understanding, as consumers play an integral role in demanding and appreciating the advancements that contribute to a safer and more transparent food supply chain. Ultimately, the future envisions a harmonious integration of these technologies, overcoming the challenges to create a reliable and efficient framework for ensuring food safety worldwide.

Conclusion

In essence, understanding the capabilities of advanced sensors, blockchain, and artificial intelligence not only strengthens our grasp on safety measures but also underscores the importance of ongoing research and careful implementation to improve worldwide food safety standards. Bringing these technologies together shows a hopeful path toward a safer, more effective, and reliable food supply chain.

* * * * *

Technologies For Pesticide Residue Elimination on Temperate Fruits for Safe Consumption

Shugufta Parveen¹, Sajad Un Nabi^{*1}, Bisma Rashid¹ and Mahendra K Verma¹

ICAR-Central Institute of Temperate Horticulture, Srinagar, J&K, 191132

*Corresponding Author: sajad_patho@rediffmail.com

Abstract

To overcome pests and disease menace in temperate fruits, farmers use a number of insecticides and fungicides. Fruits contaminated by pesticide residues pose a risk to both ecological security and human health. One of the essential methods for removing residues to ensure environmental sustainability and safety is food processing. Traditional thermal processing techniques, including as baking, roasting, blanching, and drying, have been shown to significantly lower pesticide levels; however, concentration effects can occasionally arise, producing more hazardous metabolites. A number of innovative non-thermal processing techniques, such as pulsed electric fields, cold plasma, high-pressure processing, and ultrasound, have emerged recently and demonstrate a significant ability to remove pesticide residues with little to no negative effect on the quality of fruit and vegetables.

Introduction

The temperate fruits belong to family *Rosaceae* which includes apple, peach, plum, apricot, pear, nectarine etc and one of the main challenges for successful production of these fruits is susceptibility to insect pest attacks. Their fruits make up a large portion of human diets because regular consumption may lower the risk of heart disease and some types of cancer. The estimated yield losses resulting from the attacks of different pests on different crops during different seasons vary from 10% to 35%. Unlike agricultural crops, temperate fruit crops which are grown as monoculture, the pest problems are entirely different and complex in nature. Pesticides (insecticides, fungicides) are widely being used to manage insect pests, fungal infestations of temperate fruit crops as they are prone to diseases and pests. Using pesticides increases food production, enhances food quality, and reduces crop/yield losses. It has been reported that the variety of pesticides has increased and that their global use is growing annually. Furthermore, it has long been a habit to

abuse or misuse older, more hazardous, and persistent pesticides in the environment. As a result, widespread detections of pesticide residues have been seen in soil, water, and the air. Their presence has resulted in harmful impact on human health as well as negative consequences to the ecosystem. High levels of pesticide exposure are linked to serious diseases such as headache, diarrhea, nausea, convulsions, irritation of the eyes, breathing difficulties, and even death and cause environmental pollution (**Figure1**). Furthermore, the human body contains higher amounts of pesticides than the environment does because of a process known as biomagnification. As a result high-pressure processing (HPP), fermentation, ozone, radiation, pulsed electric field (PEF), etc. are being used to reduce the residual effect of pesticides. In addition, a variety of home and commercial washing techniques may help lower pesticide concentrations. On the other hand, concentration effects can lead to a rise in pesticide residues under certain conditions, and processing might result in the development of more harmful transformation products or metabolites. In addition, certain pesticide characteristics (physicochemical properties like water solubility, vapor pressure, octanol-water partition coefficient, volatilization, etc.), the kind of fruits and environmental factors (temperature, relative humidity, etc.) influence how long pesticides remain in the fruits.

Importance of elimination of residues

Pesticide residue removal is critical for a number of reasons, including biodiversity preservation, human health, and environmental sustainability. Pesticides can leave residues on fruits, vegetables, and other crops even while they are successful at controlling crop pests. When consumed by people, these residues may build up over time and have harmful effects on health. Numerous health problems, including as neurological impairments, reproductive troubles, and carcinogenicity, have been related to long-term exposure to pesticide residues. Moreover, the effects of pesticide residues extend

beyond human health. These substances have a long half-life in the environment, polluting water and soil supplies. Water pollution can occur when pesticide runoff from crops enters rivers, lakes, and groundwater. In addition to endangering aquatic ecosystems, this contamination also puts wildlife and the larger environment at risk. The unintentional effects of pesticide use may harm birds, insects, and other non-target organisms which could lead to a decrease in biodiversity (**Figure 2**). A shift towards sustainable agriculture methods is necessary to overcome these issues. Pests can be efficiently managed while minimizing residues through the use of integrated pest management (IPM) tactics that combine mechanical, cultural, biological, and chemical application methods. Another crucial step in removing pesticide residues from the food chain is adopting organic farming methods, which omit synthetic pesticides and use natural alternatives. To put it briefly, the removal of pesticide residues is a complex process that not only protects public health but also maintains ecological stability and environmental sustainability. A robust and healthy food system for the current and future generations depends on finding a balance between efficient pest controls and reducing the ecological footprint of agriculture. Consuming fruits is the main way that individuals are exposed to pesticide residues. For humans, the recommended daily intake (RDI) of vitamins, minerals, dietary fiber, and other essential components is met by consuming fruits. They are eaten fresh or processed into things like fruit juice, purees, crisps, cans, and so on. However, because of their high susceptibility to pests and plant diseases, fruits are often treated with pesticides during the growing period in order to limit loss and preserve the high quality, which leaves pesticide residues in them. Due to the frequent use of pesticides, they have been contaminated by two or more active chemicals in recent years. When compared with animal food items, it can lower the incidence of chronic non-communicable diseases linked to nutrition and the associated environmental impact. Therefore, the risk of foodborne diseases increases as fruit consumption rises above maximum residue levels (MRLs).

Technologies for elimination and mechanism of elimination

Multiple strategies have been used to reduce the pesticide residual amounts in fruits and vegetables. One of these strategies is food processing, which modifies nutrient bioaccessibility to ensure food safety, prolong shelf life, and maintain or improve food quality. Food processing technologies can be broadly categorised based on the amount of heat input they require. These include thermal processing methods like boiling, drying, cooking, blanching, baking, roasting, sterilising, and so on, and non-thermal methods like ultrasound, cold plasma, high-pressure processing (HPP), pulsed electric field (PEF), radiation, ozone, fermentation, and so. It has been shown that following process treatments, the levels of pesticide contaminants in the final products decreases. Because of the highly oxidative potential of radicals and reactive species, ozone, for example, has been demonstrated to have a greater capacity for eliminating pesticides. Additionally, a number of commercial and home cleaning techniques may help lower pesticide concentrations. On the other hand, because of concentration effects, pesticide residues may rise in some unique situations, and processing may result in the development of more harmful transformation products or metabolites. For instance, photolysis, hydrolysis, and biodegradation would lead trichlorfon to change into more hazardous dichlorvos. The main criterion for evaluating the amount of pesticide residue in products produced by various food processing technologies when handling fruits is the processing factor (PF), which is based on the pesticide, the fruit commodity, and the processing technique. PF value is calculated as the ratio of pesticide residue concentration in the product after processing to pesticide residue concentration in fruits before processing. The concentration of pesticide is reduced when the PF value is less than 1. Conversely, a value greater than 1 indicates a pesticide concentration above the initial value observed prior to treatment. To determine the actual concentration following processing, the PF value is multiplied by the measured pesticide residue concentration of fruit. The PF value is essential for two reasons: (1) risk assessment of pesticide residues in fruits by adjusting

pesticide residues to measure dietary exposure and precisely establish MRLs; and (2) estimation of pesticide fluctuation during different processing steps.

Limitations

In order to maintain environmental sustainability and food safety, pesticide residue management is essential. However, managing pesticide residue comes with a number of limitations and difficulties. It is difficult to totally remove pesticide residues from fruits even with appropriate application and security measures. It is possible for residues to persist in water, soil, and on crop surfaces. Pesticide residue levels can vary greatly based on a number of factors, including crop variety, weather circumstances, and application techniques. It is difficult to create consistent rules and laws because of this variety. Standardized procedures for detecting and evaluating pesticide residues are lacking. The employment of various testing procedures and standards by different countries might make it challenging to compare and standardize results internationally. The possible effects and residue levels of newly produced pesticides may not yet be fully recognized. This makes it difficult to effectively control and manage the residues of newly developed insecticides. Over time, some pests become resistant to widely used pesticides. In response, farmers would use stronger pesticides or apply them more frequently, which would increase residue levels and raise possible environmental issues. There might not be enough infrastructure or resources in some areas to conduct thorough and frequent monitoring of pesticide residue levels. This may result in a higher chance of non-compliance and insufficient enforcement of the legislation. Even at recognized safety levels, pesticide residues can still be harmful to some individuals, including newborns, pregnant women, and those with weakened immune systems.

Conclusion

Treatment with pesticides requires meticulous technical evaluation. Choosing an ineffective treatment method could result in additional hazardous byproducts, because different pesticides have different physical and chemical characteristics.

All of these will help to determine the optimal approach or combination of techniques to get the best results in terms of pesticide removal. In order to maximise the station's cost-effectiveness, the processing technology employed must also be appropriate for every country, be able to adjust to its unique environmental conditions and rely on readily available resources (such as adsorbed materials). Ongoing research, international cooperation, and the creation of sustainable agriculture techniques are crucial in order to overcome these constraints.



Figure 1: Effect of Pesticide residues on environment and human life

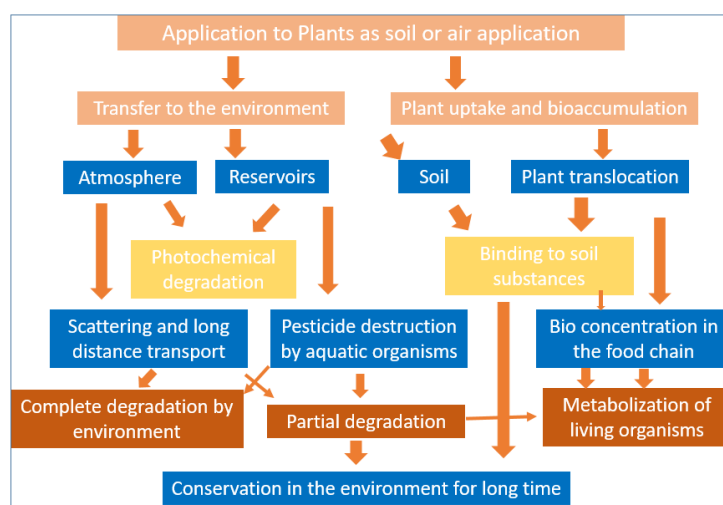


Figure 2: Schematic diagram of pesticide transport routes after application

References

- Zhang, A. A., Sutar, P. P., Bian, Q., Fang, X. M., Ni, J. B., & Xiao, H. W. (2022). Pesticide residue elimination for fruits and vegetables: The mechanisms, applications, and future trends of thermal and non-thermal technologies. *Journal of Future Foods*, 2(3), 223-240.

Bhilwadikar, T., Pounraj, S., Manivannan, S. et al., Decontamination of microorganisms and pesticides from fresh fruits and vegetables: a comprehensive review from common household processes to modern techniques, *Compr. Rev. Food Sci. Food Saf.* 18 (2019) 1003-1038.

Bassey, E.J., Cheng, J.H., Sun, D.W. Novel nonthermal and thermal pretreatments for enhancing drying performance and improving quality of fruits and vegetables, *Trends in Food Science & Technology* 112 (2021) 137-148.

* * * * *

Tech-driven Advances in Safeguarding Food: A Paradigm Shift in Microbiological Quality Assurance

Varshaa Arer

Ramaiah University of Applied Sciences, Bengaluru, India 560054.

*Corresponding Author: varshaa.arer95@gmail.com

In an era marked by heightened consumer awareness and increasingly complex food supply chains, the assurance of microbiological food safety has become a paramount concern in food industry (King et al., 2017). This article delves into the dynamic landscape of food safety and quality, shining a spotlight on the pivotal role played by advanced technologies in this domain. Our exploration of the dynamic landscape with within which the contemporary food industry operates, focusing on the transformative influence of cutting-edge technologies in addressing the multifaceted challenges of contamination detection and prevention.

In this context, the industry's response to the surging global demand for food is not just at meeting quantity metrics but also navigating the intricate terrain of quality assurance (Misra et al., 2020). As we delve into this exploration, the spotlight turns toward the groundbreaking contributions of genomic sequencing, blockchain, artificial intelligence, sensor technologies, and robotics (Figure 1). These innovations collectively redefine the industry's approach to ensuring the safety and integrity of our food supply. Beyond being tools, these technological advancements emerge as indispensable agents propelling a paradigm shift- a shift that aligns with the industry's unwavering commitment to providing consumers with food products that are not only abundant but, more importantly, safe and of highest quality.

Genome sequencing

The implementation of genomic sequencing in microbial identification involves a meticulous process that begins with the extraction of microbial DNA from the contaminated samples. This DNA is then subjected to high throughput sequencing, where modern technologies can rapidly analyse vast quantities of genetic information in relatively short period. The obtained genomic data are subsequently compared against extensive databases, enabling the

identification of specific microbial strains with unprecedented accuracy (Allard et al., 2018).

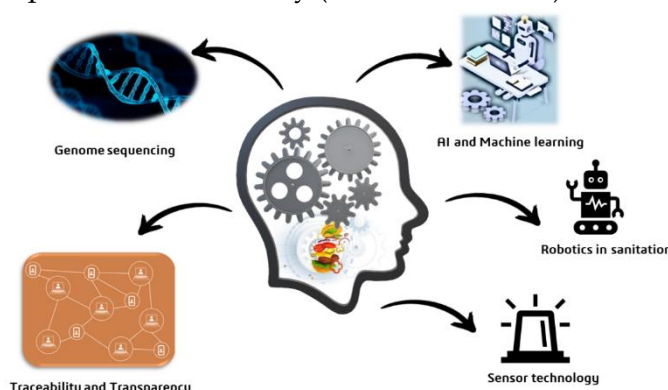


Figure 1: Technological evolution in food industry

One of the key advantages of genomic sequencing methods is their ability to discern subtle genetic variations among microbial strains. This level of precision allows for the differentiation of closely related strains, which may be crucial in determining the specific origin of contamination (Jagadessen et al., 2019). Bioinformatics tools play a vital role in this stage, assisting in the analysis and interpretation of the extensive genomic datasets generated. As a result, the methodology not only expedites the identification process but also enhances our understanding of the genetic diversity within microbial population (Zhang et al., 2019).

Furthermore, the integration of real-time sequencing technologies is gaining prominence, providing an even swifter response in identifying microbial contaminants. This capability is particularly advantageous in scenarios where rapid intervention is necessary to prevent the spread of contaminated products (Santhosh, 2022). Overall, the sophisticated methods employed in genomic sequencing contribute significantly to the evolution of microbial identification practices, equipping the food industry with powerful tools to uphold and fortify the safety and quality of our food supply.

Blockchain for traceability and Transparency

Blockchain technology is revolutionizing traceability and transparency within the intricate web of the food supply chain. At its core, blockchain

provides an immutable and decentralized ledger that chronicles every step of production process, from farm to table. Each event, such as the sourcing of raw materials, processing, and distribution, is recorded in a transparent and tamper-resistant manner. This decentralized nature ensures that the information is securely stored across a network of nodes, making it exceedingly challenging for any single entity to manipulate or falsify the data. As a result, stakeholders across the supply chain, including producers, distributors, retailers and consumers, can access a real-time, trustworthy record of the journey of each food product (De Conti, 2022).

The role of blockchain in ensuring traceability becomes particularly crucial in the context of microbiological food safety. In the event of a contamination incident, blockchain facilitates a swift and precise response by allowing for the quick identification of the exact source and location of the affected products. This capability is pivotal in preventing the spread of unsafe products throughout the supply chain and consequently, safeguarding public health (Jahanbin, 2022). The transparency afforded by blockchain not only instils confidence among consumers but also establishes a framework for accountability, encouraging all participants in the supply chain to uphold stringent safety standards. Ultimately, blockchain emerges as a transformative force, reshaping how the food industry approaches traceability and transparency to ensure the integrity and safety of our global food system (Selvaprabhu, 2023).

AI and Machine Learning in Predictive Analytics

The integration of artificial intelligence (AI) and machine learning (ML) into the realm of microbiological food safety marks a groundbreaking shift towards predictive analytics, offering a proactive approach to identifying and mitigating potential risks before they manifest. AI and ML algorithms excel at processing vast datasets, scrutinizing intricate patterns and discerning subtle trends that may elude conventional analysis. In the context of food safety, these technologies leverage their computational prowess to predict and pre-empt microbiological risks

by identifying potential sources of contamination (Macchia et al., 2023).

One key strength of AI and ML lies in their ability to analyse diverse data sources, including historical contamination incidents, environmental conditions and supply chain variables. By assimilating this wealth of information, these algorithms can identify correlations and causations that may not be immediately apparent to human observers (Kar et al., 2022). This predictive capability enables the food industry to implement targeted interventions and preventive measures, thus minimizing the likelihood of microbial contamination. Furthermore, the adaptive nature of machine learning algorithms allows them to continuously evolve as they access new data, ensuring that predictive models remain robust and reflective of the dynamic nature of the food supply chain (Akbari and Do, 2021).

In essence, the deployment of AI and ML in predictive analytics is transforming the traditional reactive stance of food safety measures into a proactive and anticipatory strategy. By harnessing the power of these technologies, the industry can fortify its defenses against microbiological risks, enhancing the overall safety and quality of food products and instilling a new level of confidence in both producers and consumers (Ganesh and Kalpana, 2022).

Sensor technologies for real-time monitoring

The integration of sensor technologies into the food production and distribution process has ushered in a new era of real-time monitoring, providing a comprehensive oversight of critical parameters such as temperature, humidity and microbial presence. These advanced sensors operate as vigilant guardians, constantly collecting and analysing data at various points in the supply chain. For instance, temperature sensors ensure that perishable goods are stored within prescribed limits, preventing spoilage and bacterial growth. Simultaneously, humidity sensors maintain ideal moisture levels, mitigating the risk of mold contamination and preserving the quality of products. The inclusion of microbial presence sensors serves as an additional layer of protection, enabling swift detection of any unwanted biological contaminants (Wetson et al., 2021).

The real-time capabilities of these sensors play a crucial role in the early detection of deviations from optimal conditions. Any variances outside predetermined thresholds trigger immediate alerts, allowing for prompt corrective actions. This proactive approach is particularly vital in preventing the escalation of issues that could compromise food safety and quality. Whether in storage facilities, transportation, or retail spaces, the constant surveillance facilitated by sensor technologies ensures that products are maintained under optimal conditions, contributing to the overall integrity of the food supply chain. As a result, the implementation of these sensors not only safeguards the quality of food products but also enhances operational efficiency by averting potential risks before they can escalate (Wetson et al., 2021).

Robotics in sanitation

The incorporation of robotics into sanitation procedures within food processing facilities represents a transformative leap towards ensuring stringent hygiene standards. Robotics play a pivotal role in minimizing human error, providing consistent and meticulous cleaning practices that are paramount in the prevention of microbial contamination. Equipped with advanced sensors and precision programming autonomous robots navigate through production spaces, reaching areas that may be challenging for human workers, and execute thorough cleaning routines with unapparelled accuracy (Ahem et al., 2023).

These robotic systems are often outfitted with sanitizing agents, allowing them to efficiently disinfect surfaces and equipment in food processing facilities. The autonomous nature of these robots ensures a methodical and consistent approach, eliminating the variability that may be associated with human operated sanitation processes. By reducing reliance on manual labour for sanitation tasks, these robots not only enhance the efficiency of cleaning practices but also contribute significantly to the overall food safety measures. The integration of robotics in sanitation procedures stands as a technological cornerstone, reinforcing the industry's commitment to minimising the risk of microbial contamination and elevating the

standards of hygiene in food processing environments (Emiliani et al., 2020).

Conclusion

As technology continues to advance, the association of innovation and microbiological food safety becomes increasingly crucial. The integration of these technologies not only enhances the industry's ability to detect and prevent contamination but also fosters a culture of continuous improvement and adaptability. By staying at the forefront of technological trends, the food industry can pave the way for safer, higher quality food products for consumers worldwide.

Reference

- King, T., Cole, M., Farber, J. M., Eisenbrand, G., Zabaras, D., Fox, E. M., & Hill, J. P. (2017). Food safety for food security: Relationship between global megatrends and developments in food safety. *Trends in Food Science & Technology*, 68, 160-175.
- Misra, N. N., Dixit, Y., Al-Mallahi, A., Bhullar, M. S., Upadhyay, R., & Martynenko, A. (2020). IoT, big data, and artificial intelligence in agriculture and food industry. *IEEE Internet of things Journal*, 9(9), 6305-6324.
- Allard, M. W., Bell, R., Ferreira, C. M., Gonzalez-Escalona, N., Hoffmann, M., Muruvanda, T., & Brown, E. W. (2018). Genomics of foodborne pathogens for microbial food safety. *Current opinion in biotechnology*, 49, 224-229.
- Jagadeesan, B., Gerner-Smidt, P., Allard, M. W., Leuillet, S., Winkler, A., Xiao, Y., ... & Grant, K. (2019). The use of next generation sequencing for improving food safety: Translation into practice. *Food microbiology*, 79, 96-115.
- Zhang, L., Loh, K. C., Lim, J. W., & Zhang, J. (2019). Bioinformatics analysis of metagenomics data of biogas-producing microbial communities in anaerobic digesters: A review. *Renewable and Sustainable Energy Reviews*, 100, 110-126.
- Santosh, K. C., & Gaur, L. (2022). *Artificial intelligence and machine learning in public healthcare: Opportunities and societal impact*. Springer Nature.

- De Conti, L. (2022). Blockchain Technology in the Agrifood Sector.
- Jahanbin, P. (2022). The investigation of blockchain and IoT integration for designing trust-driver information systems in agricultural food supply chain.
- Selvaprabhu, P. (2023). An Examination of Distributed and Decentralized Systems for Trustworthy Control of Supply Chains. *IEEE Access*, 11, 137025-137052.
- Macchia, E., Torricelli, F., Caputo, M., Sarcina, L., Scandurra, C., Bollella, P., ... & Torsi, L. (2023). Point-of-care Ultra-Portable Single-Molecule Bioassays for One-Health. *Advanced Materials*, 2309705.
- Kar, A. K., Choudhary, S. K., & Singh, V. K. (2022). How can artificial intelligence impact sustainability: A systematic literature review. *Journal of Cleaner Production*, 134120.
- Akbari, M., & Do, T. N. A. (2021). A systematic review of machine learning in logistics and supply chain management: current trends and future directions. *Benchmarking: An International Journal*, 28(10), 2977-3005.
- Ganesh, A. D., & Kalpana, P. (2022). Future of artificial intelligence and its influence on supply chain risk management-A systematic review. *Computers & Industrial Engineering*, 169, 108206.
- Weston, M., Geng, S., & Chandrawati, R. (2021). Food sensors: Challenges and opportunities. *Advanced Materials Technologies*, 6(5), 2001242.
- Ahmed, M. S., Abdulwahab, M. M., Noaman, N. M., Ismail, Z., & Palaniappan, R. (2023, October). Design and Implementation of Sterilization Robot. In *2023 IEEE 8th International Conference on Engineering Technologies and Applied Sciences (ICETAS)* (pp. 1-6). IEEE.
- Emiliani, T., Flourakis, M., Wepner, B., Wenink, J., Kok, K. P., Korme, I., ... & Lazaro-Mojica, J. (2020). *R&I recommendations for targeted action in the Food2030 pathway areas: Deliverable 3.4*. European Union.

* * * * *

Food Safety: Challenges, Major Food Borne illnesses, Advance Techniques to Ensure food safety & Future Food safety

Manjit M Khatal

MTech Student, Department of Process and Food Engineering, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, M. S. (India)

*Corresponding Author: manjitkhatal18@gmail.com

Food Safety as an "assurance that food is acceptable for human consumption according to its intended use." Food Safety ensures that food is safe for human consumption and involves handling, preparation, and storage of food in ways that prevent food borne illness.

Major challenges of food safety

Microbiological Safety - Food by nature is biological. It is capable of supporting the growth of microbials that are potential sources of foodborne diseases. Viruses are more responsible for the majority of foodborne illnesses but hospitalizations and deaths associated with foodborne infections are due to bacterial agents. The illnesses range from mild gastroenteritis to neurologic, hepatic, and renal syndromes caused by either toxin from the disease-causing microbe. Foodborne bacterial agents are the leading cause of severe and fatal foodborne illnesses. Over 90% of food-poisoning illnesses are caused by species of Staphylococcus, Salmonella, Clostridium, Campylobacter, Listeria, Vibrio, Bacillus, and E. coli

Chemical Safety - Non-food grade chemical additives, such as colorants and preservatives, and contaminants, such as pesticide residues, have been found in foods. Some food samples had higher levels of heavy metals such as lead, cadmium, arsenic, mercury, and copper than average food samples, suggesting possible leaching from the utensils and inadequate food hygiene.

Personal Hygiene - Poor personal hygiene practices of food handler and preparers pose considerable risks to personal and public health. Simple activities such as thorough hand washing and adequate washing facilities can prevent many foodborne illnesses.

Environmental Hygiene - Inadequate recycling and waste disposal equipment and facilities lead to the accumulation of spoiled and contaminated food. This leads to an increased pest and insect population that can result in risk of food contamination and spoilage. Poor sanitary conditions in the area where foods are processed and prepared contribute to poor food

storage and transport as well as selling of unhygienic food.

Major foodborne illnesses

Bacteria - Salmonella, Campylobacter, and Enterohemorrhagic Escherichia coli (EHE coli) are among the most common foodborne pathogens. Symptoms include fever, headache, nausea, vomiting, abdominal pain and diarrhea. Sources of salmonellosis include eggs, poultry and other products of animal origin. Foodborne Campylobacter is caused by raw milk, raw or undercooked poultry and drinking water. Listeria is found in unpasteurized dairy products and various ready-to-eat foods and can grow at refrigeration temperatures. Vibrio cholerae infects people through contaminated water or food. Symptoms include abdominal pain, vomiting and profuse watery diarrhea, which may lead to severe dehydration and possibly death. Rice, vegetables, millet gruel and various types of seafood have been implicated in cholera outbreaks.

Viruses - Norovirus infections are characterized by nausea, explosive vomiting, watery diarrhea and abdominal pain. Food handlers infected with Hepatitis A virus are common source of contamination and spreads typically through raw or undercooked seafood or contaminated raw produce.

Parasites - Some parasites, such as fish-borne trematodes, are only transmitted through food. Others, for example Echinococcus spp, may infect people through food or direct contact with animals. Other parasites, such as Ascaris, Cryptosporidium, Entamoeba histolytica or Giardia, enter the food chain via water or soil and can contaminate fresh produce.

Worms - Cestodes, nematodes, trematodes and helminths are worms most prevalent in regions where food preparation and storage, personal hygiene, water sanitation and environmental health are not routinely practiced Even though worm related foodborne illness are not as fatal as virus and bacteria, they account for a substantial burden to foodborne disability.

Chemicals - Naturally occurring toxins and environmental pollutants have caused many outbreaks. In addition, chemical residues used to eradicate or control pests and worms can be an independent risk of foodborne hazard. Mycotoxins, marine biotoxins, cyanogenic glycosides and poisonous mushrooms are all natural toxins. Staple foods like corn or cereals can contain high levels of mycotoxins, such as aflatoxin and ochratoxin. A long-term exposure can affect the immune system and normal development, or cause cancer.

Diagnostic advances to ensure food safety

Due to the globalization of the world's food trade, food has become a major pathway for human exposure to pathogenic microbes responsible for foodborne illness entering at many points along the value chain. Thus, tracking and detecting microbes especially pathogenic bacteria in foods back to their sources pose challenges to producer, processor, distributor, and consumer of food alike. Rapid and accurate detection of foodborne pathogens is essential for public health bio-surveillance to prevent foodborne infections and ensure the safety of foods. Detection methods of microbes have improved over time.

1. PCR-based

Polymerase chain reaction (PCR) based assay enzyme linked immuno-sorbent assay (ELISA) and instruments rely on extensive enrichment (up to 24 h) to produce enough cells for detection. Following enrichment, the assay requires DNA amplification and detection. The entire process from enrichment through detection may take several hours to days. Because of sample preparation processes and ancillary lab equipment (shakers, incubators, microplate readers) such detection system may not be practical as PONT devices. Another commonly utilized technology is based on either standard or real-time PCR (qPCR) depending on the instrument and takes up to 3.5 h for detection. The system is limited to using PCR method thus unable to perform multiple biomarkers detection.

2. NMR-Nanotechnology

Nuclear Magnetic Resonance (NMR) nanotechnology platform detects multiple target microbes hybridizing to pathogen's DNA or protein in same the device chamber that runs assays using nucleic acid, antibodies, and other biomarkers [30]. Orthogonal confirmatory tests can be achieved via multiple biomarkers of single microbial in same detection device. This raises specificity and accuracy thus serving as both screening and confirming tool at the same time. It has a dynamic range of 8 log before saturation, more sensitive than other systems due to standard amplification process plus signal amplification through the nanoparticles. Hence, this technology increases the sensitivity and specificity of detecting target microbial. End point PCR can be applied on DNA amplification while antibody ligands method can be used for protein structure amplification. Multiplexing with large sample volume enables multiple biomarker measurements to be analysed thus further increases specificity of the detection method.

The future food safety

Safe food provides basic human necessity. It supports national economy, trade and tourism, contributes to nutrition security, and underpins sustainable development. Globalization has triggered growing consumer demand for a wider variety of foods, resulting in an increasingly complex and longer global food chain. As the world's population grows, the intensification and industrialization of agriculture and animal production to meet increasing demand for food creates both opportunities and challenges for food safety. The food producers, distributors, handlers and vendors must bear the primary responsibility to ensure food safety. Consumers should remain vigilant and literate on food safety issues.

Reference

- Food and Agriculture Organization (FAO).
- Food Safety and Standards Authority of India (FSSAI).
- Fred Fung, Huei-Shyong Wang, Suresh Menon, Food safety in the 21st century, Biomedical Journal, Volume 41, Issue 2, 2018, Pages 88-95.

Safeguarding Palates: Navigating the Terrain of Food Safety and Quality

Sangya Singh

YP-II, AICRP-WIA, G. B. Pant University of Agri & Tech

*Corresponding Author: sangyachauhan@gmail.com

In the intricate world of culinary delights, ensuring food safety and quality is paramount. As consumers become increasingly conscious of what they consume, the demand for food that is not only delicious but also safe and high in quality has surged. This article delves into the multifaceted realm of food safety and quality, exploring the challenges, advancements, and crucial measures that contribute to maintaining the integrity of our meals.

The Nexus of Safety and Quality

Food safety and quality are inseparable components of a thriving culinary landscape. While safety focuses on preventing foodborne illnesses, quality encapsulates the sensory attributes, nutritional value, and overall appeal of food. The intersection of these two facets creates a holistic approach to gastronomy, safeguarding both health and satisfaction.

Challenges in the Culinary Landscape

The global food supply chain faces a myriad of challenges that can compromise safety and quality. From contamination during production and transportation to inadequate storage conditions, the journey from farm to fork is riddled with potential pitfalls. Factors such as climate change, emerging pathogens, and globalization further complicate the landscape, necessitating a proactive approach to mitigate risks.

Advancements in Technology

In the pursuit of uncompromised safety and quality, technology emerges as a stalwart ally. Blockchain technology, for instance, enables transparent supply chain traceability, allowing consumers to trace the origins of their food. IoT (Internet of Things) devices monitor storage conditions in real-time, reducing the likelihood of spoilage. These technological advancements not only enhance safety but also contribute to the optimization of food quality.

Regulatory Frameworks

Governments and international organizations play a pivotal role in shaping and enforcing

regulations to ensure food safety and quality. Stringent standards, such as the Hazard Analysis and Critical Control Points (HACCP) system, serve as a blueprint for preventing, reducing, or eliminating potential hazards in the food production process. Compliance with these frameworks is essential for businesses to uphold the trust of consumers and meet global market requirements.

Consumer Empowerment

The modern consumer is more empowered than ever, armed with information at their fingertips. Social media platforms and online reviews amplify the impact of individual experiences, influencing purchasing decisions and holding businesses accountable for the safety and quality of their products. As consumers demand transparency, food producers and retailers must prioritize integrity in their practices.

The Role of Education

Educating both consumers and industry professionals is pivotal in fortifying the foundations of food safety and quality. Training programs and awareness campaigns disseminate knowledge about proper handling, storage, and preparation of food. Equipping individuals with the know-how to make informed choices contributes to a collective effort in maintaining a safe and high-quality food ecosystem.

Sustainability and Ethical Considerations

The conversation surrounding food safety and quality is increasingly intertwined with sustainability and ethical considerations. Consumers are not only concerned about the safety of their food but also the environmental impact and ethical practices of the food industry. This shift in focus has prompted businesses to adopt sustainable practices, including responsible sourcing, eco-friendly packaging, and ethical treatment of animals.

Conclusion

As we navigate the ever-evolving landscape of food safety and quality, it is imperative to recognize the interconnectedness of these two facets. The integration of technology, adherence to robust

regulatory frameworks, and the empowerment of consumers through education are pivotal in upholding the integrity of our food supply. The future of gastronomy lies in a harmonious blend of innovation, responsibility, and a shared commitment to delivering food that not only tantalizes the taste buds but also nourishes and safeguards the well-being of consumers.

References

- World Health Organization (WHO). (2021). Food Safety. <https://www.who.int/news-room/fact-sheets/detail/food-safety>
- Food and Agriculture Organization of the United Nations (FAO). (2021). Food Quality and Safety. <http://www.fao.org/food-quality-safety/home/en/>
- U.S. Food and Drug Administration (FDA). (2021). Hazard Analysis and Critical Control Points (HACCP). [https://www.fda.gov/food/food-](https://www.fda.gov/food/food-safety-modernization-act-fsma/hazard-analysis-and-critical-control-points-haccp)
- safety-modernization-act-fsma/hazard-analysis-and-critical-control-points-haccp
- European Food Safety Authority (EFSA). (2021). Food Safety. <https://www.efsa.europa.eu/en/topics/topic/food-safety>
- He, D., & Lin, L. (2017). Food Safety Trends: A Systematic Review. *Comprehensive Reviews in Food Science and Food Safety*, 16(5), 957–975.
- Golan, E., & Unnevehr, L. (2013). Food Safety and Quality: Balancing the Dynamics of Market and Consumer. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3738417/>
- Spink, J., & Moyer, D. C. (2011). Defining the Public Health Threat of Food Fraud. *Journal of Food Science*, 76(9), R157–R163.
- Hallowell, G. D., et al. (2017). Blockchain and the future of food traceability. *Trends in Food Science & Technology*, 69, 46–56.

* * * * *

A Comprehensive Analysis of Antibiotic Resistance in Food Grade Bacteria

Ravikant V. Vinchurkar^{1*}, Monica Rose¹, Somveer², Deshmukh RR¹ and Sunita Rani³

¹Ph.D. Scholar, Dairy Microbiology Division, National Dairy Research Institute, Karnal

²Ph.D. Scholar, Dairy Engineering Division, National Dairy Research Institute, Karnal

³M.Tech. Scholar, Dairy Microbiology Division, National Dairy Research Institute, Karnal

*Corresponding Author: ravikantvinchurkar97@gmail.com

Antimicrobial resistance (AMR) arises from the constant exposure of bacteria to microbial agents. Some microbes through adaptation become able to survive and persist in the presence of antimicrobial agents, which would normally suppress or kill them. The challenging global problem of antimicrobial resistance (AMR) has enormous effects on health worldwide. Even ordinary diseases are getting harder to cure because of rising AMR in widespread bacteria. AMR genes are extensively dispersed in a variety of contexts and serve as a source of resistance-related genes as well as a means of dissemination for AR pathogens, which is one of the main causes of the rapid development of the AMR challenge. However, less is available regarding the source as well as the distribution pattern of these genes. Livestock is regarded as one of the major sources of antimicrobial resistance (AMR), along with to the widespread use of antibiotics in humans. According to reports, humans only eat 30% of antibiotics, whereas animals consume 70% of them. Currently, a number of international organizations are striving to control antibiotic resistance, including the World Health Organization's Global Antimicrobial Resistance Surveillance System. Other institutions, such the CDC and Food and Agriculture Organization, are working hard to combat the issue of antibiotic resistance (Gurieva *et al.*, 2012).

Antimicrobial resistance scenario in India

Recent studies conducted across multiple Indian regions has found residues of antibiotics in food livestock products (such chicken meat and dairy), suggesting that the use of antibiotics is common in the production of food animals (Boeckel *et al.*, 2015). The study conducted by Gandra *et al.* (2016) revealed that *Pseudomonas aeruginosa* had an antibiotic resistance rate of more than 50%, whilst *E. coli* and *Klebsiella pneumonia* had a resistance rate of more than 70% to the wide-spectrum antibiotic fluoroquinolones and third-generation cephalosporin. In 2010, Kumarasamy *et al.* undertook an investigation with the goal of examining Enterobacteriaceae isolates

from two significant Indian centres: Chennai (South India) and Haryana (North India).

Furthermore, a paper evaluated by Dixit *et al.* (2011) revealed that, since their release in 2010, resistance to even novel antimicrobial medicines like carbapenems has been developing across a variety of Gram both positive and negative microorganisms at an alarming rate. By 2050, it's predicted that AMR will cause 2 million fatalities annually in India (Laxminarayan *et al.*, 2012). Furthermore, they found that 70–80% of India's Enterobacteriaceae included ESBLs. All of these research and investigations show how quickly the antimicrobial resistance (AMR) issue is expanding in India and the necessity for various organisations to take decisive action in order to control AMR.

Antimicrobial Resistance in food grade bacteria

One of the primary channels via which antimicrobial resistance spreads from animals to humans is the food chain. Food-grade bacteria primarily helpful organisms that are recognised to play significant roles in the fermentation of food and many of them are also recognised to promote health. One of the significant categories of microorganisms found in vast quantities in both human and animal gastrointestinal tracts is food-grade bacteria. The US FDA has granted them the GRAS (Generally Recognised as Safe) designation because of their extensive history of safe use in fermented products. Globally, FAO/WHO (FAO/WHO, 2002) has sufficiently established the guidelines (including safety and security aspects) for the use of the food-grade bacteria group of bacteria as probiotics. The European Food Safety Authority (EFSA, 2018) has regulated the safety issues associated to the dissemination of antibiotic resistance via the use of food-grade bacteria in food and feed.

As per EFSA the lactobacilli intended for human consumption should be evaluated for their antibiotic resistance to gentamycin, kanamycin, streptomycin, tetracycline, erythromycin,

clindamycin, chloramphenicol, ampicillin and vancomycin. The majority of the earlier reports on AMR in food-grade food-grade bacteria were solely focused on lactobacilli because of their usage in fermented foods and as probiotics for human health. This work on these bacteria was started earlier. Antimicrobial resistance in food-grade bacteria species is currently the subject of numerous investigations. One such study was conducted in 2012 by Thumu and Halami, who identified erythromycin-resistant food-grade bacteria from a variety of Indian food samples. *Leuconostoc mesenteroides*, *P. pentosaceus*, *L. salivarius*, *L. reuteri*, *L. plantarum*, *L. fermentum*, *E. durans*, *E. faecium*, *E. lactis*, and *E. casseliflavus* were the isolates that were detected (Deshmukh *et al.*, 2023). Many fermented food products use *Leuconostoc* spp. as auxiliary cultures to provide aromas.

According to a study by Florez *et al.* (2016), these species also carry resistance characteristics that can be passed on to different species. Virginiamycin, tetracycline, streptomycin, and kanamycin resistance was demonstrated by *Leuconostoc mesenteroides* LbE16. Numerous investigations have provided adequate evidence of the prevalence of AMR in lactococci. The majority of *Lactococcus* species exhibit inherent resistance to gentamicin, trimethoprim, metronidazole, and kanamycin, according to Katla *et al.*'s 2002 study.

Mechanisms of Antibiotic Resistance

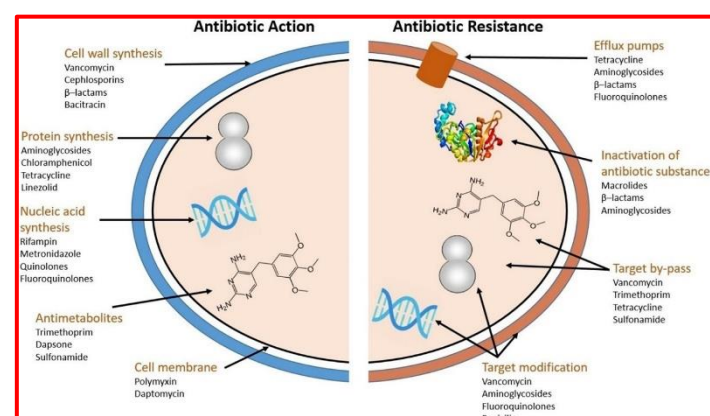


Fig 1. Mechanisms of Antibiotic Resistance in bacteria

Inhibition of Cell Wall Synthesis

Antibiotics like penicillin prevent bacteria from building a strong cell wall. Weakening the cell

wall leads to bacterial cell rupture and death as shown in fig. 1.

Interference with Protein Synthesis

Some antibiotics, such as tetracycline, target bacterial ribosomes. Inhibiting protein synthesis disrupts bacterial growth and replication.

Disruption of Nucleic Acid Synthesis

Certain antibiotics, like quinolones, interfere with bacterial DNA replication and repair. This disrupts bacterial genetic material, hindering reproduction.

Inhibition of Metabolic Pathways

Antibiotics like sulfonamides block specific metabolic pathways in bacteria. Essential processes, such as folic acid synthesis, are disrupted, leading to bacterial death.

Enzymatic Inactivation

Bacteria produce enzymes that modify or destroy antibiotics. Enzymatic inactivation renders antibiotics ineffective against resistant strains.

Alteration of Target Sites

Bacteria may modify target sites (e.g., cell wall or ribosomes) to reduce antibiotic binding. Altered targets prevent antibiotics from disrupting essential cellular processes.

Efflux Pump Activation

Bacteria develop efflux pumps to expel antibiotics from their cells. Pump activation decreases antibiotic concentration within bacterial cells.

Causes of Antibiotic Resistance in Food-grade bacteria

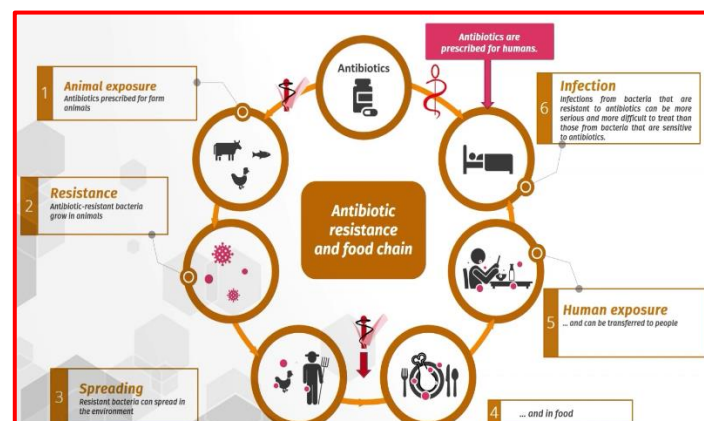


Fig 2. Factors responsible for antibiotic resistance in food chain

Overuse and Misuse of Antibiotics

Excessive use of antibiotics in agriculture for promoting growth or preventing diseases can lead to the development of resistant strains in food-grade bacteria. Inappropriate dosage and duration of antibiotic treatments in both humans and animals contribute to the emergence of resistance, illustrated in fig. 2.

Inadequate Veterinary Practices

Poor management of veterinary antibiotics, including improper prescription practices and lack of adherence to dosage guidelines, can accelerate the development of resistance in bacteria present in food-producing animals.

Horizontal Gene Transfer

Bacteria can transfer genetic material containing antibiotic resistance genes horizontally. This exchange occurs between different bacterial species, potentially spreading resistance among food-grade bacteria.

Cross-Contamination in Food Processing

Inadequate hygiene measures during food processing can result in the transfer of antibiotic-resistant bacteria from contaminated surfaces to the final food product, increasing the risk of antibiotic resistance in the food supply chain.

International Trade and Travel

Global movement of food products can facilitate the spread of antibiotic-resistant bacteria, as resistant strains may be present in food imported from regions with less stringent antibiotic usage regulations.

Environmental Contamination

The release of antibiotic residues into the environment, such as through agricultural runoff or improper disposal of pharmaceutical waste, can contribute to the selection of antibiotic-resistant strains in bacteria.

Incomplete Antibiotic Treatment in Humans

Failure to complete prescribed antibiotic courses in humans may not fully eliminate the targeted bacteria, allowing resistant strains to survive and potentially spread through human contact or the food chain.

Conclusion

In conclusion, the comprehensive analysis of antibiotic resistance in food-grade bacteria sheds light on the critical issue of emerging resistance patterns in these organisms. The study underscores the need for a vigilant and proactive approach to address this growing concern, as antibiotic resistance poses a significant threat to public health. The findings highlight the complex interplay of various factors contributing to resistance, including the use of antibiotics in food production, environmental factors, and the potential transmission of resistant strains to humans through the food chain. Efforts to mitigate antibiotic resistance in food-grade bacteria should be multifaceted, encompassing prudent use of antibiotics in agriculture, enhanced surveillance and monitoring programs, and the development of alternative strategies for disease prevention in food-producing animals. The study underscores the urgency of adopting a One Health approach, recognizing the interconnectedness of human, animal, and environmental health.

References

- Deshmukh R. R., Vinchurkar R. V., Somveer, B. Lakshmaiah and Kumari M. (2023). Molecular identification of *Lactobacilli* from traditional fermented dahi using PCR. *AgriTech Today*, 1(Special Issue), 114-116.
- Gandra, S., Mojica, N., Klein, E. Y., Ashok, A., Nerurkar, V., Kumari, M., Ramesh, U., Dey, S., Vadwai, V., Das, B. R., & Laxminarayan, R. (2016). Trends in antibiotic resistance among major bacterial pathogens isolated from blood cultures tested at a large private laboratory network in India, 2008-2014. *International journal of infectious diseases: IJID: official publication of the International Society for Infectious Diseases*, 50, 75-82.
- Gurieva, T., Bootsma, M. C., & Bonten, M. J. (2012). Successful Veterans Affairs initiative to prevent methicillin-resistant *Staphylococcus aureus* infections revisited. *Clinical infectious diseases: an official publication of the Infectious Diseases Society of America*, 54(11), 1618-1620.

- Johnson A. P. (2015). Surveillance of antibiotic resistance. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 370(1670), 20140080.
- Laxminarayan, R., Duse, A., Wattal, C., Zaidi, A. K., Wertheim, H. F., Sumpradit, N., Vlieghe, E., Hara, G. L., Gould, I. M., Goossens, H., Greko, C., So, A. D., Bigdeli, M., Tomson, G., Woodhouse, W., Ombaka, E., Peralta, A. Q., Qamar, F. N., Mir, F., Kariuki, S., Cars, O. (2013). Antibiotic resistance-the need for global solutions. *The Lancet. Infectious diseases*, 13(12), 1057-1098.
- Van Boeckel, T. P., Brower, C., Gilbert, M., Grenfell, B. T., Levin, S. A., Robinson, T. P., ... & Laxminarayan, R. (2015). Global trends in antimicrobial use in food animals. *Proceedings of the National Academy of Sciences*, 112(18), 5649-5654.

* * * * *

Evaluation of Edible Oil for Quality and Adulteration

Twinkle Mishra, Avinash Pandey, Omkar M. Limbalkar and Kishor U. Tribhuvan

ICAR-Indian Institute of Agricultural Biotechnology, Ranchi – 834 003 Jharkhand (India)

*Corresponding Author: kishor.tribhuvan@icar.gov.in

Cooking oils are like unsung heroes in our kitchens, silently contributing to the taste and health of our meals. However, the quality and safety of these oils are often overlooked. This article explores the world of edible oil testing, a process crucial for ensuring top-notch quality and detecting harmful adulterants. Edible oils, primarily vegetable oils, undergo refining processes to remove undesirable constituents, making them suitable for consumption [1]. These oils are a concentrated source of energy and essential fatty acids and provide flavour, texture, and mouthfeel to food [2]. Refined edible oils can be enriched with phenolic extracts from olive leaves and pomace, resulting in a composition similar to that of extra virgin olive oil [3]. However, the quality of edible oil blends, such as groundnut: rice bran oil and mustard: rice bran oil; can be affected by rancidity, leading to changes in physicochemical characteristics [4].

Understanding Quality

Good cooking oil is more than just flavor; it directly impacts our well-being. Edible oil testing ensures that the oils we use meet nutritional standards, are free from contaminants, and are safe for consumption. Knowing that your cooking oil is of high quality means you're making a positive contribution to your diet.

Quality is paramount when assessing edible oils, as it directly impacts nutritional value and consumer safety. In the context of edible oils, quality encompasses a spectrum of attributes that extend beyond mere palatability to encompass factors such as purity, freshness, and adherence to regulatory standards. This intricate understanding of quality is especially crucial in the face of potential adulteration, a prevalent challenge that threatens the integrity of the edible oil market.

Quality evaluation of edible oils involves a comprehensive analysis of various intrinsic characteristics. The physical attributes, including colour, clarity, and viscosity, offer initial insight into the oil's condition. Chemical parameters such as fatty

acid composition, peroxide value, and acidity provide critical information about the oil's composition, stability, and potential for oxidation. The sensory evaluation further refines the assessment by considering flavour, aroma, and overall consumer acceptability.

The Threat of Adulteration

Adulteration, the hidden enemy in our kitchens, poses serious health risks. Unethical practices like mixing inferior oils or adding harmful substances are rising. Common adulterants include lower-grade oils, refined oils, and even non-edible substances like mineral oil, all of which can adversely affect consumer health. Edible oil testing is a powerful tool to identify and eliminate these deceptive products from the market, protecting consumers from potential health hazards. Rigorous testing and analysis are required to uncover potential adulterants and maintain the quality standards set by regulatory bodies. Ensuring the authenticity of edible oils is not only a matter of consumer protection but also a vital component of preserving the food industry's reputation. The economic impact of adulteration and the potential health consequences underscores the urgency of addressing this threat comprehensively. Through a concerted effort to understand, detect, and prevent adulteration, we can fortify the resilience of our food supply chain and ensure that consumers can confidently enjoy the nutritional benefits of high-quality edible oils.

Testing Techniques

Edible oil testing involves advanced techniques, from essential sensory evaluation to high-tech methods like chromatography and spectroscopy. Testing laboratories equipped with skilled professionals and cutting-edge tools ensure accurate and reliable results, leaving no room for adulterators to go undetected.

Here are some commonly used techniques:

1. Chemical Tests:

- a) Saponification Value: This test determines the amount of alkali required to saponify a certain amount of oil. Adulterants like mineral oils

have different saponification values than edible oils.

- b) Iodine Value: This test measures the degree of unsaturation in the oil. Different oils have different iodine values, so it can help detect adulteration.
- c) Reichert-Meissl (RM) Value: It helps detect the presence of animal fats in vegetable oils. The RM value, a measure of the total volatile fatty acids in edible oils, is an important indicator of their quality and stability.

2. Chromatography Techniques:

- a) Gas Chromatography (GC): This technique separates and analyzes volatile compounds in the oil. It is helpful in detecting adulterants and measuring fatty acid composition.
- b) High-Performance Liquid Chromatography (HPLC): HPLC is used for separating and quantifying different components in the oil, including fatty acids and other contaminants.

3. Spectroscopy Methods:

- a) Ultraviolet and Infrared (IR) Spectroscopy: It can be used to analyze the functional groups present in the oil, helping to identify different types of oils and potential adulterants. Different types of edible oil have different absorption wavelengths in the ultraviolet region.
- b) Nuclear Magnetic Resonance (NMR): NMR spectroscopy provides information about the molecular structure of compounds present in the oil. The substances in edible oil can be reasonably determined by detecting the absorption degree of radiation related to the atomic nucleus in a strong magnetic field.
- c) Fluorescence spectroscopy: Because different types of edible oils have different fluorescence components, the detection process can clearly show the adulteration of edible oils.
- d) Raman spectroscopy: It is a relatively advanced method. In the application process, the corresponding adulteration and other data can be obtained through the investigation of molecular vibration information.

4. Mass Spectrometry: This technique helps identify and quantify the molecular composition of the oil. It can be used to detect contaminants and adulterants.

5. DNA-based Techniques: Polymerase Chain Reaction (PCR) can be employed to identify the specific DNA of particular plant or animal species, helping to detect adulteration.

6. Sensory Evaluation: Experienced professionals can use sensory evaluation to detect abnormal tastes or smells that may indicate the presence of adulterants.

7. Rapid Test Kits: Immunoassay Kits that use antibodies to detect specific substances that are designed to detect particular adulterants in edible oils can be used.

8. Blockchain Technology: It can be used to trace the entire supply chain of edible oils, providing transparency and reducing the chances of adulteration.

When using these tools, it is essential to follow proper testing procedures and consider the specific characteristics of the edible oil being analyzed and different quality parameters. Additionally, consulting with regulatory guidelines and standards is crucial to ensure accurate and reliable results (Table 1) [5].

Empowering Consumers and Future Trends

As consumers become more informed, certifications like FSSAI or USP offer assurance of adherence to quality standards. Several ways in which consumers can be empowered are highlighted below:

a) Education and Awareness: Educate consumers on how to read and interpret labels, focusing on ingredients, nutritional information, and certification marks. This enables them to make informed choices.

Governments, NGOs, and industry players can run campaigns to raise awareness about the importance of quality in edible oils and provide tips for detecting potential adulteration.

b) Mobile Apps and Technology: Implementing QR codes on product packaging linked to mobile apps that provide detailed information about the oil, including its source, production

methods, and test results. Consumers can use these apps for on-the-spot verification.

- c) **Community Engagement:** Conduction of community workshops and seminars to educate consumers about the characteristics of quality edible oils and how to identify potential adulteration.
- d) **Consumer Advocacy Groups:** Establishing consumer advocacy groups focused on food safety. These groups can provide a platform for sharing information, experiences, and tips on edible oil quality.
- e) **Online Review Platforms:** Encourage and utilize online platforms for consumers to share their experiences and concerns about specific edible oil brands. This collective feedback can serve as a valuable resource for others.

Future Trends in Edible Oil Evaluation:

Looking toward the future, emerging trends such as blockchain technology, advanced sensors and IoT, artificial intelligence and Machine Learning, and DNA barcoding promise to revolutionize the landscape of edible oil evaluation.

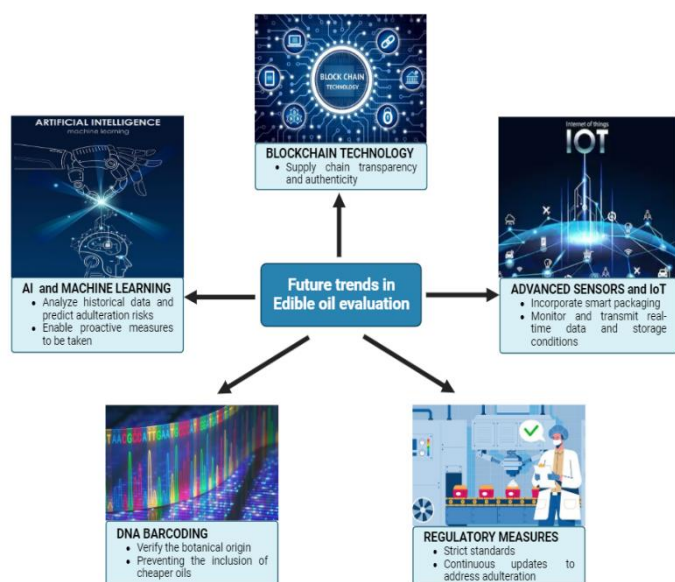


Figure 1. Emerging trends in edible oil evaluation

Conclusion

Understanding the importance of edible oil testing is crucial in our quest for a healthier lifestyle. Consumers

have the power to demand quality and transparency. By supporting rigorous testing practices, we not only protect our health but also contribute to eradicating adulteration, making our kitchens safe havens for nutritious meals. So, the next time you grab that bottle of cooking oil, remember – that knowledge is vital, and edible oil testing ensures the safety and quality of what goes into our meals.

In essence, the ongoing efforts to understand, evaluate, and combat adulteration in edible oils reflect a commitment to maintaining the highest food quality standards. Collaborative initiatives involving regulatory bodies, industry stakeholders, and consumers are essential in building a resilient and transparent food supply chain. As technology advances and awareness grows, the collective goal remains clear: to safeguard the quality and authenticity of edible oils, ensuring a healthier and more trustworthy food market for all.

References

1. Kiritsakis, A., & Christie, W. W. (2000). Analysis of edible oils. In Handbook of olive oil: analysis and properties (pp. 129-158). Boston, MA: Springer US.
2. Shahidi, F. (2004). Quality characteristics of edible oils. Quality of fresh and processed foods, 239-249.
3. Sánchez de Medina, V., Priego-Capote, F., & Luque de Castro, M. D. (2012). Characterization of refined edible oils enriched with phenolic extracts from olive leaves and pomace. Journal of agricultural and food chemistry, 60(23), 5866-5873.
4. Nasirullah, Ankaiah, K. N., Krishnamurthy, M. N., & Nagaraja, K. V. (1991). Quality characteristics of edible vegetable oil blends. Journal of the American Oil Chemists' Society, 68(6), 446-447.
5. Dunford, N. T. (2016). Edible oil quality. Oklahoma Cooperative Extension Service.

Table 1: Different quality parameters of edible oil and their standard methods for detection

Serial No.	Quality parameters	Description	Standard method of detection	Standard value
1.	Free Fatty Acid Content (FFA)	Edible oils with high FFA content reduce oxidative stability, increase acidity, and induce off-flavour.	• AOCS Ca-5a-40 • European Union Regulation No.2568/91 • analytical methods • Chemical analysis kits	≤0.05 % (based on oil weight)
2.	Acid Value	Indicates vegetable oil quality. It is measured as the amount of KOH (in milligrams) necessary to neutralize free fatty acids in 1 g of oil.	• AOCS Cd 3d-63	-
3.	Peroxide Value (PV)	Hydroperoxides in fats and oils are measured by peroxide value (PV). These are harmful to humans and are the leading oil oxidation products formed during the initial stages.	• AOCS Cd 8-53 • Fourier transform infrared (FTIR) • Near-infrared (FT-NIR) spectroscopy	PV of <1 meq/kg
4.	p-Anisidine Value (AV)	The measure of the secondary oxidation products formed by the breakdown of the primary oxidation products during extensive oxidation. AV is strongly correlated with overall oil odour intensity.	• AOCS Cd 18-90	AV of <5
5.	Polar Compounds/Total Polar Content (TPC)	A good indicator of heated oil quality. Include thermally polymerized dimeric and hydrolytically cleaved FFA, etc.	• AOCS Cd 20-91 • High-performance size exclusion chromatography	<25-27% TPC
6.	Thiobarbituric acid reacting substances (TBARS)	Lipid oxidation is measured by TBA value (milligrammes of malonaldehyde equivalents per kilogramme or micromoles per gramme)	• AOCS Cd 19-90	-
7.	Conjugated Dienes	Due to conjugate production, polyunsaturated fatty acid oxidation increases UV absorption. Helpful in for assessing vegetable oil oxidative stability.	• Measurement of conjugated dienes at 234 nm and conjugated trienes at 268 nm	-

8.	Unsaponified Matter (USM)	USM comprises hydrocarbons, terpene alcohols, sterols, tocopherols, and other phenolic substances that may limit oxidation.	AOCS Ca 6b-53	Vegetable oils: 0.5-2.5% USM Others: 5-6% USM
9.	Phospholipids	They give the oil a cloudy look, precipitate during storage, leave a harmful solid residue at the bottom of the containers, and cause refined oils to foam when frying.	AOCS Ca 12b-92	Refined oils: 30 mg/kg phosphorous Super degummed oils: <10 mg/kg phosphorous
10.	Colour	An important factor in the determination of their market value. Chlorophyll is a sensitizer of photo-oxidation, promotes oil oxidation, and acts as a catalyst poison during oil hydrogenation.	Lovibond method (AOCS Wesson Cc 13b-45, ISO Cc 13e-92)	Fully refined oil: 0.8 R (red) and 8.0 Y (yellow)
11.	Totox Value	Empirical assessment of oxidative deterioration based on PV and AV of an oil.	Totox value = $2 \times \text{PV} + \text{AV}$	-
