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Near-infrared spectroscopy: a non-invasive tool for quality evaluation of seafood

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Abstract

The present-day food supply chain is globalized, and this has led to an increase in awareness among consumers regarding seafood quality measures. For ensuring the quality parameters, although suitable preservation techniques are used, industries still face quality issues during production, storage, and distribution. However, traditional methods like sensory evaluation, biochemical and microbiological analysis are cumbersome, susceptible to variations in results, and time-consuming paving the way to explore alternative tools for quality assessment. Thus, non-destructive optical techniques involving visible and near-infrared wavelengths are now being applied for evaluating the quality of seafood on a real-time basis enabling online monitoring of all product samples. The infrared radiation of the electromagnetic spectrum is the invisible band between the visible and microwave region, having a wavelength range of 0.76 to 350 μm emitted out of substances whose temperature exceeds absolute zero, from the sun to electric heaters and gas-fired heaters. NIR techniques utilize the concept that molecules tend to absorb specific frequencies of light characterizing the corresponding structure of the molecules, enable rapid data acquisition, saves time, and determines multiple parameters. In Near-Infrared spectroscopy, the substance to be analyzed is illuminated with a broad-spectrum near-infrared source, by absorption, transmittance, reflectance, or scattering. This article reviews the application of Near-Infrared Spectroscopy for the seafood quality assessment, different modes of spectra measurement, and various instruments used in Near-Infrared Spectroscopy. Near-Infrared Spectroscopy coupled with chemometrics is a propitious tool useful in the prediction of several fish and seafood's quality attributes and authentication of various fish-and-fishery products.

Keywords Seafood Quality Assessment, Spectroscopy, Near- Infrared Spectroscopy, NIR Mode of Operation, NIR Functionality

Introduction

Seafood is an important food commodity providing a balanced diet to human with several health benefits. These include shellfish and fish, with a high content of protein, long-chain omega-3 polyunsaturated fatty acids, vitamins, and minerals (Weichselbaum *et al.*, 2013). It is highly perishable in nature because of the low content of connective tissue, the presence of autolytic enzymes, high water activity (a_w), and neutral pH (Hassoun and Karoui, 2017). This necessitates the adoption of suitable preservation techniques to sustain the quality attributes and ensure its safety for human consumption. Despite the best techniques adopted for seafood preservation, the industry often faces quality issues during production, storage and distribution.

The globalization of the food supply chain and the shift in consumer behavior and eating habits have led to growing awareness regarding seafood quality and the preservation methods adopted (Karoui *et al.*, 2010). Therefore, seafood quality and its authentication is a major concern worldwide; and the processors and regulatory agencies today are required to assure seafood quality based on traceability of the product (geographical origin), labeling (species), production method (farmed or wild), processing conditions, substitutions or additives used, etc. (Hassoun and Karoui, 2017). An important aspect of seafood quality is an analysis of quality indices using several methods. Traditionally, sensory evaluation, chemical

and microbiological analysis of the seafood is done to determine the quality. In the seafood industries and retail stores, freshness evaluation of fish products is measured by evaluating through sensory means which is either descriptive or discriminative in nature (Sant'Ana *et al.*, 2011). Chemical analysis of volatile compounds (Castro *et al.*, 2006), measurement of lipid oxidation (Li *et al.*, 2011), an assay of nucleotide and amine degradation products are done to determine the degree of freshness of seafood (Li *et al.*, 2011 and Onal *et al.*, 2013). Additionally, texture measurements using texture analyzers and electrical properties using Torrymeter and Fischtester are applied for seafood quality monitoring (Coppes-Petricorena, 2010; Oehlenschlager, 2005; Oehlenschlager, 2014).

However, traditional methods have several disadvantages like sensory evaluation is not considered ideal for working with a large amount of sample, chemical analysis is cumbersome, slow, may produce toxic waste and destructive to the product causing irreversible damage to it. The microbiological analysis identifies biological organisms and no other contents. These traditional techniques are also susceptible to variations in results and time-consuming paving the way to explore alternative tools for quality assessment. This led to the development of newer technologies that are non-destructive. One such approach is an optical technique involving the use of visual and near-infrared wavelengths. These optical methods determine results on a real-time basis that helps in online monitoring of all product samples (Alandar *et al.*, 2013). Spectroscopy in the visible (VIS) and infrared (IR) regions of the electromagnetic spectrum as an analytical technique has gained the attention of the researchers and processors for measuring the quality of seafood. Spectroscopic techniques are an optical method that enable rapid data acquisition, save time, and simultaneously determine multiple parameters (Hassoun and Karoui, 2017).

History of near-infrared spectroscopic analysis

Near-Infrared energy as defined by the International Union of Pure and Applied Chemistry (IUPAC), extends from 780-2500nm. It was discovered by Fredrick William Herschel in 1800 in an experiment wherein he projected a rainbow using a prism and observed that heating effect increased from the blue to the red zone and found maximum heating effect into the black area beyond the end of his spectrum i.e., the invisible part of the spectrum (Davies, 1998). The present-day applications of NIR spectroscopy are done depending on the earlier researches by Karl Norris who was awarded "First Fellow of Near-Infrared Spectroscopy" by the International NIR community during the 8th conference of The International Committee for NIR Spectroscopy, in the year 1997, in Germany. Norris is credited with the award due to his research on the use of Near-Infrared spectroscopy in the determination of analytes in agricultural commodities especially the protein content of wheat (Davies, 1998). Ever since Norris pioneered the use of NIR spectroscopy, a lot of research was done on its application in agriculture and food. Norris and Hart published the works on the direct spectrophotometric determination of moisture content of grain and seeds in "Proceedings of the

International Symposium on Humidity and Moisture" of the US Department of Agriculture (USDA) (Norris and Hart, 1996). Later, Phil Williams from the Canadian Grain Commission established an analysis of wheat protein all-over Canada in 1975. During the early days, the application of NIR was only used for quality evaluation of products with low-moisture content such as cereal grains like wheat, corn, and soybean. This is because of water absorption in the region of 1900–2500 nm wavelengths. Later on, silicon sensors were developed to enable data acquisition even in the shorter wavelengths of 700–1100 nm. Shorter wavelengths have better penetration which allowed non-destructive evaluation of thick samples. This enabled analysis of high moisture samples which are thick as well, like intact kernels, fruit, meat, and fish (Alandar *et al.*, 2013). NIR spectroscopy measures the chemical properties based on the changes in spectra. Therefore, the technique needs to be calibrated based on a reference method for analysis of the target parameter (Osborne, 2006). Over the years, data processing and mining are used to calibrate the NIR spectroscopy techniques based on chemometric tools (Hassoun and Karoui, 2017). Alandar *et al.* (2013) defined chemometrics as the optical measurement results correlated with the chemical analysis and statistics. Presently, the NIR spectroscopy is used for the prediction of various quality parameters and to authenticate seafood. The research in the NIR spectroscopy is mainly aimed at the assessment of freshness, chemical, and microbiological parameters of seafood (Liu *et al.*, 2013).

Near-Infrared waves and Near-Infrared spectroscopy

The infrared radiation of the electromagnetic spectrum is the band between the visible region and microwaves having a wavelength range of 0.76 to 350 μm . This is the invisible part of the spectrum (Fig 1.). It constitutes 66% of solar radiation and causes heat. Infrared energy is emitted from any substances whose temperature exceeds absolute zero, from the sun to electric heaters and gas-fired heaters. Almost all sources of light and heat generate some energy in the infrared region (Aboud *et al.*, 2019). Infrared radiation is categorized into three spectrums:

1. Near-IR (NIR) with wavelength ranging from 0.75 to 1.4 μm .
2. Mid-IR (MIR) with a wavelength between 1.4 and 3 μm .
3. Far-IR radiation (FIR) with a wavelength between 3 and 1000 μm .

The heating caused by infrared radiation depends on several factors:

- a. the emission spectrum of the source
- b. the temperature of the source
- c. the direction of the emission falling on the surface
- d. absorption and scattering of the medium

The process of scattering and absorption of the medium is important in heating. Absorption is the process of converting radiation to any other forms of energy and scattering causes the radiated energy to be directed to another destination from the original direction of propagation through reflection, refraction, and deviation (Figure 2). These result in the weakening of electromagnetic radiation (Aboud *et al.*, 2019). The Near-

Infrared, i.e., the wavelength range 780nm to 2500nm of the range of electromagnetic radiation is referred to as NIR spectroscopy (Osborne, 2006). Williams and Norris, (1987) noted that in the NIR region, the fundamental molecular vibrations of chemical bonds C-H, O-H, N-H, C = O, and other functional groups are detected and concentrations of food components like protein, fat, water, and carbohydrate having these bonds, can be determined using classical absorption spectroscopy. Although the method requires to be calibrated against a standard method as reference using multivariate

spectrum and the technique based on the absorption within this mathematics (chemometrics) (Osborne, 2006). Food substances contain various functional groups which when irradiated with NIR light, absorbs the light with frequencies that match with the vibrations of a particular functional group. The rest of the frequencies is either transmitted or reflected (Foley *et al.*, 1998). The light undergoing reflection, transmission, or absorption into was detected and the biochemical constituents of food were determined based on the calibration using chemometrics (André and Lawler, 2003).

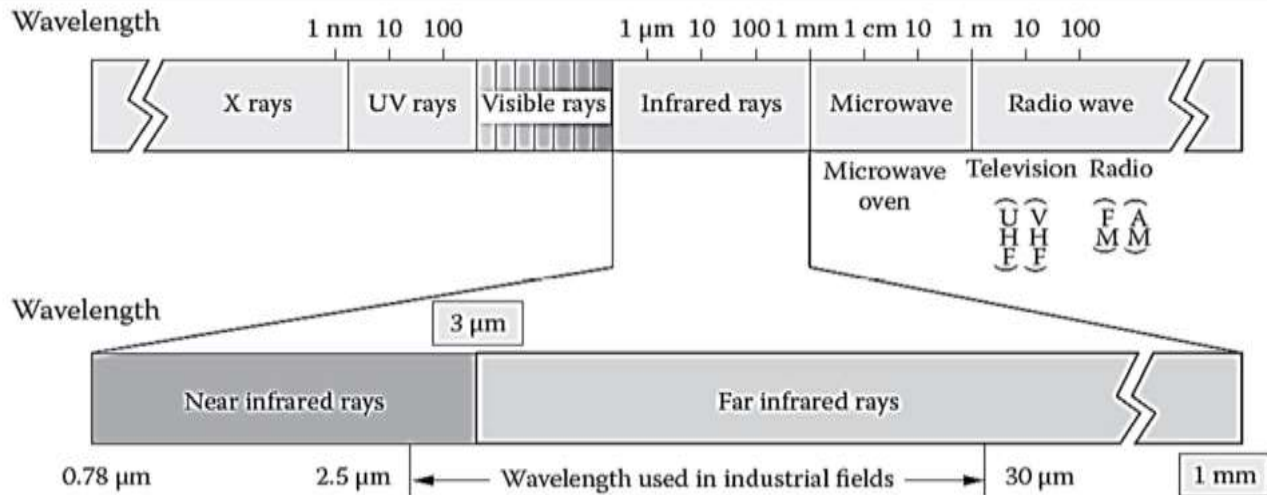


Fig 1. The spectrum of electromagnetic waves and infrared ranges (Aboud *et al.*, 2019).

Modes of Measurement of Near-Infrared Spectra

There are four standard modes of measurement of NIR spectra of samples such as transmission, reflection, transfection, and interaction (interactance) (Alandar *et al.*, 2013). The choice of the model depends on several factors, of which the type of sample to be tested is of importance.

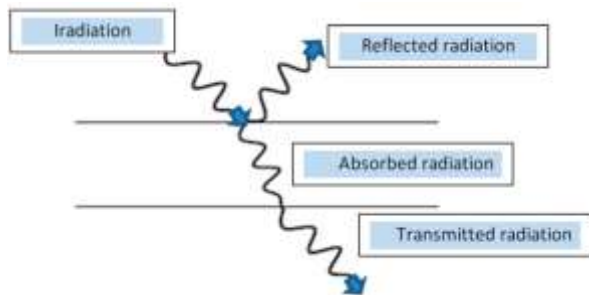


Fig. 2 Reflected, absorbed and transmitted radiation (Aboud *et al.*, 2019)

Transmission mode

In the transmission mode of measurement, the light incident on the sample passes through it, and part of the light that exits the sample is measured at a point exactly opposite to the

source of light. In solid samples, the light source is placed at a right angle to the detector (Fig. 3)

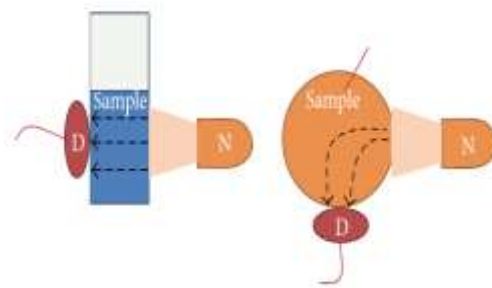


Fig. 3 Sample presentation for Transmission mode of measurement of NIR spectroscopy. N: Light source of NIR, D: detector. (Alandar *et al.*, 2013)

Reflection mode

In this mode, the source of light is positioned on the same side as that of the sample. The detectors are usually aligned at 45°angle to the sample plane for avoiding surface reflection. An integrating sphere is used in certain cases for concentrating the reflected light so that the light can be captured and integrated from different directions into the detector (Fig. 4)

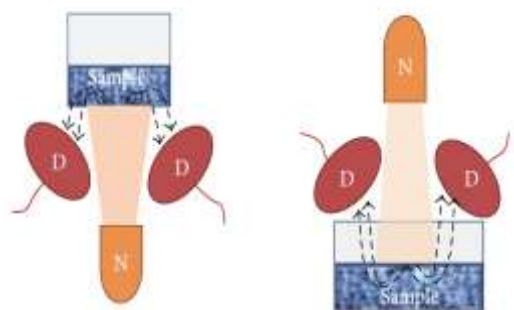


Fig. 4 Sample presentation for Reflection mode of measurement of NIR spectroscopy. N: Light source of NIR, D: detector. (Alandar *et al.*, 2013)

Transflection mode

This is a combination of transmission and reflection wherein opposite to the light source a reflector is positioned and the transmitted light passing through the sample is reflected. This reflected light then once again travels through the sample before reaching the detector. The alignment of the detector and source remains the same as in reflection measurement mode. In transflection mode, the physical path length is double the thickness of the sample as the transmitted light passes back within the sample after being reflected (Fig. 5)

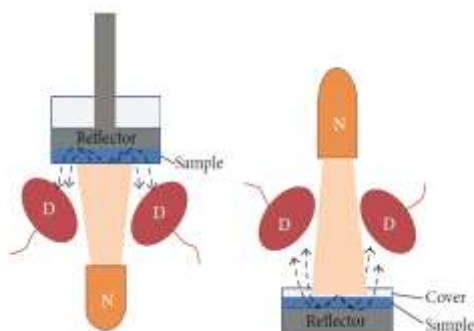


Fig. 5 Sample presentation for Transflection mode of measurement of NIR spectroscopy. N: Light source of NIR, D: detector. (Alandar *et al.*, 2013)

Interactance mode

This is also a combination of transmission and reflectance with certain modifications to make it suitable for solid samples. The illumination of the sample is achieved using fiber optic cables and it remains in direct contact with the sample surface or holder. Such direct contact avoids the chances of surface reflection and maximizes the penetration depth. The light passing through the sample is either reflected, transmitted, and/or absorbed. Source and the fibers are aligned on the same side and the transmitted and reflected light return to the detector (Fig. 6).

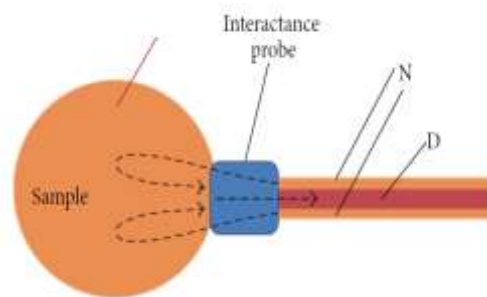


Fig. 6 Sample presentation for Interactance mode of measurement of NIR spectroscopy. N: Light source of NIR, D: detector. (Alandar *et al.*, 2013)

Different types of food and agriculture samples for NIR spectroscopy

The food and agriculture samples commonly used for analysis by NIR spectroscopy can be categorized into three types based on physical state (Fig. 7)



Fig 7. Various food samples: a. liquid samples; b. ground and small solid samples; c. relatively large samples

Liquid samples

Liquid samples such as vegetable oil, filtrated fruit juice are clear in nature and cause low scattering. Hence, such samples can be placed in a quartz cuvette, disposable glass vial, or a transflectance sample holder. The measurement model used for analysis is transmission or transflection. The liquid samples also provide an additional benefit of adjusting the thickness of the sample based on the absorptivity of major constituents.

Ground and relatively small solid samples

This category includes samples like the ground and intact cereal grains, soybean meals, powder milk, and crushed processed foods. These food samples exhibit a strong scattering characteristic which necessitates that the NIR spectra be measured using reflectance. The samples to be tested are generally positioned in glass window sample holders or quartz sample holders.

Relatively large samples that require non-destructive or non-invasive measurement

Samples such as meat, fish, fruit, and nut kernels which are sold intact fall under this category. For such samples, the composition of parameters such as fat, protein, and moisture are not distributed evenly throughout and variations exist in different parts of the sample like surface or sample core.

Hence, for these samples the interactance and transmission modes of measurements are applied. Silicon detectors are used in data acquisition which generally is in the range of 700-1100 nm (Alandar *et al.*, 2013). The food commodities and the parameters measured using NIR spectroscopy is given in table 1

Table 1. Different food groups, parameters measured and methods

Food Group	Parameters	Methods	Reference
Fruits	Sensory analysis of apples	Visible-NIR spectroscopy	Mehinagic <i>et al.</i> (2003)
	Sugar content of intact fruit	Miniaturised NIR spectrometers	Walsh <i>et al.</i> (2000)
	Soluble solids present in apricot and cherry	Vis-NIR measurement PLS regression and wavelength selection	Carlini <i>et al.</i> (2000)
	Soluble solids content of fresh jujube	Near-infrared (NIR) spectroscopy	Zhang <i>et al.</i> (2012)
	Internal quality in pear	Genetic algorithms and FT-NIR spectroscopy	Ying and Liu, (2008)
Meat	Freshness and spoilage detection in sliced pork meat	Near infrared spectroscopy	Horvath <i>et al.</i> (2008)
	Sensory characteristics of lamb meat	Near infrared reflectance spectroscopy	Andres <i>et al.</i> (2007)
	Online classification of beef carcasses for longissimus tenderness	Visible and near-infrared reflectance spectroscopy	Shackelford <i>et al.</i> (2005)
	Polyunsaturated fatty acids and biohydrogenation products in the subcutaneous fat of beef cows	Near infrared reflectance spectroscopy	Prieto <i>et al.</i> (2012)
	On-line quantitative determination of glycogen and prediction of ultimate pH in pre rigor bovine	Near infrared spectroscopy	Lomiwes <i>et al.</i> (2010)
Processed foods	Major constituents in root and tuber crop flours	Near infrared spectroscopy	Lebot <i>et al.</i> (2009)
	Nutritional content of naked oats	Near infrared reflectance and transmittance with calibration	Bellato <i>et al.</i> (2011)
	Methanol in grape-derived distillation products	near-infrared transmission spectroscopy	Damberg <i>et al.</i> (2002)
	Monitoring alcoholic fermentation of onion juice	NIR spectroscopy	Gonzalez-Saiz <i>et al.</i> (2007)
	Soluble solids contents and pH in orange juice	Chemometrics and Vis-NIRS	Cen <i>et al.</i> (2006)
	Texture and colour of dry-cured ham	Visible and near infrared spectroscopy using a fiber optic probe	Garcia-Rey <i>et al.</i> (2005)
	Dry matter, fat, pH, vitamins, minerals, carotenoids, total antioxidant capacity, and color in fresh and freeze-dried cheeses	Visible-near-infrared reflectance spectroscopy	Lucas <i>et al.</i> (2008)

Sample presentation techniques in NIR spectroscopy

The food samples can be in different forms like liquid, slurry, powdered, or solid, and therefore, suitable sample presentation techniques must be available for each type. The different types of sample presentations are

Diffuse Transmittance

Light passing through a food sample can be reflected, transmitted or absorbed. If scattering is absent as in clear transparent liquids, Beer's law is applied for defining a proportionality between transmittance and concentration of the absorbing food sample and path length. However, in food samples such as meat and cheese, scattering of the light occur and Beer's law is not applicable. This occurs as the scattering causes a change in the length of the path and the length becomes undefined. Diffuse transmittance is applied for such samples and performed in a range of 800-1100 nm wavelength (Fig. 8). This is near-infrared transmittance (NIT) and it is ideal for analyzing whole grains. For whole grains, the sample is presented in a receptacle termed as hopper, from where grains in predetermined quantities are dispensed into the measurement chamber. After the analysis is completed, the grains are discharged into a collection tray. This sample presentation is also used for on-line measurements. For meat and cheese, 1-2 cm thickness is usually maintained to enable proper data acquisition.

Diffuse reflectance

Food samples, in which the maximum portion of the radiation incident on the surface is reflected by regular or specular reflection, the amount of absorption is nil and transmittance is negligible. In the spectra range of 1100 to 2500 nm, most of the incident radiation is scattered and this situation is termed diffuse reflectance (Nilsen and Heia, 2009). Diffuse reflectance is applicable for samples like flours and powdered milk and the NIR spectroscopy for such samples is done in reflectance mode. In reflectance mode, the radiation reflected is measured by a set of detectors set at 45° to the incident beam (Fig. 9). Alternatively, an integrating sphere may be used for focussing the diffused reflection on a single detector. The samples are placed in a 1 cm deep sample cell, then enclosed with a quartz window. The cell is then put inside the instrument for NIR spectroscopy measurement. This system of sample presentation can also be modified for on-line measurements using a powder sample. Liquid samples that are otherwise measured by transmittance can also be measured by diffuse reflectance by modifying the sample presentation. Liquid samples are placed in a ceramic tile beneath the sample and the radiation after being transmitted through the sample will be reflected from the ceramic tile and transmitted back finally reaching the detector. This is called transreflectance as discussed earlier. Further, fiber-optic probes are used for presenting the samples for evaluation by using interactance mode. Such an arrangement is particularly useful for large samples such as fruit.

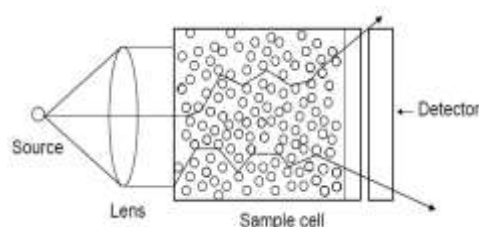


Fig. 8 Diffuse transmittance spectroscopy (Osborne, 2006)

On line samplers

NIR instruments are relatively low cost, capable of measuring the target analytes rapidly and in a non-destructive manner, which makes them a suitable instrument for online analysis.

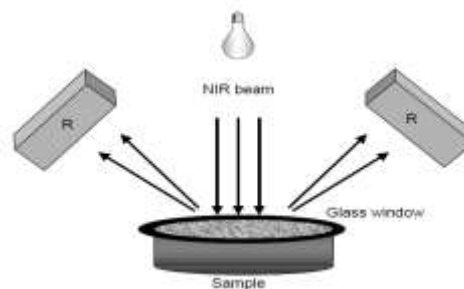


Fig. 9 Diffuse reflectance analysis for powdered sample (Osborne, 2006)

The NIR used in the online analysis is classified into three categories

Remote Sensor

This system is characterized by sensors that are set remote from the sample and has application in the food industry for the determination of different constituents like protein, fat, and moisture in whole biscuits, flour, and potato crisps. It is also used for sorting fruits and monitoring bread dough development.

By-pass Sampler

This sample presentation is used for measuring protein content in flour and is used in online systems to control the addition of gluten to flour. The sample presentation is achieved by taking direct samples from the flour stream into a sample cup using a suitable mechanism for NIR measurement.

Fibre-optic prob

This sample presentation is applied for the production of extruded snack foods, online analysis of dairy products, meat, fruit, and beer. In extrusion cooking, NIR is used to monitor the changes in starch structure. Transreflectance measurement mode is generally used and the probe is installed in the die of the extruder (Osborne, 2006).

Instruments

Near-Infrared spectroscopy is applied depending on the type of instrument chosen. It is mainly of three types (Osborne, 2006)

Monochromators

Grating monochromators are versatile instruments used for measurements in both visible and NIR spectrum. The measurement modes can be either transmittance or reflectance. There are three types of detectors: silicon (400–1100 nm), indium gallium arsenide (800-1700 nm) and lead sulphide (1100-2500 nm) detector.

A combination of silicon and lead sulphide detector may also be integrated in a system to get a wide range of spectrum in-between 400-2500 nm. Acousto-optically tuneable filter (AOTF) is another type of dispersive monochromator comprising of TeO₂ crystal, through which acoustic wave is produced at 90° angle to the incident light beam. The crystal, thus, behave like longitudinal diffraction grating with a periodicity equal to the wavelength of sound across the material.

Diode array spectrometers

These spectrometers use an array of IR emitting diodes, that function as the light source as well as wavelength selection system. The instrument works fast and non-invasive in nature and operates within the range 400–1700 nm. Diode array spectrometers are useful for ultra-rapid online measurements.

Filter Instruments

In these instruments, limited number of interference filters is added, each representing the absorption spectrum of the required applications such as protein, moisture and oil in agricultural samples. These equipments are made for routine analysis in the laboratory or for online system.

Application of Near-Infrared spectroscopy in seafood

Near-infrared spectroscopy in combination with the chemometric tools is considered a promising analytical technique for application in seafood industry. The technique is shown to be useful in prediction of several fish quality attributes and to authenticate fish and other seafoods. The seafood research involving application of NIR spectroscopy is focussed around evaluating freshness, chemical and microbiological parameters (Liu *et al.*, 2013). The different applications of the technique in seafood industry are given in table 2. The trends in use of NIR spectroscopy in seafood industry (table 2) indicates the following broad areas of application suggesting that NIR spectroscopy is a promising tool that has a widespread application in seafood industry.

- i. Evaluation of seafood freshness
- ii. Authenticity of seafood and detection of fraud/mislabeled
- iii. Detection of microbiological behaviour in seafood
- iv. Determination of spoilage and estimation of shelf life of seafood
- v. Prediction of chemical composition of seafood and its quality
- vi. Detection of contaminants/adulterants in seafood

Table 2. Application of Near-Infrared Spectroscopy in seafood

Seafood type	Parameters	Method adopted	Key Findings	Reference
Half-shell Pacific oysters	Freshness under storage at 4°C for 5 days	Reflectance mode, covering the NIR region between 833 and 2630 nm	Storage time and odor of oysters successfully predicted using NIR spectroscopy and chemometrics.	Madigan <i>et al.</i> (2013)
Salmon	Freshness during two weeks of storage in ice	VIS/NIR spectroscopy, 400-1100 nm, Partial least-square regression (PLSR) model.	The prediction correlation and error value of 0.98 and 1.20 days were obtained for NIR spectroscopy suggesting useful prediction for salmon freshness	Nilsen <i>et al.</i> (2002)
Salmon	Prediction of bacterial counts in salmon stored for up to nine days at 4°C	NIR spectroscopy, 800–2500 nm, PLSR model.	NIR spectroscopy can be used to predict total aerobic plate counts and, thus, shelf-life of salmon	Tito <i>et al.</i> (2012)
Rainbow trout	Detecting spoilage and quantifying microbial loads in minced samples stored at 21°C and fillet samples stored at 4°C	NIR spectroscopy, 600–1100 nm, Principal component analysis (PCA) application for spoilage, PLSR to predict microbial load	The usefulness of NIR spectroscopy coupled with chemometric tools for detection and monitoring of spoilage process in rainbow trout in a rapid and non-destructive way	Lin <i>et al.</i> (2006)
European sea bass	Differentiating between wild and farmed fish	NIR spectroscopy with PCA and Partial least-squared discriminant analysis (PLS-DA)	Successful differentiation between wild and farmed salmon	Ottavian <i>et al.</i> (2012)

Red sea bream	Differentiating fresh fish samples from frozen–thawed ones	VIS/NIR spectroscopy with PCA	VIS/ NIR spectroscopy is a rapid tool for online or at-line processing control of fresh and frozen/thawed fish samples	Uddin <i>et al.</i> (2005)
Tuna	Chemical parameters, like moisture, protein, total fat, and free fat	NIR spectroscopy, 600–2500 nm	NIR spectroscopy provides good reliability to predict the chemical compositions	Khodabux <i>et al.</i> (2007)
Atlantic halibut, catfish, cod, mackerel, herring, and saithe	Fat and moisture contents in fillet	VIS/NIR at 460–1040 nm	NIR spectroscopy provides good reliability to predict the chemical compositions	ElMasry and Wold, (2008)
Shrimps	Identify the fresh and frozen-thawed shrimps	Vis/NIR spectral analysis technology combined with chemometrics Discriminant Analysis (DA), Discriminant partial least-squares (DPLS), Least Squares-Support Vector Machine (LS-SVM)	Frozen-thawed shrimps could be distinguished from fresh shrimps based on visible/near-infrared spectral analysis technology combined with chemometrics methods	Zhang and Cheng, (2013)
Atlantic cod (<i>Gadus morhua</i>)	Chemical composition of fillet portion	Visible and Near-infrared spectroscopy	The impact of pre-slaughter stress on fillet residual blood can be measured by NIR spectroscopy	Olsen <i>et al.</i> (2008)
Fish meal	Discriminate fishmeal batches made with different fish species	Near-infrared reflectance (NIR) spectroscopy and chemometrics	The usefulness of (NIR) spectroscopy to discriminate fishmeal batches made with different fish species	Cozzolino <i>et al.</i> (2005)
Bigeye tuna	Fat content	Portable near-infrared spectrophotometer	Non-destructive determination of fat contained in glazed bigeye tuna	Shimamoto <i>et al.</i> (2003)
Fishmeal	Crude Protein and Moisture content	NIR Spectroscopy at 1000 and 2500 nm, multivariate regression technique based on Partial Least Squares (PLS)	NIRS using PLS is well fitted to evaluate the protein and moisture content of fishmeal	Masoum <i>et al.</i> (2012)
Red mullet, winter cod and Samlet	Combating fraud and misidentification in the seafood industry and marketing	Ultra-compact, handheld NIR spectrometer, 887–1667 nm, diffuse reflection, PCA	NIR is a very fast on-site measurement a tool to distinguish lower quality from superior quality seafood in mislabelling attempts and authentication of seafood	O’Brien <i>et al.</i> (2013)
Live, shucked, and freeze-dried Abalone	Glycogen concentrations in the foot muscle of cultured abalone	NIR spectroscopy, reflectance, 350–2500 nm, PLSR	NIR is a rapid method to monitor the factors (glycogen content) associated with abalone quality	Fluckiger <i>et al.</i> (2011)
Red Crayfish	Inorganic arsenic content	VIS/NIR spectroscopy	NIR can be used to screen inorganic arsenic content in red crayfish	Font <i>et al.</i> (2004)
Crab meat	Authenticity and adulteration	VIS/NIR spectroscopy	NIR is applied for species authenticity and detection of adulteration in crab meat	Gayo and Hale, (2007)

Conclusion

NIR spectroscopy is a valuable and useful analytical tool that could be applied for the rapid assessment of fish quality and authenticity. It can provide extensive information on changes of various chemical components (proteins, fat, and water)

during handling, processing, and storage. The disadvantage of this technique is the need to develop calibration models based on the use of chemometrics to predict unknown samples.

However, features like low energy costs, portable nature of the instrument, accuracy level, possibility to align it for online determination of parameters and rapid testing ability makes this technique a highly promising alternative for assessment of seafood quality and authenticity.

Authors' contributions

All authors (Ayari Chakrabarti, S. Chowdhury, Swarnadyuti Nath, P. Murmu and Deboshmita Dey) have contributed significantly to the conception and design of the study, the interpretation of data, and the drafting and revision of the manuscript. All authors read and approved the final manuscript.

Conflict of Interest

The authors hereby declare no conflict of interest.

Consent for publication

The authors declare that the work has consent for publication.

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