Freshness Detection and Classification of Chicken Eggs using Spectroscopy

Ms. Priti Prakash Patil
Research Scholar ,
SVPM's College of Engineering Malegaon BK Baramati.
Savitribai Phule Pune University Pune,India
priti.patil87@gmail.com

Dr.V.N.Patil
Research Guide,
SVPM's College of Engineering Malegaon BK Baramati.
Savitribai Phule Pune University Pune,India
vvnnpp2002@gmail.com

Abstract— The poultry industry plays a pivotal role in India's economy, with particular emphasis on egg production. India ranks as the world's third-largest producer of chicken eggs. Eggs are a delicate component of the human diet, and their quality can undergo substantial changes during storage. This has implications for egg quality and the classification of chicken eggs, both of which are critical factors affecting the poultry sector. Globally, numerous chicken breeds are being developed, necessitating the classification of eggs based on breed due to varying atmospheric conditions required for their storage. However, in India, there is a lack of technical methods for classifying eggs from different chicken breeds. The primary challenges faced by the poultry industry in India revolve around maintaining egg freshness and accurately classifying eggs by breed. While developed countries employ grading systems for eggs, this practice is less common in developing nations like India. To address these challenges, this study aims to propose a model that utilizes spectroscopy as a non-destructive method for assessing egg quality and freshness. The model seeks to establish a link between spectral data, collected using a handheld SCiO NIR spectrometer with wavelengths ranging from 740nm to 1070nm at a spectral resolution of 1 nm, and established destructive methods, particularly Haugh Units, to determine egg freshness based on storage duration.

Keywords— Classification of eggs, Freshness of chicken eggs, NIR Spectroscopy, Nondestructive method, AI.

I. Introduction

Eggs are undeniably a nutrient-rich dynamo, packed with vitamins, top-notch proteins, advantageous lipids, necessary microelements, and a plethora of trace elements. In the context of animal farming in India, the focal points are egg production and egg incubation. The duration of egg storage can significantly impact the nutritional value. This influence is notably seen in alterations to both the texture of the eggshell and the internal quality of the egg. For consumers, the paramount consideration when evaluating a product is its quality, a facet substantially shaped by the egg's material structure and chemical composition. These factors also influence the egg's resilience during storage. Given that consumers commonly equate freshness with quality and are wary of the uncertainty surrounding egg freshness, the pivotal standard for egg quality remains its freshness.

In a broader perspective, the degree of freshness of eggs is often contingent upon several variables, including relative humidity, environmental temperature, storage duration, the age of the hens, and their genetic lineage. Consequently, as eggs undergo storage, changes occur, including increases in pH levels, elevated yolk water content, alterations in vitelline membrane elasticity, and thinning of the albumen. It's worth noting that even eggs laid on the same day but subjected to different storage conditions or originating from distinct localities may exhibit variations in quality. Relying solely on the day of laying doesn't guarantee freshness, underlining the importance of establishing and preserving egg freshness through a real-time non-invasive technique.

To mitigate consumer confusion and minimize waste within the egg industry, egg grading is employed. Egg producers employ this process to ensure product quality consistency and facilitate standardized business and marketing practices. Egg grading is a quality control method used to categorize eggs into various classes based on both their internal and external attributes. Eggs are sorted based on internal characteristics, including the yolk, air cell, albumen, and the detection of possible abnormalities. External factors like the integrity and cleanliness of the shell also come into play. Grading is typically conducted using methods such as candling and the "broken-out" technique. Eggs are typically grouped into three classes: Grade B, Grade A, and Grade AA. Grade B eggs may exhibit irregular or stained shells, minor defects like hemoglobin stains. Eggs with AA grade and eggs with grade A are closely comparable, with the primary difference being the level of freshness. Eggs of Grade AA exhibit thicker, more robust egg whites that support high, rounded yolks. In contrast, eggs with grade A have slightly less firm egg whites than Grade AA eggs, causing them to spread out more when fried. [27].

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

Existing methods of evaluating Egg quality primarily hinges on physical attributes such as egg mass, albumen elevation, protein concentration, shell resilience, Haugh score, egg shape factor, shell hue, air sac dimension, and egg density. However, these methods do not take into account the biochemical changes that occur during the natural decline in egg quality. Eggs' freshness quality may only be partially reflected by conventional freshness metrics like the Haugh unit and yolk index, which hardly ever take into account the biological and chemical basis of merit fluctuations. Therefore, the full extent of freshness of egg is not adequately and deeply conveyed. The quality of the eggs was assessed to see if it was possible to evaluate and grade different egg varieties categorized by their predominant protein content and a variety of conventional freshness quality markers will be more complete. This grading method boosts business productivity while also enlarging the market to better serve different consumer demographics.

The terms used in previous evaluation techniques can be explained as follows:

• Egg weight: The weight of an egg, usually measured in grams.
• Albumin height: The height of the egg white, measured in millimeters.
• Protein content: The amount of protein in an egg, usually measured in grams.
• Eggshell strength: The strength of the eggshell, usually measured in kilograms per square centimeter.
• Haugh unit: A measure of the freshness of an egg, based on the height of the egg white and the albumin index.
• Egg shape index: A measure of the shape of an egg, usually measured in millimeters.
• Eggshell color: The color of the eggshell, usually measured in a color scale.
• Air chamber height: The height of the air chamber in an egg, usually measured in millimeters.
• Egg-specific gravity: The specific gravity of an egg, usually measured in grams per milliliter.
• Standard freshness indicators: Indicators used to detect the egg quality, such as HU and index of the egg yolk.
• The fundamental biochemistry underlying alterations in quality: The biochemical changes that occur during the natural decline in egg quality.

In a 2019 study led by Kelsey A. Ramírez-Gutiérreza and co-authors, a real-time processing system was proposed. This system combined computer vision, cubic spline interpolation, and artificial neural networks as a classifier to detect deformations on curved eggshells. It was rigorously tested and achieved an impressive accuracy rate of 97.5%.

Some researchers, revisited the issue of assessing the suitability of stored eggs for human consumption. In their initial research, they employed pulsed thermography as a method of investigation and developed an innovative approach to identify issues in evaluation. Their work also included the subsequent mechanical processing of thermograms and quantitative analysis using advanced image processing techniques. The study found that the air chamber factor was affected by storage time [2].

The system was proposed to detect cracks on eggshell surfaces using the LOG operator. This method enhanced crack visibility in images and subsequently obtained binary images through Hysteresis thresholding. The accuracy of this method in detecting cracked eggshells was approximately 92.5% [3].

The quality of eggs is influenced by various factors beyond n-3 PUFA content, including the diet of the hens, breed, and age. For free-range production systems, such as organic farming, factors like weather conditions, pasture quality, and the amount of time hens spend in open areas also play a crucial role in egg quality. Monitoring and controlling these variables can be challenging, and consumers often lack awareness of this information, which can impact their purchasing decisions. Assessing egg quality is a complex task for producers, but specialty eggs labeled as "Omega-3 enriched" are generally of high quality, especially in terms of their albumen protein content.

One of the PhD thesis explored the freshness detection of chicken eggs using the VIS/NIR spectroscopy by means of shelf life and quality of egg white i.e. albumen. A predictive model was developed using regression method. This model successfully related spectroscopic data to egg white pH, HU, and time to be stored, achieving validation set R2 values of 0.90, 0.79, and 0.89, respectively, and low RMSEV values (0.06, 5.05, and 1.65, respectively). This indicated that VIS/NIR spectroscopy could serve as a non-invasive method for assessing both egg merits [10].

The model was developed using neural network to identify blood spots in Grade A eggs with an impressive accuracy of 92.8%. However, the same level of accuracy was not achieved for other grades of eggs [11].

Various authors have explored different technologies for assessing egg freshness. Numerous technologies have emerged, with both destructive and nondestructive methods being employed. Destructive methods involve sensory evaluation and physio-chemical techniques, such as Haugh Unit measurements, which assess the appearance, odor, taste, and texture of eggshells and albumen to determine freshness. Nondestructive methods, such as spectroscopy, have gained significant attention for their ability to evaluate egg freshness without traditional candling. Spectroscopic methods, including infrared spectroscopy and front-face fluorescence spectroscopy, have demonstrated reliable accuracy in assessing food quality parameters [23].

All the aforementioned research and authors have developed various techniques for assessing egg defects and freshness. However, there hasn't been a recommended study conducted to identify the hen breed associated with the freshness of eggs.

In India, consumers are consistently inclined towards healthier meal choices, and many people believe that eggs are an essential component of a nutritious diet. Nevertheless, freshness is a critical factor influencing the nutritional value of eggs. Furthermore, Indian consumers prioritize knowing the source of their food. Therefore, it becomes imperative to establish the specific hen breed from which each egg originates to meet these expectations.

II. METHODOLOGY

The following methods would be used to carry out my research:

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

A. Sample Collection:
Unfertilized eggs will be collected from different poultry farms and different egg distributers. Each egg will be observed for different atmospheric conditions. Changes in the parameters like shell colour, air gap, shell texture will be observed and images of eggs at regular interval of one day will be taken to keep record.

B. Spectra Collection:
Using a portable SCiO NIR spectrometer, 660 spectral curves with 740 to 1070 nm wavelength range and 1 nm spectral interval were acquired. The spectral curves represent 30 chicken eggs with their shells intact over constant surveillance for 22 days. A flock of 20,000 hens of the H&N strain, aged 49–52 weeks, was used to harvest eggs. Hens were raised in stacked cage systems and provided a standard diet without the use of egg-laying stimulants or enhancers.

C. Preprocessing of spectrographic data:
Preprocessing of spectral data from egg samples plays a pivotal role in ensuring the accuracy and reliability of subsequent analyses. Spectral measurements are initially obtained from eggs using specialized equipment that measures the interaction of light at different wavelengths with the egg's constituents. However, these raw spectral readings often contain noise, baseline variations, and other artifacts that can obscure meaningful information. To address this, a series of preprocessing steps are applied. These steps include cleaning to remove outliers, baseline correction to align data properly, noise reduction to enhance data quality, normalization for consistent scaling, and techniques like derivative transformation, multiplicative scatter correction (MSC), and Fast Fourier Transform (FFT) to further enhance relevant spectral features. By systematically preparing and enhancing the spectral data, preprocessing ensures that the subsequent analysis, whether for quality assessment, freshness determination, or compositional analysis, is based on accurate and interpretable data, ultimately yielding valuable insights into egg properties.

D. Multivariate Calibration:
Efficient data representation is a critical component in addressing many pattern recognition challenges. It involves the identification of measurements that remain consistent within each category of interest, irrespective of variations. This crucial process, known as feature extraction, aims to distill and emphasize these distinctive measurements. In the context of this research paper, two distinct methods were employed to achieve dimensionality reduction and the extraction of pertinent wavelengths: the genetic algorithm (GA) and principal component analysis (PCA). These techniques play a pivotal role in refining the data and enhancing its suitability for accurate pattern recognition, offering valuable insights and solutions for the given research problem.

E. Principal components analysis (PCA):
Principal Component Analysis (PCA) serves as a mathematical method employed to distill valuable insights from high-dimensional data. Its primary objective is to streamline the data's dimensionality by extracting the most significant and informative attributes inherent in the dataset. Subsequently, these extracted principal components are harnessed as the input variables in the construction of a classification model. In essence, PCA plays a pivotal role in simplifying complex data while preserving the essential characteristics required for effective classification and analysis.

F. Genetic algorithm (GA):
The Genetic algorithm (GA) utilizes a binary encoding approach with a population size of 100. Its primary purpose is to identify and extract measurements that remain consistent, or insensitive, to the variations within each category of interest. This process, known as feature extraction, is instrumental in obtaining these invariant measurements, ensuring their relevance in the context of the problem being addressed.Crossover has a 0.5 crossover probability while mutation has a 0.1 mutation probability. Heuristics serve as the foundation for the convergence judgment criterion. In this research, the convergence criterion was determined by assessing the substantial disparity between the variance and the count of selected variables, a measure derived from the F-test. Additionally, the accuracy of the classifier was considered as part of the convergence judgment process. This approach was employed to ensure that the feature selection process effectively identified relevant variables and contributed to the improvement of the classification model's accuracy.

G. Development of algorithm to segregate the chicken eggs as per chicken breed.

H. Analysis and Interpretation of data.

III. EXPERIMENTATION AND RESULT

A. Spectral Analysis:

We utilized an affordable near-infrared reflectance (NIR) spectrometer, spanning wavelengths between 740 nm and 1070 nm, to gather spectral data. These datasets were systematically stored in a cloud-based repository, accompanied by their respective reference values, and meticulously time stamped for robust data management. This critical step played an integral role in the subsequent development and fine-tuning of chemo metric models.

In our experimental setup, we worked with a sample set of 30 poultry eggs characterized by intact shells, all falling within the weight range of 55 g to 65 g (size M). These eggs were procured from a larger population of strain hens, aged between 49 and 52 weeks, and housed in a stacked cage system. They were provided a standard diet without the use of any egg-laying enhancers. The spectral data used in our analysis were generated by averaging two consecutive measurements taken at the blunt end of each egg.

Our data collection initiative commenced immediately after the eggs were laid (day 0), conducted right within the poultry facility. Following this, the eggs were transported to our laboratory in thermally insulated containers. Measurements were taken from day 1 to day 21 under controlled laboratory conditions. Each measurement was precisely scheduled at 24-hour intervals, adhering to a straightforward and rapid procedure. Importantly, we adopted a non-destructive approach throughout the experiment, ensuring that we tracked the evolution of each egg's spectral characteristics over time without causing any harm to the samples.

B. Data Partition:

In the realm of machine learning, cross-validation stands as a pivotal technique aimed at optimizing the utilization of available data resources. Its essence lies in the random division of the dataset into several subsets, each serving a unique purpose in training and testing the model. This strategy helps safeguard against over fitting, a common pitfall in model development. In a specific study involving spectral data, the dataset was meticulously split into distinct sets: one for training (calibration), another for validation, and yet another for testing. The chosen methodology was repeated 10-fold cross-validation, meaning the dataset was subdivided into 10 groups. Within each fold, 9 groups were designated for calibration and validation, while the remaining one was held aside for testing. This process was iterated 50 times, ensuring that each fold took its turn as the test set. During each fold, the data was randomly partitioned, with 70% of the samples allocated for training, 20% for validation, and the remaining 10% for testing. The pivotal objective of this approach was to evaluate the model's performance measures on a completely new set of data—data that had not been used during model training. The ultimate litmus test for a competent model lies in its ability to provide accurate estimates when confronted with this unseen test data.

C. Pre-Processing:

NIR spectra, short for Near-Infrared Reflectance spectra, are intricate datasets comprising signals with overlapping information. Consequently, it's customary to engage in pre-processing to rectify any potential distortions in the raw spectra. This practice is a critical component of chemo metric modeling and is often regarded as one of the most crucial phases. The selection of the most appropriate pre-processing technique is a complex undertaking that demands careful consideration before model validation. Consequently, pre-processing of NIR spectra primarily relies on a trial-and-error approach.

In the context of this study, we analyzed the raw spectral signal along with six commonly employed pre-processing techniques. Let's delve into these techniques:

Raw Spectra (Fig 1): Raw NIR spectra represent the initial data acquired using a Near-Infrared spectrometer, and they can subsequently undergo processing and analysis to derive essential chemical insights applicable across various fields.

SavitzkyGolay Method (Fig. 2): This method includes a smoothing step for numerically deriving a vector. The Savitzky-Golay method involves fitting a polynomial of order "p" within a symmetric window of width "w" over the raw data. It then calculates the derivative of order "d" at the central data point "i." This technique is instrumental in smoothing and enhancing the quality of data while preserving important features for further analysis or visualization.

Beer-Lambert Law: This law postulates astraight-line correlation between the spectral reflectance and the component content.

SNV: SNV is a technique used for NIR data scattering correction, aiding in standardizing the data.

Multiplicative Scatter Correction (MSC): This method involves dividing the spectra by a reference spectrum to correct for scattering effects.

First Derivative: This pre-processing technique aims to reduce noise in the spectra. It involves estimating correction coefficients and then applying these corrections to the recorded spectrum.

While other techniques, such as First Spectral Derivative (FSD) and Second Spectral Derivative (SSD), are based on the finite difference method, they are typically avoided in practice, as noted by Rinnan et al. (2009). These techniques, though theoretically sound, can lead to noise inflation and are often not feasible for most real-world measurements.

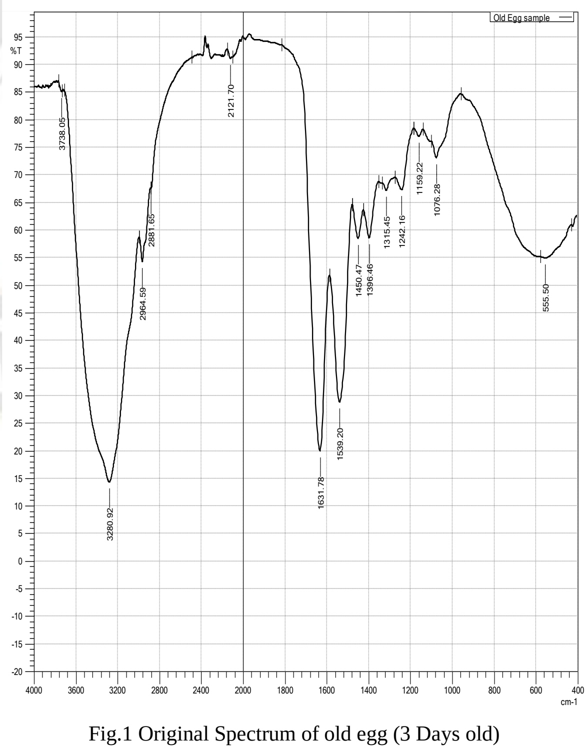


Fig.1 Original Spectrum of old egg (3 Days old)

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

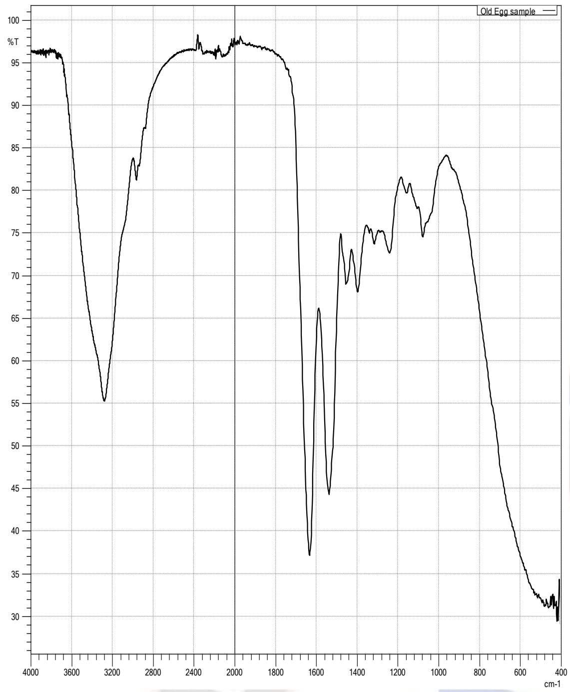


Fig. 2 Spectrum after preprocessing of old egg
(3 Days old)

Table 1: Wavelength Vs Intensity (Old Egg)

No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	555.5	54.9	1.06	576.72	430.13	6317.319	163.34
2	1076.28	73.12	4.36	1099.43	958.62	2996.04	231.259
3	1159.22	76.95	1.38	1184.29	1139.93	990.603	29.851
4	1242.16	67.26	5.37	1273.02	1184.29	2507.365	199.697
5	1315.45	67.19	1.62	1334.74	1273.02	1944.693	31.939
6	1396.46	58.59	7.07	1425.4	1352.1	2707.117	229.99
7	1450.47	58.49	5.58	1477.47	1425.4	2023.461	153.479
8	1539.2	28.79	28.63	1587.42	1477.47	6267.004	1671.294
9	1631.78	20	39.89	1816.94	1587.42	7923.16	1655.221
10	2121.7	91.05	0.9	2148.7	2102.41	387.51	20.549
11	2881.65	67.52	0.25	2885.51	2490.1	6197.082	-1941.78
12	2964.59	54.28	6.92	2995.45	2885.51	4451.256	397.954
13	3280.92	14.32	54.99	3711.04	2995.45	44423.8	24383.697
14	3738.05	85.1	0.27	3765.05	3734.19	438.137	7.876

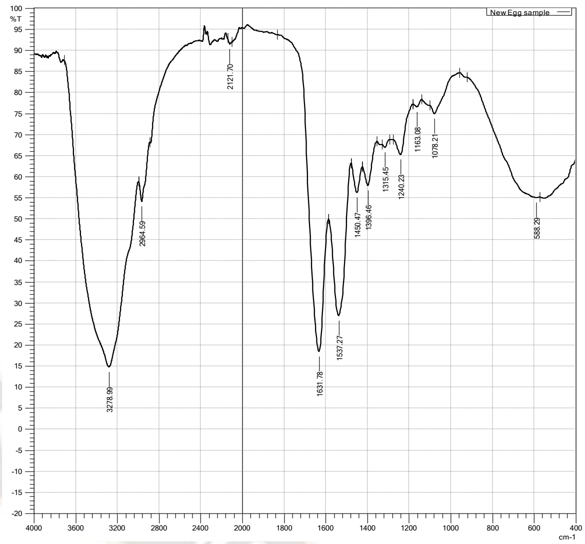


Fig. 3 Original Spectrum of freshly lay egg

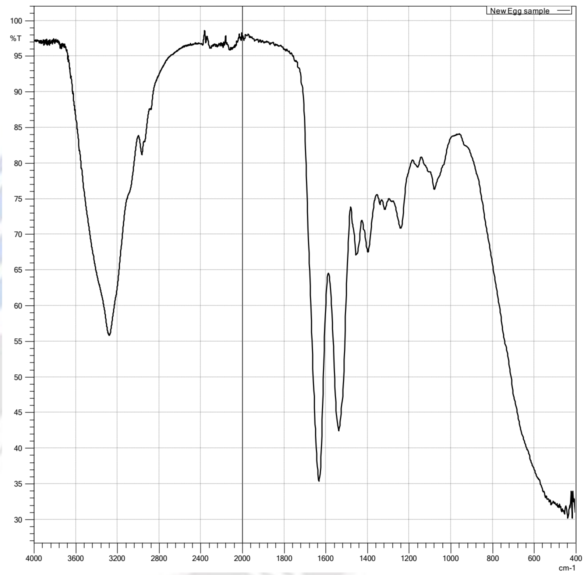


Fig. 4 Spectrum after preprocessing of freshly lay egg

Table 2: Wavelength Vs Intensity(Freshly Lay egg)

No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	588.29	54.98	1.38	921.97	572.86	11572.678	864.376
2	1078.21	74.93	3.2	1101.35	958.62	2858.979	112.7
3	1163.08	76.56	1.1	1180.44	1139.93	925.884	24.304
4	1240.23	65.21	6.76	1276.88	1180.44	2853.399	246.746
5	1315.45	66.88	1.23	1330.88	1292.31	1246.411	20.686
6	1396.46	57.91	6.75	1423.47	1354.03	2620.755	213.901
7	1450.47	56.15	6.57	1477.47	1423.47	2194.342	181.085
8	1537.27	26.99	28.81	1585.49	1477.47	6391.5	1693.866

9	1631.78	18.46	39.63	1832.38	1585.49	8343.965	1378.959
10	2121.7	91.5	0.98	2140.99	2098.55	342.353	21.322
11	2964.59	54.09	7.48	2997.38	2887.44	4440.547	422.361
12	3278.99	14.81	55.35	3711.04	2997.38	43511.132	24382.751

Fig. 5Comparison of Spectrum (Old Egg Vs Freshly Lay Egg)

D. Using destructive and non-destructive testing to measure the characteristics of eggs:

To understand how egg storage affects spectroscopic measures, egg samples were subjected to both invasive and non-invasive testing while being kept at different temperature. By the nineteenth day of storage, the egg albumen had become so thinned that the multi-tester could no longer obtain a valid HU reading. The eggs were vulnerable to injury during opening because the membrane containing the yolk had likewise thinned to a point. This behavior is probably caused by thewater being absorbed by the yolk and the membrane of the egg yolk becoming less resilient.as a result of the pH increase that follows [22]. The age of the egg and the storage temperature have a direct impact on this instability [23].

E. Reference Measurements of Freshness Using Haugh Units:

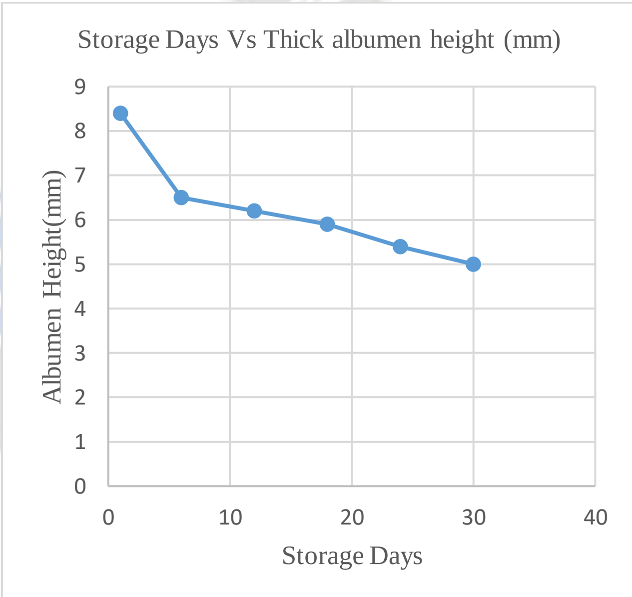
While the Yolk elevation was also measured using a Electronic measuring instrument i.e. digital Vernier calliper in accordance with the approach employed by other authors [20], The Haugh unit (Hu) of the eggs (serving as a benchmark for freshness) was determined using the employed technique (utilizing equation (1)).Ten (10) eggs from each storage group were used to calculate the Haugh unit and York height during the course of the whole storage period, which lasted from day 0 to twenty days (0-22 days of storage period), in order to observe the eggs merit using the HU.

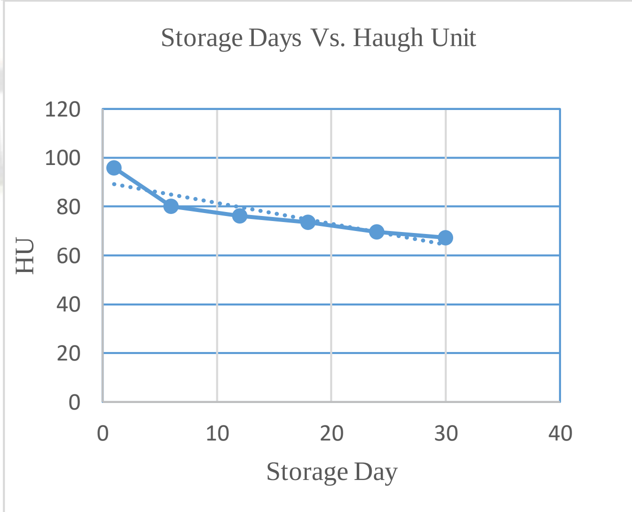
$$HU = 100 \log (h + 7.6 - 1.7w0.37) \qquad (1)$$

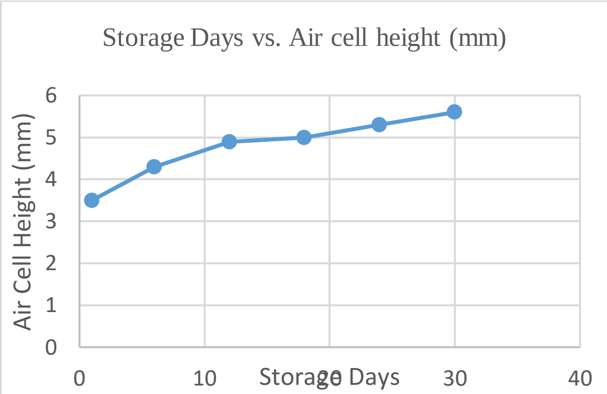
Where,
HU=Haugh unit,
h =Egg white thickness in millimetre.
w=weight of egg in grams..

Table 3: Parameter Calculation using destructive method

Storage (day)	**Thick albumen height (mm**	**HU**	**Air cell height (mm)**	**Yolk Index**
1	8.4	95.9	3.5	19.3
6	6.5	80.1	4.3	18.6
12	6.2	76.2	4.9	18.4
18	5.9	73.5	5	18.3
24	5.4	69.6	5.3	15.9
30	5	67.3	5.6	18.2







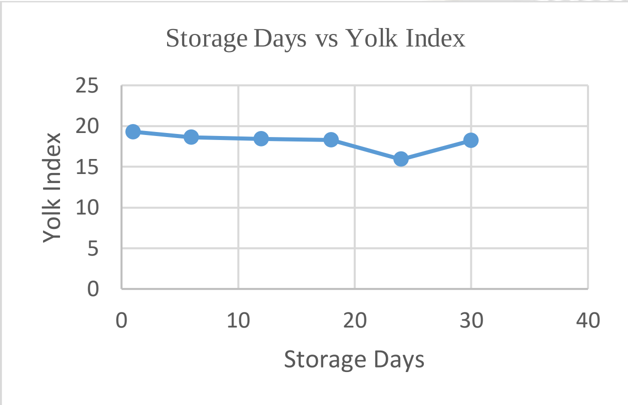


Fig. 6 Results of the analysis of variance of egg quality characteristics.

IV. DISCUSSION

One of the subset of Evolutionary Algorithm i.e GA is a search-based optimization technique based on the principles of Genetics. It's a widely applied method for generating high-quality solutions in optimization and search problems. GA operates by creating a population of individual solutions (chromosomes) and then assessing them based on a specified fitness function. The best solutions are chosen to produce a new generation of solutions, and this iterative process continues until a satisfactory solution is obtained.

The statistical approach of PCA employed to decrease the complexity of a dataset. It achieves this by transforming a group of interconnected variables into a fresh set of independent variables known as principal components. These components are arranged according to the extent of data variance they explain. PCA is often used to simplify complex datasets while preserving the most critical information.

In this research, we've effectively combined the outcomes of both PCA and GA to design an intelligent system for assessing egg quality. The results from spectral analysis and the calculation of destructive parameters contribute to building a model using artificial neural networks (ANN). This approach demonstrates the potential for identifying egg freshness reliably through NIR spectroscopy integrated with GA and ANN.

As part of the future scope of this work, you aim to further validate and establish the credibility of using NIR spectroscopy, GA, and ANN for discerning egg freshness. This could lead to significant advancements in the field of egg quality assessment and may have broader applications in the food industry.

V. CONCLUSION

Upon reviewing prior research regarding the detection of chicken egg freshness, it becomes evident that the integration of spectroscopy and Artificial Intelligence holds significant promise as a viable solution. While this paper does not present the results of the proposed model, our findings strongly suggest that NIR (Near-Infrared Reflectance) spectroscopy in conjunction with AI can effectively address the issue of assessing the duration of storage for farm eggs can be accurately assessed using spectrometric analysis. This method offers a quick and non-invasive means of determining the shelf life of eggs, which is a crucial factor linked to their freshness.

These observations suggest the potential for constructing predictive models using techniques like Partial Least Squares (PLS) and Artificial Neural Networks (ANN) regression, offering a non-destructive means of evaluating shelf life of egg, a vital superiority and purity indicator.

The use of a mobile device-compatible NIR spectroscopy tool is recommended for assessing egg shelf life, although extensive research is required to evaluate the system's extended trustworthiness. At present, combining this approach alongside conventional invasive methods is advisable.

In summary, this study proposes a model for both detecting and classifying chicken egg freshness using spectroscopic data. Spectroscopic data, offering comprehensive chemometric insights, when integrated with destructive sample analysis parameters, holds promise for model development and practical application.

REFERENCES

[1] Kelsey A. Ramírez-Gutiérrez, Alejandro Medina-Santiago, Alfonso Martínez-Cruz, Ignacio Algredo-Badillo, Hayde Peregrina-Barreto "Eggshell deformation detection applying computer vision" [Comp. Electron. Agric. 158 (2019) 133–139] Computers and Electronics in Agriculture, Volume 162, July 2019, Pages 1049

[2] F. Freni, A. Quattrocchi, S. A. Piccolo & R. Montanini (2019): Quantitative evaluation of eggs freshness using flash thermography, Quantitative InfraRed Thermography Journal

[3] BaoGuanjun, Jia Mimi, XunYi, CaiShibo,YangQinghua⁎ Cracked egg recognition based on machine vision Computers and Electronics in Agriculture 158 (2019) 159–166 ELSEVIER 7 January 2019

[4] Samuel M. Yimenu,, J. Y. Kim, and B. S. Kim, Prediction of egg freshness during storage using electronic nose 2017 Poultry Science 96:3733–3746

[5] M. Lordelo, E. Fernandes, R. J. B. Bessa, and S. P. Alves Quality of eggs from different laying hen production systems, from indigenous breeds and specialty eggs 2017 Poultry Science 96:1485–1491

[6] M. Ketta, E. Tůmová Department of Animal Husbandry, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, Prague, Czech Republic Eggshell structure, measurements, and quality-affecting factors in laying hens: a review Czech J. Anim. Sci., 61, 2016 (7): 299–309

[7] KapareAvinash A., MahangareTushar T., PawarNitesh D.,PataneYogeshB.,Patil Sanjay B. Egg Freshness Detection Based On Digital Image Processing JOURNAL OF INFORMATION, KNOWLEDGE AND RESEARCH IN ELECTRONICS AND COMMUNICATION ENGINEERING ISSN: 0975 – 6779| NOV 16 TO OCT 17 | VOLUME – 04, ISSUE – 02

[8] W. F. HOLST, H. J. ALMQUIST, AND F. W. LORENZ Study of Shell Texture of the Hen's Egg September 14, 1931

[9] M. Aboonajmi, A. Akram, T. Nishizu, N. Kondo, S.K. Setarehdan, A. Rajabipour An ultrasound based technique for the determination of poultry egg quality Res. Agr. Eng. Vol. 56, 2010, No. 1: 26–32

[10] Nicolas Abdel- Nour CHICKEN EGG QUALITY ASSESSMENT FROM VISIBLE/NEAR INFRARED OBSERVATIONS A thesis submitted to the Graduate and Postdoctoral Office in partial fulfillment of the requirements for the degree of Master of Science October 2008

[11] V. C. PATEL, R. W. MCCLENDON and J. W. GOODRUM ,Color Computer Vision and Artificial Neural Networks for the Detection of Defects in Poultry Eggs Artificial Intelligence Review 12: 163–176, 1998.

[12] R. Mota-Grajales, J.C. Torres-Peña, J.L. Camas-Anzueto, M. Pérez-Patricio, R. GrajalesCoutiño, F.R. López-Estrada, E.N. Escobar-Gómez, H. Guerra-Crespo, Defect detection in eggshell using a vision system to ensure the incubation in poultry production, Measurement (2018)

[13] Wang Fang ; Wen YouxianDetecting Preserved Eggshell Crack Using Machine Vision2011 International Conference of Information Technology, Computer Engineering and Management Sciences Year: 2011 | Volume: 3 | Conference Paper | Publisher: IEEE

[14] Yang Q H, Jia M M, Xun Y, Bao G J. Detection of egg stains based on local texture feature clustering. Int J Agric&BiolEng, 2018; 11(1): 199–205

[15] Soltani, M., Omid, M., Detection of poultry egg freshness by dielectric spectroscopy and machine learning techniques, LWT - Food Science and Technology (2015)

[16] K.N.Monira, M. Salahuddin and G. Miah,2003. Effect of Breed and Holding Period on Egg Quality Characteristics of Chicken , International Journal of Poultry Science, 2:261-263

[17] DilipKumar Jang Bahadur, L. Lakshmanan,A novel method for optimizing energy consumption in wireless sensor network using genetic algorithm,Microprocessors and Microsystems, Volume 96, 2023, 104749, ISSN 0141-9331, https://doi.org/10.1016/j.micpro.2022.104749.

[18] HasanAkyurek,AylinAgmaOkur Effect of Storage Time, Temperature and Hen Age on Egg Quality in Free-Range Layer Hens October 2009 Journal of Animal and Veterinary Advances 8(10):1953-1958

[19] J. BRAKE, T. J. WALSH, C. E. BENTON, JR., J. N. PETITTE, R. MEIJERHOF and G. PEN ˜ ALVA Egg Handling and Storage 1997 Poultry Science 76:144–151

[20] Jacqueline P. Jacob, Richard D. Miles and F. Ben Mather Egg Quality University of florida IFAS Extension

[21] Juliet R. Roberts Factors Affecting Egg Internal Quality and Egg Shell Quality In Laying Hen Journal of Poultry Science, 41:161-177,2004

[22] D. Siddharth, D. K. J Saini, P. Singh, An Efficient Approach for Edge Detection Technique using Kalman Filter with Artificial Neural Network, International Journal of Engineering, Transactions C: Aspects Vol. 34, No. 12, (2021) 2604-2610

[23] Yadav, P, S. Kumar, and D. K. J.Saini. “A Novel Method of Butterfly Optimization Algorithm for Load Balancing in Cloud Computing”. International Journal on Recent and Innovation Trends in Computing and Communication, vol. 10, no. 8, Aug. 2022, pp. 110-5, doi:10.17762/ijritcc.v10i8.5683

[24] VeselinNachev, ChavdarDamyanov and Tanya Titova WAVELET NEURAL NETWORK FOR NON-DESTRUCTIVE EGG FRESHNESS DETERMINATION Academic Journal of Science, CD-ROM.ISSN:2165-6282::1(2):95–103(2012

[25] JiewenZhao ,HaoLin ,Quansheng Chen ,Xingyi Huang ,Zongbao Sun, FangZhouIdentification of egg’s freshness using NIR and support vector data description Journal of Food Engineering, Volume 98, Issue 4, June 2010, Pages 408-414

[26] Li Sun & Lei-ming Yuan &Jian-rongCai&Hao Lin &Jie-wen Zhao Egg Freshness on-Line Estimation Using Machine Vision and Dynamic Weighing Food Anal. Methods (2015) 8:922–928

[27]Jang Bahadur, D. K., and L.Lakshmanan. “Enhancement of Quality of Service Based on Cross-Layer Approaches in Wireless Sensor Networks”. Journal of Theoretical and Applied Information Technology ISSN: 1992-8645, 15th October 2022. Vol.100. No 19

[28] Dilip Kumar Jang Bahadur Saini, Shailesh D. Kamble, Ravi Shankar, M. Ranjith Kumar, DhirajKapila, Durga Prasad Tripathi, Arunava de,Fractal video compression for IOT-based smart cities applications using motion vector estimation,Measurement: Sensors,2023,100698,ISSN 2665-9174,https://doi.org/10.1016/j.measen.2023.100698

[29] SamanAbdananMehdizadeh ,SaeidMinaei , Nigel H. Hancock , Mohamad Amir KarimiTorshizi An intelligent system for egg quality classification based on visible-infrared transmittance spectroscopy, INFORMATION PROCESSING IN AGRICULTURE 1 (2014) 105–114