

**NOVEL STRATEGY FOR ENHANCING THE SHELF
LIFE STABILITY OF TABLE EGGS UNDER VARIED
STORAGE CONDITIONS**

Thesis

**Submitted to the
DEEMED UNIVERSITY
Indian Veterinary Research Institute
Izatnagar - 243 122 (U.P.), India**



**Dr. Wadajkar Prasad Shivaji
Roll No. M-6399**

**IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF**

**Master of Veterinary Science
(Poultry Science)**

2024



Dedicated to...

*My Beloved Parents
and
Respected Guide*





भा.कृ.अनु.प.-केन्द्रीय पक्षी अनुसंधान संस्थान
इज्जतनगर -243122, (उ.प्र.), भारत



DIVISION OF POST HARVEST TECHNOLOGY
ICAR-CENTRAL AVIAN RESEARCH INSTITUTE
IZATNAGAR - 243 122, U.P., INDIA

Dr. Rokade Jaydip Jaywant

M.V.Sc., Ph.D.
Scientist

Dated: 24/9/2024

Certificate

*Certified that the research work embodied in this thesis entitled "**Novel strategy for enhancing the shelf life stability of table eggs under varied storage conditions**" submitted by Dr. Wadajkar Prasad Shivaji, Roll No. M-6399, for the award of **Master of Veterinary Science degree in Poultry Science** at ICAR-Indian Veterinary Research Institute, Izatnagar, is the original work carried out by the candidate himself under my supervision and guidance.*

*It is further certified that Dr. Wadajkar Prasad Shivaji, Roll No. M-6399 has worked for more than 21 months in this Institute and has put in more than 150 days attendance under me from the date of registration for the degree of **Master of Veterinary Science** of the Deemed University, ICAR-Indian Veterinary Research Institute as required under the relevant ordinance.*

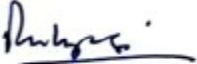
(Rokade Jaydip Jaywant)
Chairman
Advisory Committee

Certificate

We the undersigned members of Advisory Committee of Dr. Wadajkar Prasad Shivaji, Roll No. M-6399, a candidate for the degree of Master of Veterinary Science with the major discipline in Poultry Science, agree that the thesis entitled "Novel strategy for enhancing the shelf life stability of table eggs under varied storage conditions" may be submitted in partial fulfillment of the requirement for the degree.

We have gone through the contents of the thesis and are fully satisfied with the work carried out by the candidate, which is being presented for the award of Master of Veterinary Science degree of this Institute.

It is further certified that the candidate has completed all the prescribed requirements governing the award of Master of Veterinary Science degree of the Deemed University, ICAR-Indian Veterinary Research Institute, Izatnagar.

Signature 
Name Dr. Praveen K Tyagi
External Examiner

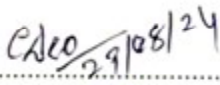

(Rokade Jaydip Jaywant)
Chairman
Advisory Committee

Date : 24/9/24

Date :

MEMBERS OF STUDENT'S ADVISORY COMMITTEE

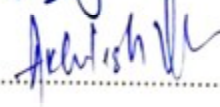
Dr. Chandra Deo, Principal Scientist & Head
Division of Avian Nutrition and Feed Technology, ICAR-CARI, Izatnagar


.....
29/08/24

Dr. Anju Kala, Scientist
Division of Animal Nutrition, ICAR-IVRI, Izatnagar


.....

Dr. Akhilesh Kumar, Scientist (Sr. Scale)
Division of Medicine, ICAR-IVRI, Izatnagar


.....

ACKNOWLEDGEMENTS

First and foremost, I would like to express my love to **Mummy** and **Papa** for giving me the best of everything, for giving strength to reach for the stars and chase my dreams. I would like to thank my dear Sister, **Pooja** for being with me all the time without saying a no for my dreams, your sacrifice and love given me all my achievements. Also, I owe my deep love to my dear Brother-in-Law (Jija), **Vilas** for providing me with unfailing support and continuous encouragement throughout my period of study. This accomplishment would not have been possible without all of you.

I deem it a great pleasure and privilege to have worked under the able and highly exceptional guidance of **Dr. Rokade Jaydip Jaywant**, Scientist and Chairman of Advisory Committee, Division of Poultry Housing and Management, ICAR-CARI, Izatnagar for his constant encouragement, meticulous guidance, transcendent suggestions, scientific cerebration, talented direction and untiring help amidst of his hectic schedule. His polite nature and moral support always boosted my confidence in crossing over many obstacles in my research. I would always be indebted to him for planning and execution of the work, critical appraisal of the manuscript, completion of thesis work in time and care and affection bestowed on me. I feel fortunate and lucky enough to get Jaydip Sir as my mentor for mvsc study.

I am equally grateful to all members of my advisory committee **Dr. Chandra deo**, Pr. Scientist, ICAR- CARI, **Dr. Akhilesh Kumar**, Scientist (SS), ICAR-IVRI and **Dr. Anju Kala Mam**, Scientist (SS), ICAR-IVRI for their timely help and encouragement during my study.

I also extend my sincere thanks to respected **Dr. Gautham, Dr. Monika and Dr. M. Gopi** for his scientific suggestions and guidance also express my sincere thanks to Scientists; **Dr. A. Biswas**, Division of LPT, ICAR-IVRI for valuable contribution to complete my lab work within time. I also extend my sincere thanks to the **Sky**, Division of Post Harvest Technology, ICAR- CARI, **Vivek Shrivastav**, Senior Research Fellow, Division of Post Harvest Technology, ICAR- CARI, for supporting me during my lab analysis. I wish to thank all the faculty of CARI and IVRI for enlightening me through teaching the subject during these days.

I am always indebted to **Dr. Nagesh and Dr. Deepak** for always being there with my ups and downs during my Journey in IVRI. With the feelings come from the deep core of heart,

words are helpless to mean. I also appreciate his help in my statistical analysis. I can hardly find any suitable word for my friends **Dr. Sumedh, Dr. Shalini, Dr. Karan, Dr. Rinkal, Dr. Ashutosh, Dr. Nilay, Dr. Shubham, Dr. Sandesh** for being there for me in each and every moment.

This endeavor would not have been possible without my beloved **Dr. Monika ma'am**, whose care and love during my hard times reminds me of my sister. I extend my deep affection to her, who stood with me even though the time was hard for her too. I cherish the memories with my people **Sumedh and Shalini**, that made me strong enough to smile when I was at the weakest.

Thanks to my dear senior **Dr. Sanjay Kolagire, Dr. Vaidehi Chandurkar, Dr. Babasaheb Khetri, Dr. Rishab Parve, Dr. Manoj Donadkar and Dr. Akash Mot** for their intense help and care my entire research work, I really learned a lot from you all.

With immense pleasure, I express my sincere thanks to my colleagues, **Dr. Nilay, Dr. Sagar, Dr. Pradeep, Dr. Lokesh, Dr. Shiva, Dr. Priyanka Parte and Dr. Priyanka Sharma**, you have all been great friends molding me into a better individual, supporting and helping me my academic and personal journey.

I would like to thank my divisional seniors, **Dr. Shriram, Dr. Manoj, Dr. Rajan, Dr. Mukesh, Dr. Abhijeet, Dr. Sruthi, Dr. Kanmoni, Dr. Munir, Dr. Hudson** and my favorite juniors, **Dr. Aditya, Dr. Rishikesh, Dr. Prashant, Dr. Sachin, Dr. Surya, Dr. Martina** for helping as and when required during the periods of course work and research.

I owe my deep special respect to all CARI People, **Parvinder Bhaiya, Karan Bhaiya, Rambabu Bhaiya, Seema ji, Sanjiv Bhaiya, Swale, chen Bhaiya, Neha Ji and Nazir bhaiya** who all stood with me throughout my experiment period.

I also extend my sincere thanks to all **members of Maha mess-IVRI** for their kindness, valuable support and for beautiful memories at IVRI, I am grateful Mess **staff Mr. Sundar, Mr. Shubham, Mr. Bharat** for providing nice food.

I am forever indebted to **Dr. B. Narladkar sir**, my teacher who pushed me forward to do PG and Chase my dreams.

I am always thankful to my people **Mahi, Rahi, Manik, Maroti, Sourabh, Chandrakant, Ajay, Aji** for their love, affection and emotional support throughout this journey.

I owe my thanks to **Chachu (Mr. Dharmendra)** for their help in presenting this manuscript nicely

Finally, I would like to extend my thanks to those who have played their parts directly or indirectly in my research work. All might not have mentioned but none is forgotten.

A handwritten signature in black ink, appearing to be 'Wadajkar Prasad', with the date '18/9/24' written below it.

(Wadajkar Prasad)

Date: 18/9/24

Place: ICAR-IVRI, Izatnagar

ABBREVIATIONS

\$:	United State Doller
%	:	Percentage
°C	:	Degree Celsius
µl	:	microliter
µm	:	micrometre
AI	:	Albumin Index
AL	:	Albumin
AMS	:	Agriculture Marketing Service
ANOVA	:	Analysis of Variance
BAHS	:	Basic Animal Husbandry Statistics
BIS	:	Bureau of Indian Standards
CARI	:	Central Avian Research Institute
CFU/mL	:	Colony Forming Units/millilitre
CIPHET	:	Central Institute of Post Harvest Engineering & Technology
cm	:	Centimetre
CO ₂	:	Carbon dioxide
<i>E. Coli</i>	:	<i>Escherichia coli</i>
EMB	:	Eosin Methylene Blue
Et al.	:	Et alia
EW	:	Egg Weight
FAO	:	Food and Agriculture Organization of the United Nations
Fig.	:	Figure
g	:	Gram
G	:	Gravitational Constant
GRAS	:	Refers to a designation granted by regulatory authorities in the United States, certifying that a specific substance or ingredient is generally recognized as safe for human consumption.
H	:	Height
hrs.	:	Hours
HU	:	Haugh Unit
i.e.	:	That is
ICAR	:	Indian Council of Agricultural Research
ICMSF	:	International Commission on Microbiological Specifications for Foods

mg	:	Milligram
ml	:	milliliter
mm	:	millimeter
mPa.s	:	Millipascal-seconds
NABCONS	:	National Bank for Agriculture and Rural Development Consultancy Services Private Limited
ND	:	Not Determined
No.	:	Number
PBS	:	Phosphate Buffered Saline
PCA	:	Plate Count Agar
pH	:	Power of Hydrogen
PHL	:	Post Harvest Loss
RPC	:	Rice Protein Concentrate
SE	:	Standard Error
SEM	:	Scanning electron microscope
SG	:	Specific Gravity
SPSS	:	Statistical Package for the Social Sciences
T	:	Treatment
TPC	:	Total Plate Count
U	:	Unit
UE	:	Unwashed Eggs
USD	:	United State Doller
USDA	:	United States Department of Agriculture
W	:	Weight of Egg
WE	:	Washed Eggs
wk.	:	Week
YI	:	Yolk Index

LIST OF TABLES

Table No.	Title	On/After Page No.
Table 4.1:	Effect of Transportation on weight of an egg over the storage time period	41
Table 4.2:	Effect of Transportation in percentage of egg weight loss over the storage time period	41
Table 4.3:	Effect of Transportation on the air cell diameter over the storage time period	43
Table 4.4:	Effect of Transportation on specific gravity of an egg over the storage time period	43
Table 4.5:	Effect of Transportation on shape index of an egg over the storage time period	43
Table 4.6:	Effect of Transportation on surface area of egg over the storage time period	43
Table 4.7:	Effect of Transportation on Haugh unit value over the storage time period	45
Table 4.8:	Effect of Transportation on albumin index value over the storage time period	45
Table 4.9:	Effect of Transportation on yolk index quality over the storage time period	47
Table 4.10:	Effect of Transportation on albumin weight (%) over the storage time period	47
Table 4.11:	Effect of Transportation on yolk weight (%) over the storage time period	47
Table 4.12:	Effect of Transportation on yolk color over the storage time period	47
Table 4.13:	Effect of Transportation in thickness of shell over the storage time period	49

Table No.	Title	On/After Page No.
Table 4.14:	Effect of Transportation on the pH of an egg over the storage time period	49
Table 4.15:	Effect of Transportation on the albumin pH over the storage time period	51
Table 4.16:	Effect of Transportation on the yolk pH over the storage time period	51
Table 4.17:	Effect of cold storage on weight of an egg over the storage time period	53
Table 4.18:	Effect of cold storage in percentage of egg weight loss over the storage time period	53
Table 4.19:	Effect of cold storage on the air cell diameter over the storage time period	55
Table 4.20:	Effect of cold storage on specific gravity of an egg over the storage time period	55
Table 4.21:	Effect of cold storage on shape index of an egg over the storage time period	55
Table 4.22:	Effect of cold storage on surface area of egg over the storage time period	55
Table 4.23:	Effect of cold storage on Haugh unit value over the storage time period	57
Table 4.24:	Effect of cold storage on albumin index value over the storage time period	57
Table 4.25:	Effect of cold storage on yolk index quality over the storage time period	57
Table 4.26:	Effect of cold storage on albumin weight (%) over the storage time period	57
Table 4.27:	Effect of cold storage on yolk weight (%) over the storage time period	59

Table No.	Title	On/After Page No.
Table 4.28:	Effect of cold storage on yolk color over the storage time period	59
Table 4.29:	Effect of cold storage in thickness of shell over the storage time period	59
Table 4.30:	Effect of cold storage on the pH of an egg over the storage time period	59
Table 4.31:	Effect of cold storage on the albumin pH over the storage time period	61
Table 4.32:	Effect of cold storage on the yolk pH over the storage time period	61

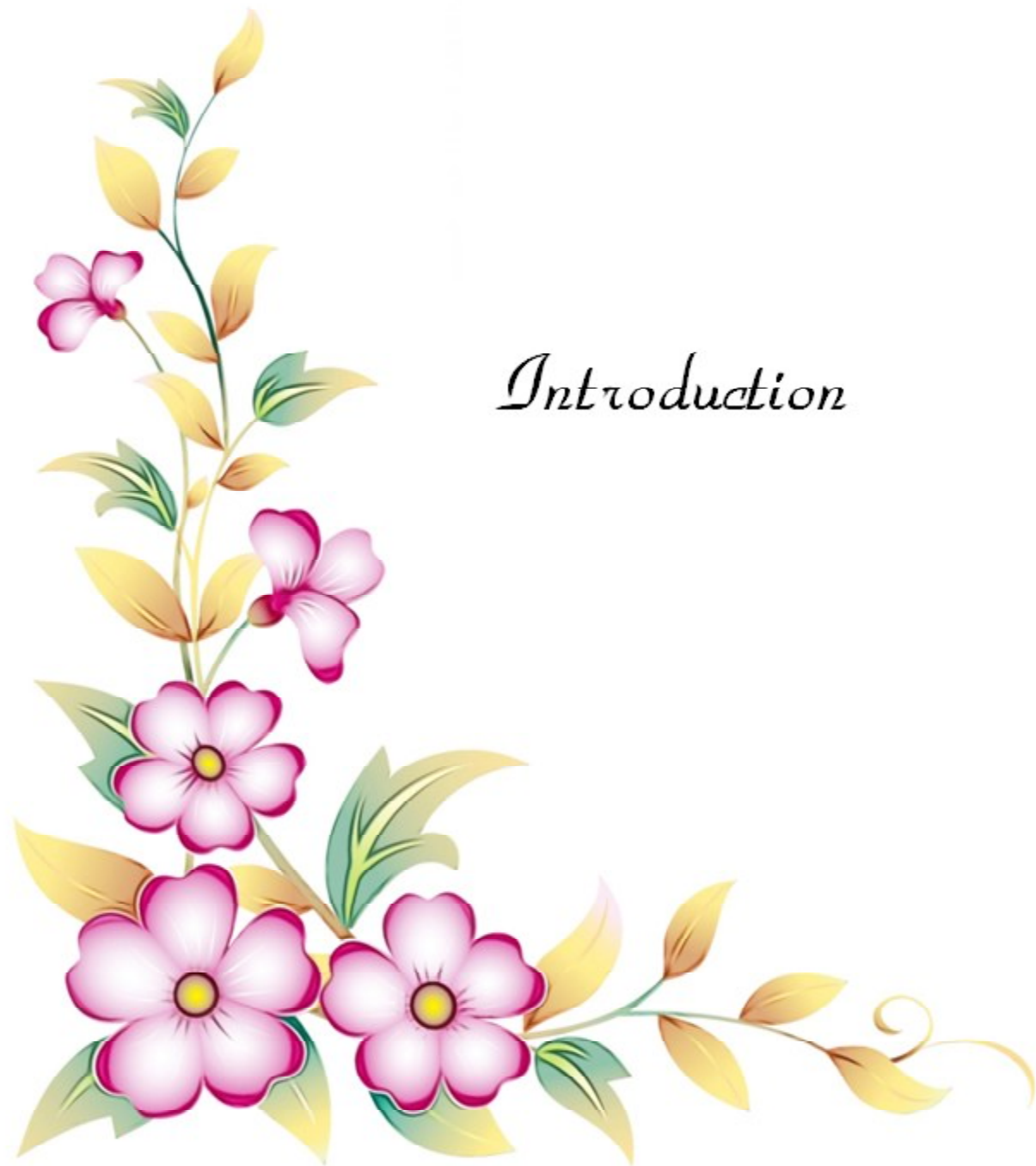
LIST OF FIGURES

Figure No.	Title	On/After Page No.
Fig. 1:	Fresh farm collected Eggs	29
Fig. 2:	Preparation of Eggs spraying Herbal Spray (CARI EGG Shield)	29
Fig. 3:	Eggs sprayed with the Herbal Spray (CARI EGG Shield)	29
Fig. 4:	Vehicle used for transportation of eggs	29
Fig. 5:	Eggs stored in cold storage room	31
Fig. 6:	Length and Width of Egg	33
Fig. 7:	Weight of an Egg in water	35
Fig. 8:	Broken eggs on Egg Analyzing Platform to perform the Internal Quality Assessment	35
Fig. 9:	Albumin quality assessment of an egg	37
Fig. 10:	Separation of Yolk and Albumin	37
Fig. 11:	Weighing of Separated Albumin	37
Fig. 12:	Yolk quality assessment of an egg	37
Fig. 13:	Weighing of Separated Yolk	37
Fig. 14:	Loss of egg weight % due to transportation and storage	45
Fig. 15:	Increase in air cell due to transportation and storage	45
Fig. 16:	Haugh Unit value after transportation and storage	45
Fig. 17:	Egg pH after the transportation and storage	51
Fig. 18:	Albumen pH after the transportation and storage	51
Fig. 19:	Yolk pH after the transportation and storage	51
Fig. 20:	Results of Total Plate Counts of transported eggs	51
Fig. 21:	Results of <i>E. Coli</i> of transported eggs	51

Figure No.	Title	On/After Page No.
Fig. 22:	Loss of egg weight % after one month of cold stored eggs	55
Fig. 23:	Increase in air cell after one month of cold stored eggs	55
Fig. 24:	Haugh Unit value after one month of cold stored eggs	55
Fig. 25:	Egg pH after one month of cold stored eggs	61
Fig. 26:	Albumen pH after one month of cold stored eggs	61
Fig. 27:	Yolk pH after one month of cold stored eggs	61
Fig. 28:	Results of Total Plate Counts of cold stored eggs	61
Fig. 29:	Results of <i>E. Coli</i> of cold stored eggs	61

CONTENTS

Sl. No.	CHAPTER	PAGE NO.
1.	INTRODUCTION	01-03
2.	REVIEW OF LITERATURE	04-27
3.	MATERIALS AND METHODS	28-39
4.	RESULTS	40-62
5.	DISCUSSION	63-75
6.	SUMMARY AND CONCLUSIONS	76-82
7.	MINIABSTRACT	83
8.	HINDIABSTRACT	84
9.	REFERENCES	85-105



Introduction

In the intricate fabric of India's socio-economic landscape, a scientific exploration uncovers a range of factors that intricately shape its trajectory and influence on a global scale. Acknowledged as the 5th largest economy in nominal GDP by the International Monetary Fund, the nation's economic ability forms a foundational pillar for its multifaceted role. Simultaneously, holding the distinction of being the 4th largest military power underscores its strategic significance in international affairs. As it aspires to ascend to the 3rd largest economy by 2030, according to projections by the International Monetary Fund, the nation stands at the forefront of economic evolution, positioning itself as a key player in shaping the global economic landscape.

India is a global agricultural powerhouse. It is the world's largest producer of milk, pulses, and spices, and has the world's largest cattle herd (buffaloes), as well as the largest area under wheat, rice and cotton. It is the second largest producer of rice, wheat, cotton, sugarcane, farmed fish, sheep & goat meat, fruit, vegetables and tea. With the nation claiming the 3rd largest position in egg productions and 5th in meat Production (World Bank Group). The Silver Revolution was significant development in Indian agriculture and contributed significantly to its expansion. Over the next 40 years, the nation is tasked with the unprecedented challenge of producing agricultural food as though the next 8000 years depend on it. Livestock plays an important role, contributing 30% of Agricultural GDP and 5.3% of total Gross Value Added (GVA). The agricultural sector, encompassing agriculture and allied activities, constitutes 18.2% of total GVA. Noteworthy is the growth rates of 6.19% in egg production, elevating

the nation's rank to 8th in poultry meat production. Poultry, a significant component, contributes 51.5% to overall meat production in India (FAO, 2022).

Even with these achievements, problems still exist. In various climates, there are risks associated with transporting eggs from key egg production centres like Andhra Pradesh (AP), Telangana (TL), and Tamilnadu (TN) to other regions. Inadequate infrastructures such as roads and packaging, together with effects of climate change, cause post-harvest egg qualities to decrease. The Indian poultry sector is valued at \$28.18 billion in 2022 and is expected to reach approximately \$44.97 billion by 2028, at a CAGR of 8.1% (BAHS, 2023).

But poultry's business is losing money as a result of post-harvest egg loss. In India, there are more than 3,500 crore and 7.19 percent. Among the difficulties include irregular egg production and inadequate state transportation, that results in loss and contamination in transit. The percentages of the post-harvest losses vary from 10 - 25 percent, which affects the price and calibre of chicken products and raises concerns about the health of humans. Some of the actions done to address these challenges include building infrastructure for the storage and transportation of the eggs, raising farmer awareness, and doing research on improving post-harvest insurance in different climates. When India's crops are large, the focus must turn to product qualities and PHL (postharvest losses) to meet the needs of the growing population and generate export business (Gulati *et al.*, 2024).

Understanding science, technology and research can contribute to innovation that leads to longevity and productivity. Make everything fresher, tastier. This study focuses on designing strategies to reduce post-harvest losses along the farm-to-table value chain. Emphasis will be placed on egg storage, transportation, qualities, and shelf-life validation. Research will also explore microbial pathogens in the eggs while stored for a long period, identifying technologies to increase shelf life without compromising qualities. The project's goal is to develop a transportable Phyto biotic spray for eggs that will lengthen their shelf life and promote ecologically friendly poultry husbandry. Having agencies such as FSSAI and BIS oversee compliance will increase the effectiveness of these initiatives.

Objective

- 1. To evaluate the efficacy of herbal-based egg spray in transported eggs for reducing microbial spoilage and improving shelf life at different storage temperature.**
- 2. To study the effect of herbal-based egg spray on cold stored eggs for improving shelf life.**



*Review
of
Literature*



2.1 Understanding Post-Harvest Loss (PHL) in Poultry: Key Concepts and Implications

According to Kader (2002), postharvest loss is characterized by the weakening in both amount and the quality of nourishment generation from point of gather to utilization. Quality losses relate to modifications in nutrient/caloric composition, worthiness, and edibility of an item, especially predominant in created nations. These natural losses include inside and outside biochemical changes that affect colour, flavour, wholesome quality, and calorific esteem without a critical alter in weight or volume.

In differentiate, quantitative loss, being very serious in nature, comes about in a decay within the esteem inside of a supply chain due to lacking post-harvest administration hones. Variables contributing to this sort of loss incorporate dampness loss, physical harm, deterioration, decaying, senescence, and bacterial/fungal diseases, as sketched out (Kader, 2002). This comprehensive definition highlights the multifaceted nature of postharvest losses, including both subjective and quantitative dimensions.

Postharvest losses along the nourishment chain make agriculturists lose salaries and irritate nourishment frailty and destitution (Robinson and Kolavelli *et al.*,2010). The losses are essentially classified into two: corruption in both amount and the qualities of nourishment (Kiaya *et al.*,2014). Agreeing to Kitinoja and Gorny (1999), in creating nations, amount losses are more common than quality losses. Thinks about have too uncovered that different components

impact postharvest losses. For case, Weir and Knight (2000) and Mutanyagwa, Isinika, and Kaliba (2018) detailed that instruction impacts farmer's postharvest losses. Babalola (2010), on another side of it, uncovered a relationship between farmers cultivate estimate and their postharvest losses. Advance, other ponders uncovered that the nature of street features a coordinate connection with the sort of transport framework utilized by agriculturists and dealers, which, in turn, impacts their postharvest losses (Kader *et al.*, 2005). For occasion, smallholder makers who cannot bear trucks with cooling offices resort to taxis (Ortmann and Ruler *et al.*, 2010) or open enormous trucks uncovered to the searing sun for an expanded period, expanding the disintegration of commodities. Studies by Thompson (2003), Watson (2016), Komarnicki (2016), Barska and Wyrwa (2016) uncovered that the sort and nature of bundling fabric exceedingly impact postharvest losses of items. Moreover, the mechanical stacking of create can leads to splits or bruises (Ahmadi *et al.* 2012; Komarnicki *et al.* 2016).

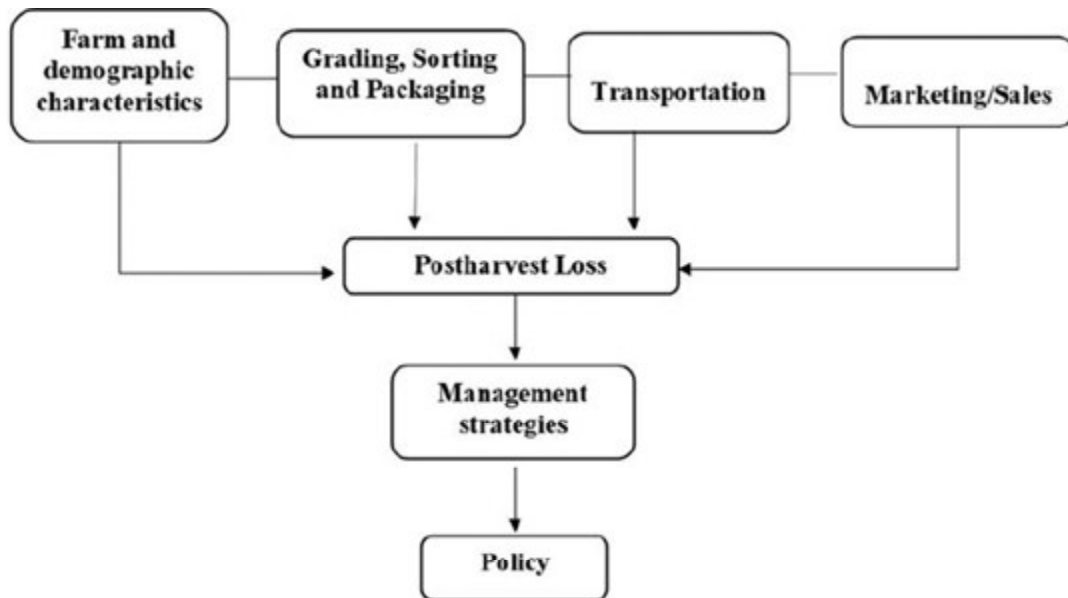


Fig.2.1: Understanding of Post harvest loss

The conceptual system in Figure 1 was outlined based on writing audit on the postharvest losses of rural commodities (Kader *et al.* 2005; Mutanyagwa, Isinika, and Kaliba *et al.* 2018; Weir and Knight *et al.* 2000) and more particularly on eggs (Lat and Reyes *et al.* 2017). From Figure 1, the cultivate and statistic characteristics such as sexual orientation, cultivate measure, instruction, involvement, FBO support, nature of the street and the sort of transport

utilized were hypothesized to impact the exercises and stages of postharvest losses in egg generation. Moreover, the different postharvest exercises included in egg generation are reviewing, sorting and bundling of eggs. Other stages included are the transportation of the eggs, promoting and the deals of egg created. Postharvest losses do happen in all of these stages or exercises along the egg value-chain prepare. Diverse techniques will be required in overseeing the causes of egg postharvest losses. These procedures might be upgraded into approaches to oversee and decrease the postharvest losses experienced by ranchers and marketers inside the egg esteem chain.

The Service of Nourishment Preparing Businesses (MOFPI, 2022) considers losses amid gathering and ensuing stages as post-harvest losses. Emphasizes the tall perishability of eggs along with eggs products items, focusing the quick degrading without an exclusive cold chain. Eggs are regarded unusable indeed with minor absconds, posturing a potential chance for hurtful microbiological action and wellbeing costs (Panda, 1989).

Several considers, counting those by FAO (2011) and Kumar (2017), have pointed to comprehend the variables contributing to post-harvest losses and define procedures to moderate their effect on nourishment frameworks, with the potential to lighten hunger. Karwowska (2021) give a definition of post-harvest losses in poultry, characterizing them as happening from cultivate to fork and traversing stages such as preparing, transportation, and capacity until coming to the shopper. These losses have a critical effect on the productivity, benefit and supportability of poultry sector. Viably tending to such losses requires a comprehensive approach, joining progressed preparing strategies, upgraded transportation frameworks, updated capacity offices, strong quality control along its measures and expanded mindfulness among partners with respect to minimizing losses at each organize of poultry supply chain, as highlighted (Onwude *et al.* 2020).

2.1.1 Economics of the Post Harvest Loss Towards the Poultry

Poultry post-harvest losses, as characterized by Jha (2015), envelop financial losses caused amid the dealing with, transportation, and capacity of poultry items, particularly eggs and meat. These losses transcendently emerge from variables such as deterioration, defilement, and dishonourable dealing with practices.

As per ICAR-CIPHET Consider (2015) appears that postharvest loss of egg sector is around 7.19 % and the according to the study of NABCONS in 2022 underscores the considerable financial impacts of post-harvest losses inside poultry egg sector is 6.09 %. These losses not as it were reducing benefit for ranchers but moreover contribute to expanded costs for buyers, went with by the wastage of important assets all through supply chain of poultry.

Several thinks about, counting one by Pradhan (2018), emphasize the noteworthy size of post-harvest losses in the poultry segment. Gauges recommend that losses in broiler bird's meat can shift from 05% to the 20%, unexpected upon capacity and transportation conditions. Essentially, field ponders, like by Jayathilakan (2012), report egg generation losses extending from the 10% to 15%. These discoveries emphasize the horror of addressing post-harvest losses within poultry sector to upgrade financial maintainability and asset utilization efficiency.

As per Spang (2019), the financial effects of post-harvest losses amplify past the coordinate costs of ruined items, enveloping costs related to environmental pollution, transfer and the misusing of assets contributed within the generation handle. Furthermore, these losses can result in a reduced accessibility of poultry items within the showcase. Successfully tending to these multifaceted issues requires to collaborative exertion including agriculturists, policymakers and processors to actualize procedures that diminishes the wastage along with the improve the in general proficiency of supply chain of the poultry.

Potential solutions for reducing post-harvest losses are provided by Alakali (2019). These include the use of advanced conservation advances, improvements in transportation offices, and the selection of appropriate care and capacity enhancers according to NABCONS-2022, poultry meat, drain, marine angle, and inland angle account for about 67.69% of the total loss in animals created, or 1,52,790.42 crores. Eminently, poultry eggs and meat, owing to their tall perishability, contribute to 21.70% of animals deliver losses, comparable to 2.35% of national GDP for the primary quarter of year 2022-23. Particularly, the poultry meat sector encounters a generally post-The need for thorough research to improve effectiveness and

maintainability within the Indian broiler industry is highlighted by the notable lack of a thorough study examining the extent of these losses, the factors influencing them, and effective techniques for minimizing such losses. harvest loss of 5.63%. These figures emphasize the critical financial effect of post-harvest losses within poultry sector, justifying intensive endeavours to play down such losses and reinforce the sector's sustainability. According to a 2011 report by Nourishment and Agribusiness Organization (FAO) centring on worldwide nourishment losses in Europe, counting Russia, losses were assessed at different stages. Roughly 5% of losses happened amid preparing and bundling and an extra 4% amid dispersion. These losses were particularly related with meat, counting poultry meat. Within the setting of Indian broiler sector, emphasize the potential for considerable financial losses ascribed to live shrivel amid transportation and the holding (Prakash and Prabakaran *et al.*, 2020). In spite the of sector's significant esteem, there has been a striking nonappearance of a comprehensive consider surveying degree of these losses, the components affecting them, and successful methodologies for minimizing such losses. This underscores the require for in-depth inquire about to upgrade effectiveness and maintainability inside the Indian broiler sector.

2.1.2 Post-Harvest Loss of the Eggs

The matter of postharvest losses in poultry, with a specific centre on eggs, speaks to an outstanding concern, with inquire about in this space being generally restricted compared to closely resembling thinks about in crops. (Kumar *et al.*, 2017) clarify that these losses stem from a combination of coordinate physical losses and diminishments in quality, subsequently reducing the financial esteem of egg items. Beneath extraordinary conditions, such as inappropriate taking care of or capacity, the potential exists up to 80% loss of the full egg yield. This underscores the criticalness of tending to postharvest losses into the poultry sector, emphasizing the require for comprehensive investigate and successful moderation techniques to upgrade financial supportability and minimize squander. (Fox *et al.*, 2013).

In order to ensure food security, postharvest losses must be minimized. This is particularly important in developing countries, where losses can sometimes exceed 50% as a result of inefficient innovation, a lack of expertise in handling crops, and the requirement for calculated

returns (Adarkwa *et al.*, 2011). Post-harvest losses for eggs at the national level were reported in a ponder (ICAR-CIPHET 2015) as 7.19 percent, although this figure appears to have decreased to 6.09 percent in the NABCON-2022 report. Long showcase outlets were found to contribute to higher losses compared to brief ones. In a comprehensive ponder on post-harvest losses inside the egg supply chain in India, (Hegazy *et al.*, 2016) assessed the losses to extend from ten to twenty five percent. The financial repercussions of these losses amplify past the coordinate costs of spoiled products, enveloping costs related to transfer, natural contamination and the wastage of assets contributed within the generation prepare, as sketched out (Spang *et al.*, 2019). Successfully tending to and relieving these losses is basic for guaranteeing the in general productivity and supportability of poultry sector.

Since chicken eggs contain 96% natural protein and other nutrients, they have been used for a long time. While lacking in vitamin C and low in calcium, chicken eggs are a great source of vitamin D. Seventy-five percent of an egg is water. While making up only one-third of the edible portion, yolk provides 78% of the calories, almost all of the calcium, phosphorous, zinc, press, vitamin B6, B12, A, folic acid, and thiamine, as well as almost half of the protein and riboflavin of the whole egg (Réhault-Godbert S *et al.*, 2019). Yolk of the egg is bound with the vitelline film in circular shape. Egg whites add up to strong substance ranges from 11-13% (P.V. Sreenivasaiah, 2006). Egg whites is within the four layers external lean white, external thick white, inward lean white, chalaziferous layer 23.2%, 57.3%, 16.8%, 2.7% separately. pH of freshly laid eggs whites is almost 7.6-8.5 and yolk is 6.0, but this esteem may increment to 9.0 and 6.4-6.8 amid capacity separately. Eggs contain a few cancer prevention agents which decrease free radicals emerging from cellular digestion system. Positive affiliations between oxidative stretch and the frequency of persistent maladies, such as cancers and heart infections, have been detailed (Rao and Rao *et al.*, 2007).

Turning over to the composition and structure of eggs, their distinctive strategy protects both the developing foetus and the quality and freshness of the egg. The different components, counting the eggshell, external and inward shell layers, egg albumen and yolk, each satisfy particular parts in this respect. Eggs stand out as healthfully thick, advertising basic amino acids, proteins, vitamins (A, D, B12, choline) and minerals (press, zinc, selenium), rendering

them a profitable and flexible choice within the domain of dietary options. The exchange between egg capacity term and temperature is of foremost significance within the upkeep of the egg quality. Drawn out storage at surrounding temperatures postures the chance of lessening freshness, supplement substance, and overall quality, though refrigeration serves as relieving calculate, impeding weakening. Ideal capacity conditions, including both term and temperature, play a significant part in the maintaining security measures and quality of the eggs for buyers. Logical examinations emphasize the noteworthy effect of capacity length and the temperature on the egg quality. Refrigeration develops as a prescribed improve to maintain inner egg qualities, with a recommended greatest capacity term of 30 days, whereas room temperature capacity ought to be constrained to 15 days. Different components, counting temperature, egg age, mugginess, taking care of eggs and capacity conditions, collectively contribute to complex flow affecting inner egg quality. Proactive thought and administration of these components are basic to reduce postharvest losses and guarantee the persevering freshness and security of the eggs for observing customers (smith *et al.*, 2023).

2.1.3 Effect of Transportation on Egg

The oscillations resulting from transportation are impacted by factors such as road surface conditions, distance, travel speed, load, and specific truck attributes, including suspension and axle count (Singh *et al.*, 1991; Pierce *et al.*, 1992). The influence of transportation on agricultural products is contingent upon the type of packaging employed (Shulte Pason *et al.*, 1990). In previous studies, Panda *et al.*, (1973) observed a notable 16% decline in Haugh units for eggs subjected to journey hazard tests and packaged in wooden boxes compared to control eggs. Additionally, Adam and Skinner (1963) noted a maximum 10% difference in Haugh units among eggs positioned differently during a 1900 km refrigerated transport, with a peak decrease of 18%. Transport-related stresses may affect the physical characteristics of the vitelline membrane–yolk system. Notably, there were no significant disparities in air cell height (Berardinelli *et al.*, 2003). Jarring due to uneven road surfaces or potholes has the potential to augment cracked eggs while also leading to the detachment of the air cell membrane from the shell membrane (Knox and Olsen 1936). Roland (1988) estimated cracked egg percentages in Grade A cartons at the destination (retail store) to range from 5 to 7%. During

distribution, packages within a shipment are subject to varying handling conditions, influenced by truck suspension systems, traffic density, road conditions, package location on the truck, and atmospheric conditions (Nethercote *et al.*, 1974). A substantial portion (over 55.00%) of egg breakage occurs at the bottom, particularly in the absence of cushioning in cartons packaged in plastic crates, resulting in cracks predominantly on the top or bottom of the shell. This aligns with the findings of Denton *et al.*, (1981), where 56.28% of broken eggs had damage on the bottom, corroborating the present study.

The vibrations due to transportation are influenced by road roughness, distance, and travelling speed, load, some characteristics of the truck such as the suspension and the number of axles (Singh *et al.*, 1991; Pierce *et al.*, 1992), the effects of the transportation on agricultural products depend on the type of packaging (Shulte Pason *et al.*, 1990) some types of packaging, such as bulk bins, can remarkably amplify vibrations during transportation from the bottom to the top of the shipment column (O'Brien *et al.*, 1965; O'Brien & Guillou *et al.*, 1969). The present research reviews the effects of transport vibrations on the parameters describing the egg quality: Haugh unit, vitelline membrane strength and air cell height (A. Berardinelli; V. Donati *et al.*, 2003).

In simulated tests, the highest breakage rates were observed after 75 and 180 minutes, accounting for 40.70% and 43.02%, respectively. Notably, there was no significant difference in breakage rates for eggshells packed in corrugated boxes based on exposure time. However, Expanded Polystyrene (EPS) cartons packed in plastic crates exhibited less breakage at 15 minutes compared to after 75 and 180 minutes (Seydim and Dawson, 1999). Romanoff and Romanoff (1949) proposed that water diffusion from albumen into the yolk during egg incubation results in yolk swelling, causing stretching and weakening of the vitelline membrane. This weakening could be due to the loss of a membrane layer or digestion by a tryptic protease in the albumen. Keener (2006) demonstrated that the Vitelline Membrane Strength of the yolk, evaluated based on its breaking strength, is contingent upon storage time and conditions.

Ensuring shell strength is imperative to prevent damage during handling and preserve eggs during transport from farm to market. The design of egg production, processing, and

packaging systems must account for the physical properties of eggs and their resistance to damage from mechanical shock (Altuntas and Sekeroglu *et al.*, 2010). For effective preservation during transport, eggshells must possess sufficient strength to prevent cracking (Altuntas and Sekeroglu *et al.*, 2008). Factors such as egg shape index and shell thickness influence the proportion of damaged eggs during handling and transport (Anderson *et al.*, 2004). Furthermore, the USDA (1938) highlights that a larger air cell results in weaker egg contents, facilitating deterioration. This observation suggests that air cell size can serve as a tool for detecting egg freshness. BIS 2023 guidelines recommend storing eggs at temperatures between 0-7°C for a period of three months with a relative humidity of 75 to 80 percent.

2.2 Cold Storage of Egg along with Coating

Washed and unwashed eggs were subjected to storage under six different scenarios, and both types of eggs were stored at temperatures up to 35°C to evaluate the sell-by-date. Despite temperature fluctuations or continuous storage at 30°C for 5 days, subsequent storage at 10°C resulted in significantly higher Haugh unit and yolk index on day 15. These results indicate that refrigerating eggs from retail sales until consumption is effective for egg quality management, despite the exposure of up to 35°C during distribution. In terms of sell-by-date evaluation, washed eggs retained class B quality for an additional 37 days beyond the recommended sell-by-date at 15°C, which is above the regulated storage temperature. However, unwashed eggs-maintained class B quality for approximately 20 days at 30°C–35°C, emphasizing the need for sell-by-date guidelines for unwashed eggs (Ji-hoon *et al.*, 2023). Consumers in South Korea typically acquire eggs stored under refrigeration conditions, in contrast to consumers in India (100%) and Thailand (36%) who predominantly purchase eggs stored at ambient temperature. After acquisition, a substantial majority of consumers in South Korea (89%), Thailand (74%), and India (80%) opt to store their eggs within a refrigerated environment (Koppel *et al.*, 2014). Given the prevailing average annual temperatures in these regions, maintaining eggs at room temperature would significantly impact the overall shelf life of the eggs (Koppel *et al.*, 2016). Various coating materials, including chitosan, proteins, and oils such as mineral oil, have been investigated for their efficacy in preserving the internal quality of eggs (No *et al.*, 2005; Kim *et al.*, 2006, 2009; Caner and Cansiz *et al.*, 2008).

Mineral oil has been identified as a highly effective sealant for eggshells and is currently employed in coating commercial table eggs (Stadelman, 1995). Earlier studies (Stadelman & Wilson, 1958; Kamel *et al.*, 1980) demonstrated superior quality in eggs coated with mineral oil compared to non-coated eggs. However, limited information is available regarding the impact of long-term storage, especially under refrigerated conditions, on the internal quality of eggs coated with mineral oil, except for the study by Biladeau & Keener (2009). Our research group (Waimaleongora-Ek *et al.*, 2009) conducted a study on the quality and shelf-life of eggs coated with mineral oil exhibiting six different viscosities and stored at 25°C for 5 weeks. The findings revealed that the mineral oil coating with a viscosity of 26 mPa.s significantly reduced weight loss in eggs by more than tenfold (approximately 0.85% for coated eggs compared to 8.78% for non-coated eggs) and extended the shelf life of chicken eggs by at least 3 weeks compared to non-coated eggs, i.e., a shelf life of 5 weeks compared with 2 weeks, respectively.

Refrigerated storage at 4°C significantly minimized the weight loss of both coated and noncoated eggs. For instance, the weight loss (8.71%) of noncoated eggs after 10 weeks (about 2 and a half months) of storage at 4°C was slightly lower (not significant) than that (9.23%) of noncoated eggs after 5 weeks of storage at 25°C. The weight loss (0.54%) of mineral oil-coated eggs after 10 weeks (about 2 and a half months) at 4°C was significantly lower than that (0.85%) of mineral oil-coated eggs after 5 weeks at 25°C. The mineral oil coating effectively reduced the weight loss of eggs by at least ten times after 15 weeks (about 3 and a half months) at 4°C (1.19% for coated and 12.44% for noncoated eggs) or after 5 weeks at 25°C (0.85% for coated and 9.23% for noncoated eggs). This observation aligns with the findings of Waimaleongora-Ek *et al.*, (2009).

Comparison of Egg distribution regulations across World

Nation	Distribution ¹	Storage temperature	Sell-by-date
Korea	WE	0°C–10°C	45 days
	UE	1°C–35°C	ND
United States	WE	Below 7.2°C	30 days
Canada	WE	Below 10°C	ND
European Union	UE	Above 5°C	21 days

Permitted types of eggs that can be distributed.
WE, washed eggs; UE, unwashed eggs; ND, not determined.

(Ji-hoon *et al.*, 2023)

2.3 pH of Egg

The estimation of pH in eggs, enveloping both egg yolk and egg albumen (egg whites), could be a significant figure that essentially impacts eggs quality and usefulness. Silverside *et al.*, (1994) have recognized the utility of pH as an important apparatus for characterizing modifications in egg albumen's quality over capacity periods, though noticing its time-consuming nature.

In a late laid egg, the pH ordinarily falls inside the run of 7.6 - 7.8, rendering it gently antacid, as famous (Chandrasekara and Shahidi *et al.*, 2012). The egg albumen's pH encounters an upward move because of the CO₂ loss from the egg amid capacity, driving to an increment in pH and dry matter, thus diminishing the thickness of the egg, as explained (Samli *et al.*, 2005). The maturing preparations of eggs, like the archived (Scholtyssek *et al.*, 1981), comes about in a decay in thickness and actuates changes in taste and flavor.

Heath (1977) point by point that in recently laid eggs, the egg white's pH falls inside the extent of 7.6 to 8.5. As capacity advances, the egg white's pH experiences an increase, coming full circle in a top esteem of roughly 9.7, unexpected upon temperature varieties. Conflictingly, (Sharp and Powell *et al.*, 1931) watched that after 3 days of capacity at 3 °C, the egg whites pH stabilizes at 9.18. (Li-Chan *et al.*, 1995) detailed a steady egg whites pH close 9.4, notwithstanding of capacity temperatures traversing from 3 to 35°C over 21 days.

The rise in egg white's pH is credited to the loss of CO₂ through the shell pores, unexpected upon variables like broken up CO₂, bicarbonate particles, carbonate particles, and protein balance. Bicarbonate and carbonate particle concentrations are subject to the fractional CO₂ weight within the outside environment.

In recently laid eggs, the yolk pH ordinarily approximates 6.0; in any case, amid capacity, it continuously rises, coming to a run of 6.4 - 6.9. Maintaining egg quality all through taking care of and dissemination requires unflinching perseverance from all included work force. It is pivotal to recognize that quality of an egg, once laid, cannot be upgraded, underscoring the fundamental significance of protecting quality from its inception. The acidic nature of egg yolk is proved by its lower pH, extending from 6.0 - 6.2, as built up (Farrell *et al.*, 1998). In differentiate, egg white shows alkalinity with the next pH which is around 7.6 - 8.0, outperforming that of the yolk, as detailed (Monge *et al.*, 1999). The perceivable pH qualifications between egg albumen and yolk play an essential part in managing different useful properties, counting protein soundness, emulsification, and frothing capacity, as clarified upon (Abeyrathne *et al.*, 2013). These unique pH levels over distinctive egg components moreover apply impact on microbial development and chemical exercises, in this manner applying a significant effect on egg security and quality all through capacity and preparing, as demonstrated (Mine and Oberle *et al.*, 2002). It is basic to work out fastidious observing and control over egg pH inside the nourishment sector, a basic underscored (Anton *et al.*, 2002), to ensure their freshness, steadiness, and security of both eggs and eggs inferred products.

It is detailed that ideal duplication of Salmonella happens at a pH run of 4.5-9.0. Salmonella spp. Will develop to a wide pH extent of 3.8–9.5, with an ideal pH run for growth of 7–7.5 (ICMSF 1996). No increase and expansion happen if the egg is kept at 4°C. Indeed, if the Salmonella passed through the eggshell, soluble pH and nearness of lysozyme, conalbumin and other bioactive components anticipate sudden duplication of Salmonella.

2.4 External Quality of the Egg

External Quality of the Egg includes physical characteristics of egg's generally appearance and its shell. The external surface of an egg shell is encompassed by the cuticle

which could be a waxy natural layer; its thickness in chickens ranges from 0.5 to 12.8 μm (Parsons *et al.*, 1982). The eggshell cuticle thickness is almost 1 μm within the red junglefowl (*Gallus gallus*). Eggshell films are composed of protein (around 95%) with a little amount of polysaccharide (Parsons *et al.*, 1982). The internal shell layer of the chicken is approximately 20 μm , and the external layer is approximately 50 μm thick. These films anticipate the entrance of microorganisms into the egg (Nys and Gautron *et al.*, 2007).

Key parameters related to outside egg quality serve as pivotal markers of the egg's cleanliness, freshness, and general quality. Here are a few noteworthy outside quality parameters:

2.4.1 Eggshell Quality

This incorporates traits such as eggshell color, surface and eggs cleanliness. A clean, perfect shell and smooth is by and large considered as a sign of better quality (Bain *et al.*, 2016).

2.4.2 Egg Estimate

Egg estimate may be pivotal parameter, regularly measured by weight or categorized into distinctive estimate grades. Weight of egg is a basic figure affecting both customer inclination and commercial egg reviewing benchmarks (Silversides & Scott *et al.*, 2001; Rathgeber and Sharma *et al.*, 2014). These parameters play an imperative part in deciding the outside eggs quality and are critical contemplations for both buyers and egg sector. There are a few vital quality of eggs parameters which are enrolled below:

2.4.3 Eggshell Color

The color of eggshell can change from white color to different shades of brown, blue, or green, impacted by breed of feathered creature and the nearness of shades within the slim down (Bain *et al.*, 2016).

2.4.4 Texture of Eggshell

The surface of eggshell is significant for its cleanliness and security of the inner substance. A uniform and smooth surface is considered as a sign of great outside quality of egg (Jones *et al.*, 2018).

2.4.5 Thickness of Eggshell

The thickness of an eggshell is a vital parameter influencing egg quality, resistance to breakage, and defilement. It is affected by components like the bird's age, nourishment and breed (Vilariño *et al.*, 2012).

2.4.6 Shape of an Egg

Egg shape indicates to the general frame of egg, changing from circular to the oval or stretched. The shape can influence shopper discernment and appropriateness for distinctive culinary applications (Rodenburg *et al.*, 2018).

2.4.7 Size of an Egg

Egg measure is decided by weight of an egg and can affect customer inclinations and item utilization (Abdul Azeez *et al.*, 2018).

2.4.8 Strength of Eggshell

Eggshell quality is vital for ensuring the substance of egg amid dealing with transportation. Eggshell quality affected by variables like calcium accessibility, winged creature sustenance and age (Samiullah *et al.*, 2016).

2.4.9 Pores of Eggshell

The number of eggshell pores and estimate of the pores on eggshell influence egg's capacity towards the trade of gases with the outside environment, impacting shelf life and freshness. There are 7000-12000 pores on egg shell. Maximum number of pores found on broad end of an egg (Bain *et al.*, 2016).

2.4.10 Contamination of Eggshell Surface

The visible dirt and fecal defilement on eggshell can affect shopper recognition and cleanliness. Appropriate egg dealing with, and cleaning hones are basic to preserve outside quality of egg (Jones *et al.*, 2018).

2.4.11 Egg Shape Index

The shape of an egg, measured as proportion of length the of the egg to eggs width, is utilized to survey egg shape consistency. It plays a pivotal part in determining eggshell's strength and can change over distinctive strains of the hen and breeds (Monira *et al.*, 2003; Roberts and Willenberg *et al.*, 2016).

2.5 Internal Egg Quality

Internal egg quality is related to the characteristics of the egg's components, including the yolk, egg white (albumen) and chalaza. These components play a vital role in indicating the freshness of the egg, its nutritional value and its suitability for various food processing applications. The assessment of internal egg quality encompasses the functional, sensory and microbiological properties of both the egg yolk and egg whites. For a fresh egg, the ideal composition consists of approximately 32% yolk, 58% egg albumen, and 10% shell (Leeson *et al.*, 2006).

The egg albumen is composed of four distinct layers. The first is the chalaziferous layer, or chalazae, which surrounds the yolk and constitutes about 3% of the egg albumen. The second layer is the inner thin albumen, making up 17% of the egg albumen and enveloping the chalazae. The third component is the thick albumen, comprising 57% of the egg whites, which forms a protective barrier for the inner thin albumen and the yolk, located at each end of the egg. Finally, the outer thin albumen accounts for 23% of the egg albumen and lies just inside the shell membranes, where it connects to the thick albumen (USDA, 2000). Yolk color is a significant internal quality parameter, influenced by the hen's diet, particularly the levels of carotenoids (USDA, 2000).

Albumen provides both physical and chemical barriers to microorganisms. The physical barrier is attributed to its viscosity, which is a result of carbon dioxide/pH-dependent interactions of ovomucin and lysozyme, preventing microbial growth. The thick structure of egg albumen and the integrity of the chalazae are believed to be due to ovomucin, a glycoprotein that exhibits an isoelectric pH of 10.2. Thick egg whites contain ten times more ovomucin than thin egg whites, and ovomucin consists of two components: α (carbohydrate-rich) and β (carbohydrate-poor), which are non-covalently bonded. The α -ovomucin appears to be particularly responsible for the thick properties. It is hypothesized that the structure of thick

albumen arises from the interaction between acidic ovomucin and cationic lysozyme, with lysozyme co-precipitating with ovomucin.

Loss of carbon dioxide results in an increase in the pH of egg albumen (Akyurek and Okur *et al.*, 2009), leading to structural changes that render the albumen waterier and decrease its quality (Hurnik *et al.*, 1978; Lapao *et al.*, 1999; Jones and Musgrove *et al.*, 2005). The albumen of a freshly laid egg has a pH of approximately 7.6, which can rise to 9 or higher with prolonged storage (Quicker *et al.*, 2000).

Not only does the thick and thin albumen become less viscous, but the chalazae, which helps center the yolk within the egg, deteriorates with extended storage and pH changes (Fromm *et al.*, 1967). The vitelline membrane of the yolk weakens over time, losing its elasticity and allowing water to diffuse into the yolk from the albumen, causing the yolk to flatten and making the membrane more prone to rupture during breaking (Zeidler *et al.*, 2002; Jones and Musgrove *et al.*, 2005). Introducing carbon dioxide into the storage environment of eggs inhibits the movement of water from the albumen to the yolk (Romanoff and Romanoff *et al.*, 1949), helping to preserve albumen quality and acid-base balance. The age of the egg and its suitability for various culinary applications can be assessed by evaluating the size and position of the air cell (Jones *et al.*, 2016). Furthermore, the internal quality of the egg is influenced by its pH, a critical parameter for both freshness and functional properties (Farrell *et al.*, 1998). The decline in internal egg quality post-laying is attributed to the loss of water and CO₂ through the shell, resulting in a shift in pH that leads to a waterier albumen due to the breakdown of thick albumen protein structures. The cloudy appearance of egg albumen is also a result of CO₂ loss; as the egg ages, the reduction in CO₂ causes the albumen to become more transparent, distinguishing it from fresh eggs. The surface quality of the eggshell is important for protecting the internal contents. A consistent, smooth surface is indicative of good external egg quality (Jones *et al.*, 2017).

2.5.1 Albumen Height

The egg albumen height refers to the stature of egg albumen and is utilized, in conjunction with egg weight, to calculate Haugh unit. A more noteworthy egg albumen height is characteristic of superiority of freshness of egg and quality (Nys *et al.*, 2007).

2.5.2 Yolk Color

The color of egg yolk may be basic quality characteristic that shapes shopper discernments of both quality of egg and wholesome esteem. The essential determinant of yolk color is the eat less of laying hen, with diets wealthy in carotenoids driving to more strongly and darker-colored yolks (Hargis *et al.*, 1977).

2.5.3 Yolk Index

The egg yolk list, which is ratio of yolk height to yolk width, Performs the role of a metric for assessing yolk quality and its freshness. An increased yolk Index is demonstrative of prevalent yolk quality, as emphasized (Khalifa and Mahmoud *et al.*, 2010).

2.5.4 Yolk Weight

The weight of the egg yolk serves as an indicator of the egg's nutritional content, influenced by factors such as the age and breed of the hen. Yolk weight can be positively affected by maintaining a well-balanced diet, as recommended (Banjo *et al.*, 2018).

2.5.5 Eggshell Film Quality

The quality of the eggshell membrane is significant in ensuring the strength and flexibility of the egg against external pressure. Adequate mineral and calcium nutrition plays a crucial role in affecting the quality of the shell membrane (Silversides and Budgell *et al.*, 2004).

2.5.6 Haugh Unit

The Haugh unit is a crucial metric for evaluating the internal quality of eggs, specifically measuring the height of the thick albumen (egg white) in relation to the egg's weight. Developed by Raymond Haugh in 1937, this measurement has become a standard in the industry for assessing egg freshness and protein quality. The formula for calculating the Haugh unit (HU) is expressed as:

$$HU=100 \log [H+7.57-1.7W0.37]$$

Where,

h = Represents the height of the thick albumen in millimeters

w = The weight of the egg in grams.

The Haugh unit score ranges from 0 to 130, with higher values indicating better quality. Eggs are classified based on their Haugh unit scores as follows:

- AA quality: 72 or more
- A quality: 60 to 71
- B quality: 31 to 59
- C quality: 30 or less

The Haugh unit is typically measured using a destructive testing method, where a sample of eggs is broken onto a flat surface, and the height of the albumen is measured with a micrometer. The United States Department of Agriculture (USDA) has recognized the Haugh unit as a reliable method for determining internal egg quality, reinforcing its importance in the egg grading process (Haugh *et al.*, 1937; Jones *et al.*, 2017).

The significance of the Haugh unit lies in its ability to correlate the weight of the egg with the height of the thick albumen, providing a more accurate assessment of freshness than simply measuring albumen height alone. This relationship ensures that the evaluation takes into account the size of the egg, which is essential for accurate quality assessment.

2.6 Microbiological Aspects of Egg Quality: Exploring the Microbial Dimensions

Freshness is a critical factor in determining egg quality. After eggs are laid, their internal quality begins to deteriorate due to the loss of moisture and carbon dioxide through the pores of the eggshell (Nongtaodum *et al.*, 2013). This deterioration indicates a decline in the egg's quality, safety and edibility, influenced by various factors such as microorganisms, time, temperature and environmental conditions. Fresh eggs are highly perishable due to their nutrient and moisture content, which can promote the growth of bacteria, molds and other microorganisms. As eggs decay, they may undergo changes in appearance, odor, taste and texture, rendering them unsuitable for consumption (Techer *et al.*, 2014).

2.6.1 Microbiology of Eggs: A Key Aspect of Quality and Safety

Egg microbiology is a crucial aspect of egg quality and safety. The microbiological quality of eggs can be affected by several factors, including hygiene practices during egg

collection, handling and storage. One of the primary indicators of deterioration in eggs is the presence of microorganisms such as bacteria, molds and yeasts. These microorganisms can enter eggs through contaminated eggshells or through the pores of the shell (Gantois *et al.*, 2009).

Freshly laid eggs are initially sterile, but the eggshell can quickly become contaminated by fecal matter from the hen's environment, washing water and other materials during collection. While chicken eggs are generally free from microorganisms at the time of laying (Board *et al.*, 1966; Board and Tranter *et al.*, 1995), the shell can easily become contaminated shortly after laying. The number of microorganisms on an eggshell can range from 300 to 500 at oviposition and under appropriate temperature and humidity conditions, these numbers can rapidly increase to 20,000 or 30,000 within just one hour after laying (Macnorth and Chime *et al.*, 1990). The microbial population on the eggshell can vary widely, with counts ranging from hundreds to tens of millions, averaging around 100,000 (Board and Tranter *et al.*, 1995).

2.6.2 Pathways of Microbial Contamination

Microorganisms can contaminate eggs through two primary pathways: vertical and horizontal transmission. The total number of microorganisms per hen's egg shell has been reported to range from 10^2 to 10^7 , with an average of 10^4 . Pathogens such as *Salmonella* spp. may be found on the shell or inside the egg (Techer *et al.*, 2013).

Most microbial contaminants of eggs are gram-negative bacteria, with enteric pathogens like *Salmonella enteritidis* posing the most significant risk. The contents of eggs provide an excellent medium for bacterial growth, raising concerns about the potential for contamination by pathogenic microbes, particularly *S. enteritidis*, in egg production and processing industries (Baran and Jan *et al.*, 2011).

As eggs age, their natural defenses, such as the cuticle, gradually weaken, increasing their susceptibility to microbial attack (Aristocrat *et al.*, 2007). Elevated levels of spoilage microorganisms can lead to undesirable flavors and odors and may pose health risks to consumers (Kassaify *et al.*, 2020). Therefore, continuous monitoring of egg microbiology and the implementation of appropriate storage and handling practices are essential for ensuring the microbiological safety and quality of eggs (Sim *et al.*, 2019).

2.6.3 Factors Influencing Microbial Growth

According to Board et al. (1965), the development of chromogenic microorganisms or the activity of bacterial hydrolytic enzymes are the initial causes of bacterial spoilage in shell eggs. This occurrence is highly dependent on hygiene conditions during egg production, handling, transportation and of course, storage duration and temperatures.

Microbial growth is particularly favorable in the egg yolk, which is rich in nutrients and has a physiological pH, while the egg white is less conducive to bacterial growth due to its lack of essential components, including iron, an alkaline pH and various antibacterial molecules. While gram-positive bacteria are more prevalent on the shell, they have a lower capacity to penetrate the egg's natural defense mechanisms. In contrast, gram-negative bacteria, primarily *Salmonella*, are more mobile and less nutritionally demanding, making them more likely to breach barriers and proliferate (Harry *et al.*, 1963).

According to Board and Fuller (1994), a period of 7 to 20 days at room temperature is required for microorganisms present on the shell to be detected within the egg contents. It is crucial to note that consuming spoiled eggs can pose health risks, as harmful bacteria like *Salmonella* can multiply within them. To minimize the risk of egg spoilage, it is advisable to store eggs in their original carton in the refrigerator at temperatures below 45°F (7°C) and to check for signs of spoilage before using them in cooking or baking. When in doubt, it is better to discard eggs that show any signs of deterioration to avoid potential foodborne illnesses (Sreenivasaiah, 2006).

2.6.4 Horizontal Transmission of Pathogens

Shortly after laying, eggs can be quickly contaminated with pathogens through horizontal transmission. This microbial transfer can occur on any contaminated surface that the egg comes into contact with after laying (Board and Tranter *et al.*, 1995). The eggshell is particularly vulnerable to bacterial entry immediately after laying, as the egg is warmer (the hen's core body temperature is 42°C or 107.6°F) than the surrounding environment. This temperature difference can create negative pressure that facilitates the entry of bacteria through the moist pores of the shell (Board *et al.*, 1966). Thin shells can further encourage the penetration of microorganisms (Macnorth and Chime *et al.*, 1990).

Most of the bacteria found on the eggshell surface are gram-positive, with *Micrococcus* being the dominant species, which is relatively resistant to drying. The egg lysozyme present in the egg white and other proteins helps prevent the growth of gram-positive bacteria. The outer surface of the eggshell is covered with a cuticle that acts as a barrier against bacterial intrusion. However, alterations in the structure of the cuticle due to improper handling (such as exposure to feces, washing, prolonged storage and cuticle damage) can enhance bacterial penetration. The eggshell and its contents can become contaminated with various microorganisms from multiple sources, including feces, dust, feed, housing, transportation and storage containers, humans and other animals (European Food Safety Authority *et al.*, 2005).

2.6.5 Preventing Microbial Intrusion

Since bacteria require moisture to penetrate the pore canal, it is crucial to keep the egg surface dry to prevent microbial intrusion (Flashes and Board *et al.*, 1985). The eggshell serves as a mechanical barrier against bacterial invasion. Thus, maintaining the quality of the eggshell is essential to reduce bacterial penetration (Sauter and Peterson *et al.*, 1974). The shell membrane is a complex structure made up of proteins and polysaccharides that acts as a bacterial filter (Haines and Moran, 1940). During prolonged storage, an increase in pH can favor bacterial growth, further underscoring the importance of proper handling and storage practices to maintain egg quality and safety.

2.7 Preservation of Internal Egg Quality through Coating Applications: An In-Depth Analysis of Benefits

2.7.1 Refrigeration and Coating: Complementary Approaches

Refrigeration is highly effective in preserving egg quality. Surface coating is an alternative method to preserve egg quality, although it is less effective than refrigeration (Nongtaodum *et al.*, 2013). During the first half of the 20th century, storing eggs in refrigerated warehouses was a common practice. Preservation was later advanced with the introduction of carbon dioxide into the cold storage air. Nowadays, very few, if any, cold storage eggs find their way to the retail market. Cold storage temperatures below 8°C limit the growth of most microorganisms and related mesophiles and slow down the loss of internal quality (Humphrey *et al.*, 1994).

2.7.2 Coating's Impact on Internal Quality

The application of coatings extended the preservation of internal egg quality parameters, including Haugh Unit (HU), Yolk Index (YI) and pH, by up to 4 weeks compared to uncoated eggs. Uncoated eggs showed significantly inferior values ($P < 0.001$) for HU (54.45), albumen pH (9.18) and Yolk Index (0.28) after an 8-week storage period. Interestingly, among all coated eggs, mineral oil showed the most promising results, with average HU (70.54), pH (8.48) and Yolk Index (0.35) values following storage. This emphasizes the effectiveness of coatings, especially mineral oil, in protecting and improving key internal quality indicators during extended storage periods (Pires *et al.*, 2018).

Heath (1977) observed that by preventing carbon dioxide (CO₂) loss through the shell oiling, there was consistent maintenance of albumen pH at 8.3 over a 7-day storage period at 22°C. In contrast, when oiled eggs were stored at a lower temperature of 7°C, the albumen pH experienced a slight decrease from 8.3 to 8.1 within the same seven-day period (Li-Chan *et al.*, 1995). Furthermore, the use of rice protein coating has emerged as a practical approach for extending the shelf life of eggs during storage. Eggs coated with varying rates of rice protein concentrate (RPC) in solution, particularly at concentrations of 10% and 15% RPC, have demonstrated to be an effective strategy for maintaining the internal quality of eggs when stored at room temperature, as highlighted (Pires *et al.*, 2018).

Waimaleongora-Ek (2009) conducted a study demonstrating the effectiveness of mineral oil coating in maintaining the internal quality of eggs. Using Haugh unit and yolk index as indicators, the study showed that mineral oil coating increased the shelf life of eggs by at least 3 weeks at 25°C compared to uncoated eggs. In separate studies, Jirangrat (2010) and Jones (2018) reported a significant reduction in weight loss in eggs coated with mineral oil, even after 15 weeks (about 3 and a half months) of storage. This is due to the barrier caused by oil coating to gas exchange. Furthermore, Nongtaodum (2013) demonstrated that eggs coated with edible oils, including rice bran, coconut, palm and soybean oil, preserved the internal quality of eggs for at least 4 weeks longer than uncoated eggs. That's a threefold increase in the egg shelf life observed in the oil-coated eggs.

Oil-coated eggs had a longer shelf life than non-coated eggs, deteriorating at the 3rd week of storage at 25°C. Additionally, Torrico (2011) stated that mineral oil coatings minimized weight loss (0.5%) and preserved the albumen and yolk quality of eggs for at least 3 weeks longer than those observed for non-coated eggs at 25°C. Nongtaodum (2013) found that edible oil (coconut, rice bran, palm, and soybean) coating may protect internal quality of eggs at least 4 weeks longer than non-coated eggs. The oil replaces the natural bloom, the protective coating on the exterior part of the egg, which is removed during washing.

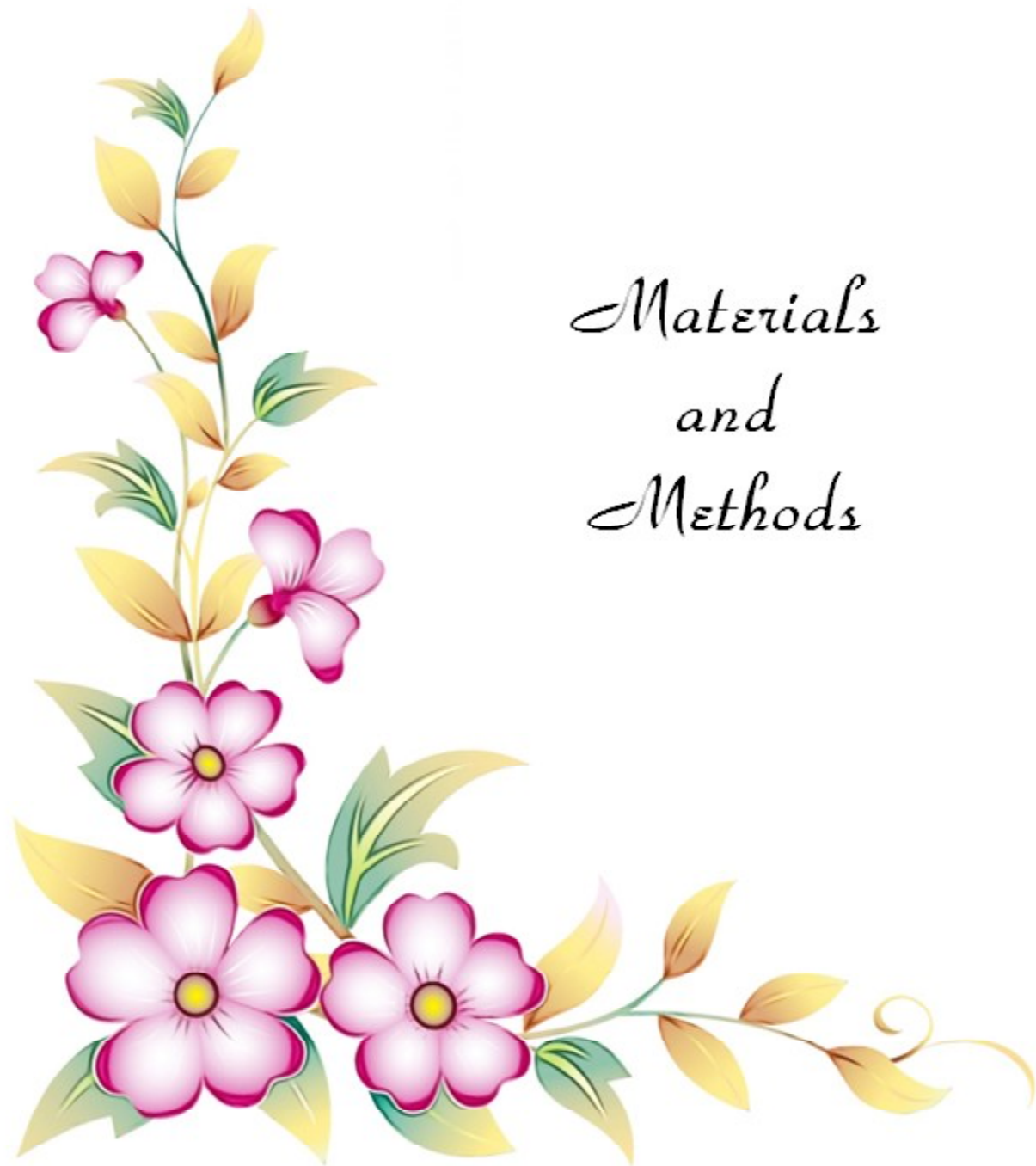
2.7.3 Edible Coatings: Enhancing Egg Preservation

The development of edible coating materials for egg preservation made from polysaccharides, proteins, or lipids, or their combinations, has received a lot of attention in an effort to solve the aforementioned issues (Rhim *et al.*, 2004; Knight *et al.*, 1972, Yüceer and Caner *et al.*, 2014, Waimaleongora-Ek *et al.*, 2009). According to (Ananey-Obiri *et al.*, 2018), an edible coating is described as a thin layer of food components that forms readily on food surfaces. The edible coating is thus recognized as generally recognized as safe (GRAS). These coats prevent microorganisms from reaching the interior shell eggs. They thus increase their storage period and reduce financial losses. Past research found that coatings improved shell quality, protected interior quality, and reduced microbial load on the surface (Falguera *et al.*, 2011).

Various coatings have been tested to see how they affect the quality and freshness of eggs over time. For instance, coating eggs with whey protein isolate and storing them at 25°C for 4 to 6 weeks has been found to extend their shelf life. Eggs treated with whey protein concentrate and kept at 25°C for 28 days showed better freshness, retaining important qualities like the Haugh unit (a measure of egg quality) and minimizing weight loss. When eggs were coated with a mix of soy protein isolate, whey protein isolate, and wheat gluten, they became stronger and more resistant to bacteria after 28 days at the same temperature. Using mineral oil and paraffin wax as coatings and storing the eggs at 7°C for 12 weeks also proved effective, improving egg quality by enhancing the Haugh unit, increasing CO₂ levels, lowering the albumen's pH, and strengthening the membrane around the yolk. Additionally, coating eggs with mineral

oil for 15 weeks at both 4°C and 25°C helped keep them fresher for longer. Lastly, applying á-chitosan for 4 weeks at 25°C was particularly successful in extending the egg's shelf life (Eddin *et al.*, 2019).





*Materials
and
Methods*

This completed study entitled “A Novel Strategies for improving Storage Stability of Table Eggs Under Varied Temperature Conditions Post Transportation.” Was carried out at the Division of Post Harvest Technology, ICAR-Central Avian Research Institute (CARI), Izatnagar, Bareilly, Uttar Pradesh. An encapsulated derived antimicrobial formulation was prepared using a cold method. The prepared formulation was characterized for vesicular size, shape, and encapsulation efficiency using a zetasizer, SEM, and spectroscopy, respectively. The optimized formulation was used as a spray for evaluating its antibacterial efficacy. This spray is under patenting by the name of “**CARIEGG SHIELD**” (Patent No.202311066448).

Objective 1: To evaluate the efficacy of herbal-based egg spray in transported eggs for reducing microbial spoilage and improving shelf life at different storage temperature

A total of eight hundred (n=800) fresh eggs (Fig. 1) were collected from the laying hen farm at Central Avian Research Institute, Izatnagar, Bareilly (UP). However, this selection process was involving certain criteria or certain conditions recorded and the selected eggs were used for further research or analysis. From these eggs only 400 eggs of T2 and T4 treatment group were sprayed (Fig. 2 and 3) with herbal based solution and all 800 eggs transported for 12 hours (Fig. 4).

The transported eggs were divided into four treatment groups of 200 eggs each, in 4 replicates of 50 eggs each. In the first group (T1), eggs were stored in refrigerator at 2-8°C. In the second group (T2), eggs were also be stored in refrigerator (2-8°C) but with the application

of herbal based spray. The third group (T3) include eggs stored at ambient temperature ($26.5^{\circ}\text{C}\pm 3$), while the fourth group (T4) include eggs that were stored at ambient temperature ($26.5^{\circ}\text{C}\pm 3$), but with the application of herbal based spray.

This descriptive experiment was conducted to examine the effects of the herbal based spray treatment, storage and transportation on egg quality and safety. By dividing these treatment groups, the study focused on the adverse impact of the difference and provided a better understanding of optimization of egg transport process.

This experimental study aims to evaluate the impact of different transportation and storage methods, including processed and unprocessed, on quality and the safety of eggs. This study aims to explain the influence of different conditions on the characteristics of the egg, including internal properties such as integrity, microbiological safety and overall external quality. By analyzing these changes, this study aims to better understand how to optimize the transportation and storage of eggs, thus improving the safety of eggs.

Experimental Design

Sr. No.	Treatment	Internal Parameters Eggs /Replicate	Total No. of Eggs
T ₁	2-8°C Temperature	50/4	200
T ₂	26.5°C±3 Temperature	50/4	200
T ₃	2-8°C Temperature – Spray	50/4	200
T ₄	26.5°C±3 Temperature –Spray	50/4	200
	Total		800

*All treatment eggs were transported for 12 hrs. And divided in treatments. After the 12-hour transportation period, a comprehensive analysis was conducted by examining 50 eggs. This experimental design aims to investigate and compare effects of transportation on the selected parameters, with the non-transported group serving as a baseline for reference.

Ten eggs from each treatment cohort were undergo a rigorous and systematic analysis at defined intervals, precisely at time points of 0, 6, 12, 18, 24, 30, and day till eggs gets deteriorates. The objective of this analytical scrutiny is to probe diverse parameters associated with post-harvest loss after the transportation of eggs. The comprehensive assessment will



Fig. 1: Fresh farm collected Eggs



Fig. 2: Preparation of Eggs by spraying Herbal Spray (CARI EGG Shield)



Fig. 3: Eggs sprayed with the Herbal Spray (CARI EGG Shield)



Fig. 4: Vehicle used for transportation of eggs

delve into aspects such as internal-external structural integrity, microbial load, and other pertinent factors, with the aim of discerning the temporal evolution of these parameters under influence of distinct treatment conditions.

Objective 2: To study the effect of herbal-based egg spray on cold stored eggs for improving shelf life

A total of twelve hundred fresh eggs ($n=1200$) sourced from the laying hen farm at Central Avian Research Institute, Izatnagar, Bareilly (UP). During the selection process, specific criteria such as cleanliness, uniform shape, size, and weight of the eggs were documented. The chosen eggs meeting these criteria will be earmarked for subsequent research or analysis. Subsequently, the selected eggs were repositioned for an entire day. The chosen eggs were designated for subsequent research or analysis, followed by storage under cold storage conditions (Fig. 5).

From the farm 1200 eggs were collected from which 600 eggs were kept as it is and remaining 600 eggs were sprayed by herbal spray “CARI EGG SHIELD”. These all 1200 eggs were kept in cold Storage (10-15°C) for a month. After one month of cold storage, the stored non sprayed eggs were categorized into two groups. The first group (T1) comprising three hundred eggs (300) will remain consistently in cold storage (10-15°C) until the completion of the experiment. In the second group (T2), the comprising three hundred eggs (300) were extracted from cold storage after one month and exposed to ambient temperature conditions (26.5°C±3). Here, T3 & T4 groups six hundred 600 eggs were sprayed before cold storage (10-15°C) of one month at 0th day. In the third group (T3), the three hundred (300) eggs were kept in cold storage (10-15°C) until the completion of experiments. In the fourth group (T4), the comprising three hundred eggs (300) extracted from cold storage and exposed to ambient temperature conditions (26.5°C±3).

Experimental design

Sr. No.	Treatment	Internal Parameters Eggs /Replicate	Total No. of Eggs
T ₁	Cold Storage (10-15°C)	75/4	300
T ₂	Ambient Temperature Conditions (26.5°C±3).	75/4	300
T ₃	Cold storage (10-15°C)- Spray	75/4	300
T ₄	Ambient Temperature Conditions (26.5°C±3) - Spray	75/4	300
Total			1200

Ten eggs from each treatment were undergo a rigorous and systematic analysis at defined intervals, precisely at time points of 0, 6, 12, 18, 24, 30, and day till eggs gets deteriorates. The objective of this analytical scrutiny is to probe diverse parameters associated with post-harvest loss. The comprehensive assessment was delved into aspects such as internal-external structural integrity, microbial load and other pertinent factors, with the aim of discerning the temporal evolution of these parameters under influence of distinct treatment conditions.

Recorded Parameters:

For the analysis of eggs quality in both the above Objective at different time interval following data were recorded precisely for the analysis of quality parameters.

I. External Egg Quality Parameter

- a. Weight of an Egg
- b. Egg Appearance
- c. Shape Index
- d. Eggs Surface Area
- e. Dimeter of Air Cell
- f. Length of Egg
- g. Width of Egg
- h. Cleanliness
- i. Colour
- j. Specific Gravity,
- k. Weight Loss of Egg (%) Because of Prolonged Storage



Fig. 5: Eggs stored in cold storage room

II. Internal Egg Quality Parameter

- a. Length and Width of Albumen
- b. Dimeter of Egg Yolk
- c. Albumen Index
- d. Yolk Colour
- e. Shell Weight
- f. Albumen Weight
- g. Albumen Height
- h. Yolk Height
- i. Yolk Index
- j. Haught Unit
- k. Thickness of Shell
- l. Weight of Yolk

III. pH of Egg

- a. pH of Whole egg
- b. pH of Yolk
- c. pH of Albumen

IV. Microbial quality parameter

- a. Total Plate Count
- b. E- Coli Count

3.1 External Egg Quality Parameter

3.1.1 Egg weight

Weight of each egg were carefully recorded every six days from day 0 to day 30. This recording process was involving use of the precision balance to ensure accuracy to the nearest 0.05 grams. Frequency and accuracy of weight measurement was provided a better understanding of changes in the egg weight in the body at a given time and provide important information for studying impact of difference between the transportation and storage on this important measurement.

3.1.2 Weight loss:

After every six day loss of egg was computed in the relation to initial weight of the egg on day zero, by using the following equation:

$$\text{Weight loss (\%)} = \frac{\text{Final weight (g)} - \text{Initial weight (g)}}{\text{Initial weight (g)}} \times 100$$

(Paula *et al.*, 2021)

This equation quantifies the percentage change in egg weight on a regular interval basis, offering a standardized measure to assess and compare the magnitude of weight loss across different treatment groups.

3.1.3 Appearance of egg:

The assessment encompasses various parameters related to egg quality, including egg size, shape, shell texture, shell colour, and the overall cleanliness and soundness of the eggs. The evaluation is aimed to provide the comprehensive understanding of eggs physical characteristics and external attributes of the eggs within each treatment group. The systematic analysis of these parameters was contributed valuable insights into impact of different transportation and storage conditions, with and without antibacterial treatment, on overall quality and visual attributes of the eggs.

3.1.4 Egg length & width:

Shell egg dimensions, both width and length, will be precisely measured using a Digital Vernier calliper (Fig. 6). This instrument allows for accurate and detailed measurements of egg, enabling a thorough assessment of its physical characteristics. Use of the Digital Vernier calliper ensures a high level of precision in determining dimensions, contributing to the comprehensive understanding of variations in egg size within the specified treatment groups. These recorded parameters of an eggs helped to analyse the shape index changes at different intervals.

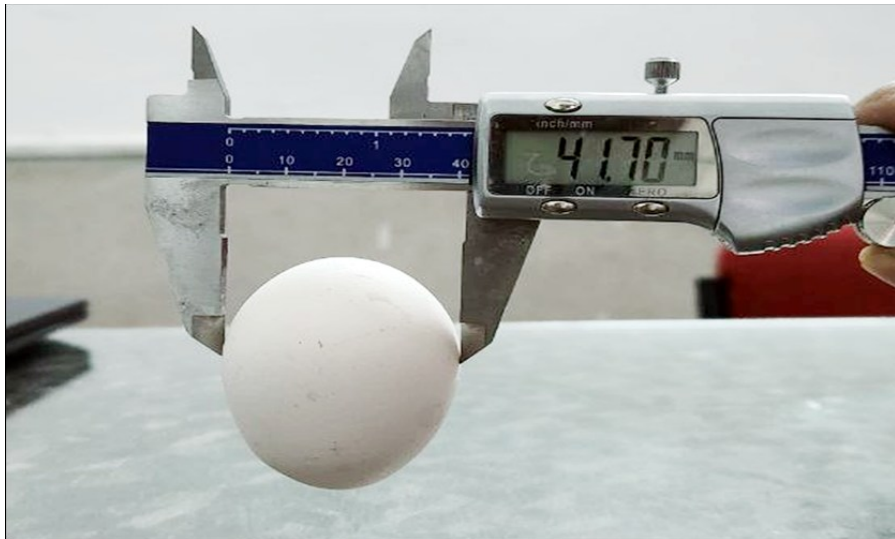
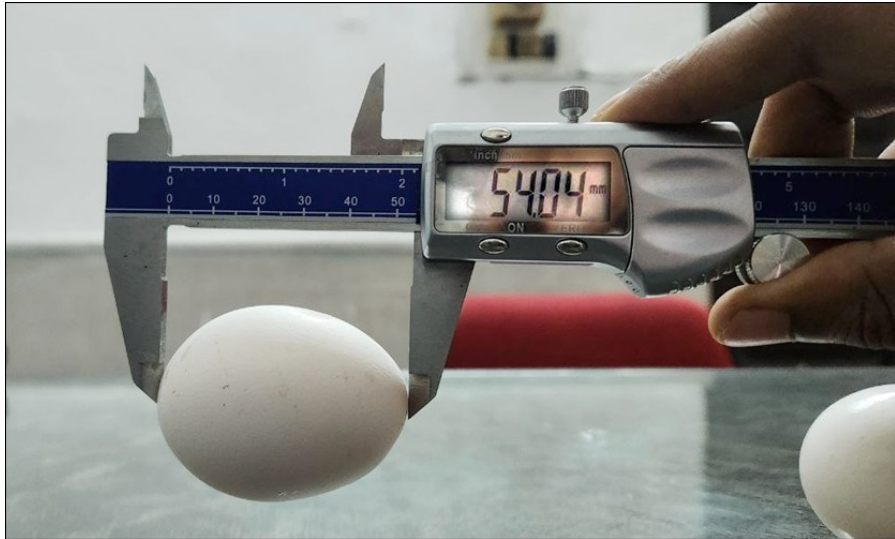


Fig. 6: Length and Width of Egg

3.1.5 Shape Index:

The dimensions of an egg, encompassing both its maximum breadth and length as mentioned above (Fig. 6). The ensuing calculation of the shape index was derived through application of the following formula. This methodological approach adheres to scientific precision, employing calibrated instruments to ascertain accurate measurements for subsequent analytical purposes.

$$\text{Shape Index} = \frac{\text{Max. Breadth of egg (cm)}}{\text{Max. Length of egg (cm)}} \times 100$$

(Schultz *et al.*, 1953)

3.1.6 Specific gravity (SG)

The determination of parameters was conducted employing a systematic methodology. The measurement process involved weighing the object both in the distilled water and in air, utilizing a precision analytical balance characterized by a sensitivity of 0.05 grams. The ensuing calculation was executed according to specified equation, ensuring a meticulous and controlled experimental procedure, indispensable for scientific rigor and accuracy. For analysis of eggs specific gravity weight was recorded in air and in water (Fig. 7). For weight in water, we took 100 ml distilled water egg were dipped in it and recorded the weight. Eggs took out from water by wired hook and the tier the weighing balance after each recording. The temperature of water was kept to 23°C so while doing the analysis the temperature correlation was maintained to 0.9975 (Kell *et al.*, 1975).

$$\text{Specific gravity (SG)} = \frac{\text{Egg Weight in air(g)}}{\text{Weight in Water (g) * Temperature correlation}}$$

(Hempe *et al.*, 1987)

3.1.7 Surface Area:

Given the ellipsoidal nature of an egg, the determination of its surface area necessitates application of formula for surface area of an ellipsoid:

$$\text{Surface Area} = 4\pi (a^2 + b^2)/2$$

Here, “a” represents length of egg, measured from one end to other, while “b” denotes width of egg, gauged at widest point perpendicular to its length. While using this formula accurately, precise measurements of the egg’s length and width was recorded using the digital vernier calliper. These measured values were substituted into the formula, and the ensuing computation allows for determination of egg’s surface area (Narushine *et al.*, 2005).

3.1.8 Air cell Dimeter:

The air cell diameter of eggs was determined by using a Digital Vernier calliper, with measurements taken from the broad end of eggs. This procedure ensures the precise quantification of the diameter of the air cell, contributing to accurate data acquisition in conformity with scientific methodologies (Narushin *et al.*, 2023).

3.2 Internal egg quality

3.2.1 Albumen Index

Upon breaking egg on a smooth surface (Fig. 8), dimensions of thick albumen will be precisely assessed at three distinct points. The height (measured in mm) was determined using an AMES spherometer, while the Length and width were recorded using a Digital Vernier calliper (Fig. 9). To enhance accuracy, the average values of these measurements were calculated and subsequently utilized in the estimation of albumen index. This calculation was made by using the Heiman and Carver (1936) methodology, which ensures a methodical and rigorous scientific approach to evaluating albumen properties.

$$\text{Albumen Index} = \frac{\text{Average albumen height (mm)}}{\text{Average albumen width (mm)}}$$

3.2.2 Haugh unit score

Haugh Unit stands as the predominant parameter used for evaluating quality of albumen. The calculation of Haugh Unit done by utilizing height of albumen (measured in millimetres) (Fig. 9) and weight of egg (measured in grams). The computation of Haught Unit was conducted according to following formula:



Fig. 7: Weight of an Egg in water

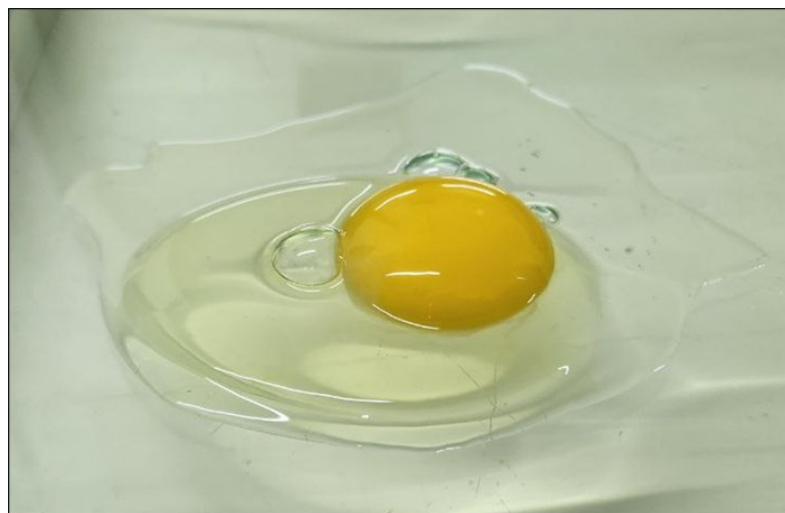


Fig. 8: Broken eggs on Egg Analyzing Platform to perform the Internal Quality Assessment

$$\text{Haugh Unit} = 100 \log \left(H - \frac{\sqrt{G(30W^{0.37} - 100)}}{100} + 1.9 \right)$$

(Haugh *et al.*, 1937)

This formula incorporates both the physical attributes of albumen and the overall weight of egg, providing a comprehensive metric that perform role as a quantitative indicator of the albumen quality. The widespread utilization of Haugh Unit underscores its significance as a reliable measure in the assessment of the egg quality within scientific and agricultural contexts.

Where,

H = Albumen Height (mm)

G = 32.2 (Gravitational constant)

W = Weight of Egg (g)

3.2.3 Albumen weight

Following the precise measurement of the width and height of thick albumen, a precisely separation of albumen from yolk was achieved using a blunt knife (Fig. 10). Subsequently, weight of isolated albumen was accurately determined by means of a weighing balance characterized by a precision of 0.5 milligrams (Fig. 11). This careful and systematic procedure ensures the acquisition of accurate data regarding the mass of the albumen, contributing to precision and reliability of subsequent analytical assessments (Hisasaga *et al.*, 2020).

3.2.4 Yolk Index

Upon the successful separation of albumen and yolk, with the yolk maintained in an intact state, the spherical characteristics of yolk was quantified as the yolk index. These measurements were involving the utilization of an AMES spherometer to measure height of yolk and a Digital Vernier calliper to measure the yolk width (Fig. 12). The calculation of yolk index was done through application of following formula:

$$\text{Yolk Index} = \frac{\text{Yolk Height (mm)}}{\text{Yolk width (mm)}} \text{ (sauter } et al., 1951)$$

This formula encapsulates ratio of the yolk's height to its width, providing a numerical representation of the yolk's spherical nature. Integration of precise measuring instruments and a systematic formula underscores the scientific rigor applied in characterizing the yolk index.

3.2.5 Yolk weight

Weight of yolk was accurately determined by using a weighing balance with a precision of 0.5 mg (Fig. 13). The resulting measurements were expressed in grams (g) that signifies the mass of yolk and was obtained with careful attention to precision and accuracy. This quantitative information performs role as a fundamental metric in the comprehensive assessment of egg composition and quality. The use of a weighing balance with high accuracy underscores the commitment to rigorous scientific methodologies in obtaining reliable data (Hisasaga *et al.*, 2020).

3.2.6 Yolk colour

The colour of yolk was measured by employing a Roche's yolk colour fan (Fig. 12). This method involves comparing the colour of egg yolk to a standardized set of colour samples provided by the yolk colour fan. The fan typically consists of a range of colours representing different yolk shades. By visually matching the yolk colour to the closest reference on the fan, an objective measurement of yolk colour is achieved. This non-invasive and visually comparative approach provides a standardized means of evaluating and categorizing yolk colour in a qualitative manner, contributing to overall assessing quality of yolk (Bovskova *et al.*, 2014).

3.2.7 Shell thickness

Thickness of eggshell was quantified using the specialized equipment, like a Digital eggshell thickness gauge. The measurement process involves assessing the average thickness of the eggshell at three distinct edges namely the broad, middle and narrow regions. The use of these multiple measurements enhances accuracy and provides a comprehensive representation of the overall eggshell thickness. This meticulous approach ensures a thorough evaluation of

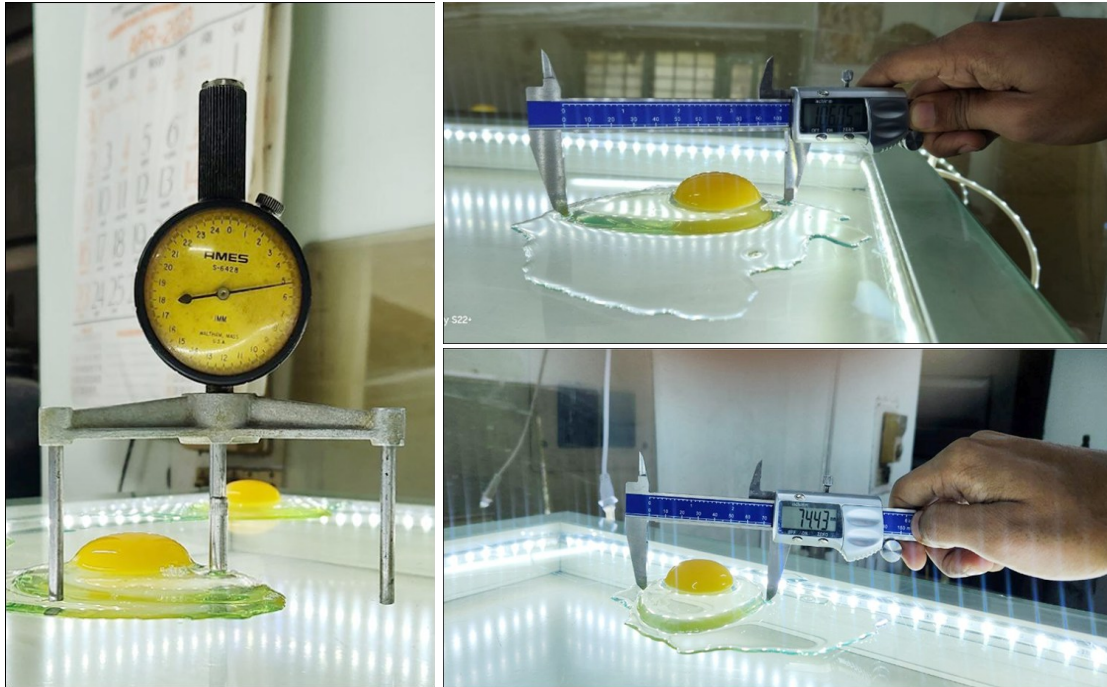


Fig. 9: Albumin quality assessment of an egg

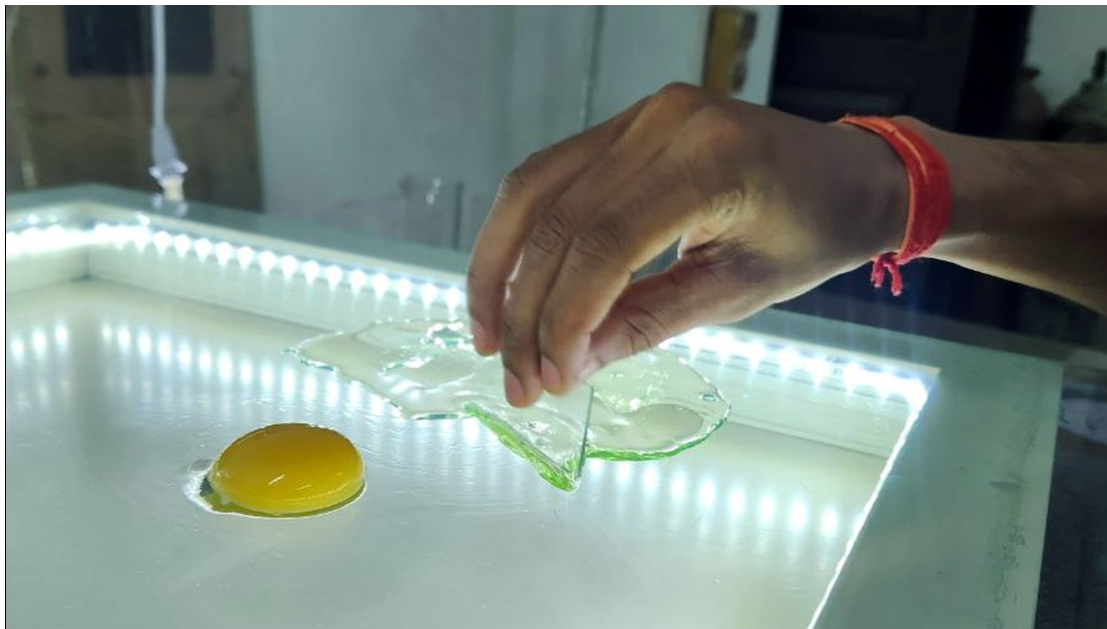


Fig. 10: Separation of Yolk and Albumin



Fig. 11: Weighing of Separated Albumin

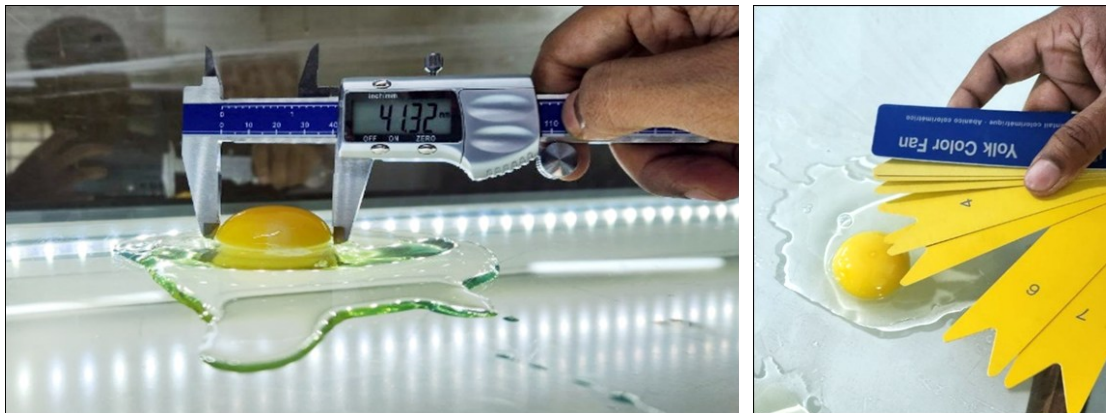


Fig. 12: Yolk quality assessment of an egg



Fig. 13: Weighing of Separated Yolk

structural integrity of the eggshell, contributing to precision and reliability of scientific assessments related to egg composition and quality (Hunton P. *et al.*, 2005).

3.3 pH of eggs

Following separation of albumen from yolk for weighing, both components were distributed to 03 replicate glass beakers. The pH of yolk and albumen was determined using the pH meter from Electronic Instrument Ltd. Approximately 2.0 grams of each sample were homogenized in 20.0 ml of de-ionized water within a beaker. Before pH measurement, the pH meter was standardized using buffer solutions with pH values of 4.01 and 9.20. Subsequently, the electrode was rinsed with de-ionized water and then immersed into the homogenate, allowing sufficient time for stabilization before recording the pH reading. This meticulous procedure, as detailed by Eke (2013), ensured accurate and standardized pH measurements, essential for comprehensive characterization of the chemical properties of both the albumen and yolk (Dong *et al.*, 2017).

3.4 Microbial quality parameter

3.4.1 Total Plate Count (TPC)

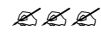
Changes in the bacterial populations were assessed by spread-plating 0.1 ml of pertinent dilutions on the plate count agar following the serial dilution of both egg content and egg surface solutions in phosphate-buffered saline (PBS). After a two-days incubation period at 37°C, colonies were enumerated (Garibaldi *et al.*, 1970).

3.4.2 E. Coli Count

Evaluation of variations in the bacterial populations involved spread-plating of 0.1 ml of the relevant specked dilutions on EMB (Eosin-Methylene Blue) Agar subsequent to serial dilutions of both egg surface and egg content solutions in PBS (phosphate-buffered saline). After two days of incubation at 37°C, the colonies were manually counted (Peter feng *et al.*, 2020).

3.5 STATISTICAL ANALYSIS

The data acquired throughout the study was undergo statistical analysis to derive meaningful insights. The significance of differences in-between means was assessed through application of two-way and one-way Analysis of Variance (ANOVA) tests. The statistical analysis was conducted using SPSS or R software, both widely recognized tools for robust data analysis in the field of research.





Results

The aim of this study was to improve shelf life of transported eggs by herbal spray & also to check the quality of cold stored eggs at different temperature interval by internal, external and microbial parameters. The hypothesis posited that herbal spraying would increase the shelf life of transported eggs when stored at lower temperatures. The two experiment was conducted with duration of 30 & 60 days and the results obtained are presented as below.

Objective 1: To evaluate the efficacy of herbal-based egg spray on transported eggs for reducing microbial spoilage and improving shelf life at different storage temperature

4.1 EXTERNAL PARAMETERS:

4.1.1 Egg Weight

The result of herbal sprayed egg weight after the 12 hrs. Of transportation is presented in Table no. 4.1. After the 12 hrs. Of transportation no significant ($P>0.05$) difference in the egg weight of different treatment group were observed till 18th day. After 18th day significant decrease in egg weight trend was continued till end of experiment. Before transportation, the initial weights of the eggs across the treatment groups were relatively similar, with T1 recording an average weight of 52.71 ± 0.55 g, T2 at 53.37 ± 0.63 g, T3 at 52.00 ± 0.075 g and T4 at 51.28 ± 0.57 g. After the transportation, T1, T2, T3 and T4 had weights of 52.36 ± 0.56 g, 53.22 ± 0.62 g, 51.91 ± 0.75 g and 51.17 ± 0.57 g respectively. After the transportation till the 24th day of storage, T2 continued to show a significant ($P<0.05$) decline, reaching a final weight of 46.63 ± 0.73 g by end of the experiment. As the storage period increases, significant comparative weight loss was observed in all groups. T2 group had the lowest weights recorded

throughout the study and demonstrated a statistically significant ($P < 0.05$) difference, indicating a strong correlation between treatment and weight loss. However, T3 shows maximum a relatively stable weight throughout the duration of the experiment, ending with a weight of 50.15 ± 0.84 g on day 24. T1 and T4 also showed a gradual decline in weight, T1 at 48.98 ± 1.29 & T4 at 46.89 ± 0.68 g on day 24. This statistically significant ($P < 0.05$) differences in weight loss compared to the control group was served. Overall, the results indicate that the treatment groups significantly ($P < 0.05$) affected the weight of the eggs over time, with T2 showing the most substantial weight loss, while T3 maintained the highest average weight throughout the study.

4.1.2 Egg Weight Loss (%)

The changes in egg weight loss percentage in herbal sprayed eggs after the 12 hrs. Of transportation is presented in the Table no. 4.2 & Fig. 14. After transportation, T1 recorded an egg weight loss percentage of 0.21 ± 0.01 %, which was comparatively lower than that of T2, which had the higher loss i.e. 0.27 ± 0.03 %. The T3 and T4 displayed intermediate values, with T3 - 0.16 ± 0.02 % and T4 - 0.23 ± 0.02 %. As the storage period progressed to the 6th day, T2 continued to show a significant ($P < 0.05$) increase in egg weight loss percentage, reaching 3.10 ± 0.34 %, while T1 shows less increased - 1.26 ± 0.03 %. The T3 and T4 groups exhibited increase in egg weight loss, with 0.75 ± 0.03 % and 2.37 ± 0.25 % respectively. till 30th day of experiment, similar trend of increasing egg weight loss percentage is seen where T2 recorded a final highest egg weight loss percentage of 12.57 ± 1.01 % and then T4 with 9.31 ± 0.56 % loss, showcasing the most significant ($P < 0.05$) loss throughout the study. During this complete experiment least increase in egg weight loss percentage seen in, T3 - 3.54 ± 0.15 % & then T1 - 4.40 ± 0.16 %. The statistical analysis indicated significant ($P < 0.05$) differences among the treatments, where T2 shows highest egg weight loss percentage followed by T4 at the 30th day. Overall, the results highlight that T2 exhibited the greatest increase in egg weight loss percentage over the 30-day period, while T1 and T3 showed the least increase, indicating that temperature & spray significantly influenced the weight retention of the eggs.

Table 4.1: Effect of Transportation on weight of an egg (g) over the storage time period

	Before Transportation	After Transportation	06 th Day	12 th Day	18 th Day	24 th Day	30 th Day	P value
T1 Non-Spray (4-7°C)	52.71±0.55 ^A	52.56±0.56 ^{AB}	51.78±0.66 ^{AB}	51.22±0.74 ^{AB}	49.79±0.98 ^{AB}	49.71±1.06 ^{ABab}	48.98±1.29 ^{Bab}	0.008
T2 Non-Spray (26.5 ± 3°C)	53.37±0.63 ^A	53.22±0.62 ^A	51.71±0.61 ^{AB}	50.28±0.61 ^{BC}	48.92±0.66 ^{CD}	47.83±0.64 ^{CDa}	46.63±0.73 ^{Db}	0.000
T3 Spray (4-7°C)	52.00±0.75	51.91±0.75	51.61±0.75	51.31±0.74	50.97±0.74	50.7±0.74 ^a	50.15±0.84 ^a	0.562
T4 Spray (26.5 ± 3°C)	51.28±0.57 ^A	51.17±0.57 ^A	50.24±0.57 ^{AB}	49.41±0.59 ^{ABC}	48.59±0.6 ^{BCD}	47.53±0.59 ^{CDb}	46.89±0.68 ^{Db}	0.000
P value	0.118	0.134	0.291	0.165	0.132	0.016	0.006	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P <0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P <0.05)

Table 4.2: Effect of Transportation in percentage of egg weight loss (%) over the storage time period

	After Transportation	06 th Day	12 th Day	18 th Day	24 th Day	30 th Day	P Value
T1 Non-Spray (4-7°C)	0.21±0.01 ^{Bbb}	1.26±0.03 ^{Bb}	2.05±0.11 ^{Bc}	2.95±1.20 ^{Abc}	3.71±0.15 ^{Ac}	4.40±0.16 ^{Ac}	0.000
T2 Non-Spray (26.5 ± 3°C)	0.27±0.03 ^{Ea}	3.10±0.34 ^{DEa}	5.76±0.51 ^{CDa}	8.31±0.77 ^{BCa}	10.31±1.03 ^{ABa}	12.57±1.01 ^{Aa}	0.000
T3 Spray (4-7°C)	0.16±0.02 ^{Bb}	0.75±0.03 ^{Bb}	1.32±0.05 ^{ABc}	1.98±0.10 ^{Ac}	2.49±0.16 ^{Ac}	3.54±0.15 ^{Ac}	0.000
T4 Spray (26.5 ± 3°C)	0.23±0.02 ^{Ea}	2.37±0.25 ^{Da}	4.06±0.33 ^{Cb}	5.76±0.43 ^{Bbb}	7.88±0.56 ^{Ab}	9.31±0.56 ^{Ab}	0.000
P value	0.001	0.000	0.000	0.000	0.000	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P <0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P <0.05)

4.1.3 Air cell Diameter

The experimental results of Air Cell Diameter (measured in mm.) of treated herbal sprayed eggs after 12 hrs. of transportation presented in the Table no. 4.3 & Fig. 15. The air cell diameter shows comparatively significant ($P<0.05$) difference over the 30 days of experimental period after the transportation. Before the transportation, the air cell sizes for the treatment groups were relatively similar, with T1 measuring 15.75 ± 0.62 mm, T2 - 14.77 ± 0.32 mm, T3 - 15.97 ± 0.26 mm and T4 - 15.58 ± 0.3 mm. These initial measurements indicate a consistent baseline across all treatment groups. As the study progressed to the post transportation, increases in air cell diameter were observed across all treatment groups. The T1 increased to 18.78 ± 0.69 mm, T2 to 17.97 ± 0.32 mm, T3 to 18.15 ± 0.27 mm and T4 to 18.35 ± 0.31 mm wherein slightly more increased in air cell diameter found in T1 and T2 which are non-treated eggs than T3 and T4 eggs. By the 6th day, T1 continued to show an increase in Air cell diameter to 20.71 ± 0.92 mm, while T2 further sharply expanded to 23.85 ± 0.44 mm, T3 showed a slight increase to 19.98 ± 0.32 mm and T4 reached 21.98 ± 0.30 mm. The trend of increasing air cell size continued to the 30th day showed where maximum significant ($P<0.05$) increase in air cell value observed in T2 at 31.81 ± 0.49 and followed by T4 - 28.95 ± 0.34 mm, T1 - 26.2 ± 0.95 mm & T3 - 24.19 ± 0.3 and Statistical analysis revealed significant ($P<0.05$) differences in air cell size among the treatment groups across all time points. This indicates that the treatments had a significant ($P<0.05$) impact on the size of the air cell throughout the study period. the findings demonstrate a clear trend of increasing air cell size over the 30-day period for all treatment groups, with T2 exhibiting the highest increase.

4.1.4 Specific Gravity

The experimental results of specific gravity of treated herbal sprayed eggs after 12 hrs. of transportation presented in the Table no. 4.4. It shows significant ($P<0.05$) difference among all treatments over the period of 30 days. Specific gravity is an important parameter that can provide insights into the quality and freshness of eggs, as it is influenced by factors such as air cell size and egg weight. Before the transportation, all treatment groups exhibited similar specific gravity values, with T1 at 1.08 ± 0.00 , T2 at 1.08 ± 0.00 , T3 at 1.083 ± 0.001 and T4 at

1.082±0.02. These initial measurements indicate a consistent baseline across the groups. Transportation doesn't show significant ($P>0.05$) effect on air cell size, T1 decreased slightly to 1.076±0.00, while T2 shows reduction in specific gravity to 1.077±0.00. T3 maintained a value of 1.081±0.01 and T4 recorded a specific gravity of 1.080±0.01. By the 6th day, a significant ($P<0.05$) decline was observed in T2 at 1.067±0.01 and mild decline was observed at T1 and T4, (1.069±0.01 & 1.074±0.00 respectively). The T3 remained relatively stable at 1.079±0.01. The trend of decreasing specific gravity by the previous 6th day continued through the following measuring period of experiment of the 30th day, where T1 reached 1.053±0.009, T2 sharply decrease to 1.041±0.003, T3 maintained a value of 1.068±0.009 and T4 recorded 1.046±0.004. Statistical analysis indicated significant ($P<0.05$) differences in specific gravity among the treatment groups across all time points.

4.1.5 Shape Index

The results presented in Table 4.5 indicated the effect of transportation on the shape index of eggs over a storage period. It showed that the shape index remained non-significant ($P>0.05$) across all treatments and time points. For the non-spray group stored at 4-7°C, the shape index at 30th day was - 75.58±1.97, indicating that these cooler conditions effectively preserved the eggs' structural integrity. Similarly, the non-spray eggs & storage 26.5 ± 3°C maintained a shape index of 74.42±0.75, demonstrating resilience even at higher temperatures. The spray treatment at 4-7°C yielded a shape index of 74.54±0.84, showing that the combination of spraying and cool storage also effectively maintained shape quality. However, the spray treatment & storage at 26.5 ± 3°C resulted in the lowest shape index of 73.81±0.89, suggesting that while the shape was preserved, the warmer conditions may not be as beneficial. Overall, these findings suggest that both non-spray and spray methods, regardless of temperature can effectively maintain the shape quality of eggs during storage, providing valuable insights for producers and distributors aiming to optimize egg quality.

4.1.6 Surface Area

The data in Table 4.6 indicates the effect of transportation on the surface area of eggs (mm²) over a defined storage period, across all treatments, the surface area measurements

Table 4.3: Effect of Transportation on the air cell diameter (mm) over the storage time period

	Before Transportation		After Transportation		06 th Day	12 th Day	18 th Day	24 th Day	30 th Day	P value
	Before Transportation	After Transportation	Before Transportation	After Transportation						
T1 Non-Spray (4-7°C)	15.75±0.62 ^E	18.78±0.69 ^{DE}	20.71±0.92 ^{CDb}	22.38±0.95 ^{BCbc}	23.95±0.98 ^{ABbc}	25.43±0.95 ^{ABbc}	26.2±0.95 ^{Abc}	0.000		
T2 Non-Spray (26.5 ± 3°C)	14.77±0.32 ^F	17.97±0.32 ^{Eb}	23.85±0.44 ^{Da}	26.96±0.44 ^{Ca}	28.92±0.49 ^{Ba}	30.48±0.49 ^{ABa}	31.8±0.49 ^{Aa}	0.000		
T3 Spray (4-7°C)	15.97±0.26 ^F	18.15±0.27 ^{Da}	19.98±0.32 ^{Cb}	21.35±0.35 ^{Bc}	22.53±0.33 ^{Bc}	23.61±0.3 ^{Ac}	24.19±0.3 ^{Ac}	0.000		
T4 Spray (26.5 ± 3°C)	15.58±0.3 ^E	18.35±0.31 ^E	21.98±0.3 ^{Dab}	24.17±0.32 ^{Cb}	26.33±0.31 ^{Bb}	27.93±0.34 ^{ABb}	28.95±0.34 ^{Ab}	0.000		
P value	0.173	0.273	0.000	0.000	0.000	0.000	0.000	0.000		

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.4: Effect of Transportation on specific gravity of an egg over the storage time period

	Before Transportation		After Transportation		06 th Day	12 th Day	18 th Day	24 th Day	30 th Day	P value
	Before Transportation	After Transportation	Before Transportation	After Transportation						
T1 Non-Spray (4-7°C)	1.080±0.00 ^A	1.076±0.00 ^A	1.069±0.01 ^A	1.065±0.01 ^{AB}	1.061±0.01 ^{ABab}	1.058±0.01 ^{Bab}	1.053±0.009 ^{Bab}	0.047		
T2 Non-Spray (26.5 ± 3°C)	1.080±0.00 ^A	1.077±0.00 ^A	1.067±0.01 ^{AB}	1.052±0.01 ^{BC}	1.048±0.00 ^{BCb}	1.043±0.00 ^{Cb}	1.041±0.003 ^{Cb}	0.000		
T3 Spray (4-7°C)	1.083±0.01	1.081±0.01	1.079±0.01	1.077±0.01	1.074±0.00 ^a	1.070±0.01 ^a	1.068±0.009 ^a	0.751		
T4 Spray (26.5 ± 3°C)	1.082±0.02 ^A	1.080±0.01 ^A	1.074±0.00 ^{AB}	1.064±0.01 ^{BC}	1.053±0.01 ^{BCb}	1.046±0.01 ^{BCb}	1.043±0.004 ^{Cb}	0.000		
P value	0.999	0.969	0.760	0.180	0.005	0.002	0.000	0.000		

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.5: Effect of Transportation on shape index of an egg over the storage time period

	Before Transportation		After Transportation		12 th Day	18 th Day	24 th Day	P value
	Before Transportation	After Transportation	Before Transportation	After Transportation				
T1 Non-Spray (4-7°C)	75.58±1.97	75.58±1.97	75.58±1.97	75.58±1.97	75.58±1.97	75.58±1.97	75.58±1.97	1.00
T2 Non-Spray (26.5 ± 3°C)	74.42±0.75	74.42±0.75	74.42±0.75	74.42±0.75	74.42±0.75	74.42±0.75	74.42±0.75	1.00
T3 Spray (4-7°C)	74.54±0.84	74.54±0.84	74.54±0.84	74.54±0.84	74.54±0.84	74.54±0.84	74.54±0.84	1.00
T4 Spray (26.5 ± 3°C)	73.81±0.89	73.81±0.89	73.81±0.89	73.81±0.89	73.81±0.89	73.81±0.89	73.81±0.89	1.00
P value	0.78	0.78	0.78	0.78	0.78	0.78	0.78	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.6: Effect of Transportation on surface area (mm²) of egg over the storage time period

	Before Transportation		After Transportation		12 th Day	18 th Day	24 th Day	P value
	Before Transportation	After Transportation	Before Transportation	After Transportation				
T1 Non-Spray (4-7°C)	65.34±0.39	65.34±0.39	65.34±0.39	65.34±0.39	65.34±0.39	65.34±0.39	65.34±0.39	1.00
T2 Non-Spray (26.5 ± 3°C)	65.28±0.47	65.28±0.47	65.28±0.47	65.28±0.47	65.28±0.47	65.28±0.47	65.28±0.47	1.00
T3 Spray (4-7°C)	64.7±0.30	64.7±0.30	64.7±0.30	64.7±0.30	64.7±0.30	64.7±0.30	64.7±0.30	1.00
T4 Spray (26.5 ± 3°C)	65.61±0.77	65.61±0.77	65.61±0.77	65.61±0.77	65.61±0.77	65.61±0.77	65.61±0.77	1.00
P value	0.427	0.427	0.427	0.427	0.427	0.427	0.427	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

don't show significant ($P>0.05$) difference throughout the storage duration. For the non-spray eggs stored at 4-7°C, the surface area was consistently recorded at 65.34 ± 0.39 , indicating that these cooler conditions effectively preserved the eggs' surface area without any degradation. Similarly, the non-spray group & storage at $26.5\pm3^\circ\text{C}$ showed a surface area of 65.28 ± 0.47 , reflecting minimal impact from the higher temperature. The spray T3 yielded a slightly lower surface area of 64.7 ± 0.3 , suggesting that while spraying did not significantly ($P>0.05$) harm the surface area, it was marginally less than the non-spray counterparts. The T4 resulted in a surface area of 65.61 ± 0.77 , which was the highest among the treatments, indicating that the combination of spraying and warmer temperatures may have had a positive effect on surface area preservation. Effect of transportation indicating not statistically significant ($P>0.05$) differences in surface area across the various conditions and time points. This suggests that transportation and storage conditions did not adversely affect the surface area of the eggs, reinforcing the conclusion that both non-spray and spray methods can effectively maintain egg quality.

4.2 INTERNAL PARAMETERS

4.2.1 Haugh Unit

The experimental results of Haugh unit of treated herbal sprayed eggs after transportation presented in the Table no 4.7 & Fig. 16. HU values show the significant ($P<0.05$) difference through experimental period of 24 days. The HU is a critical measurement of egg quality, reflecting the freshness and thickness of the egg white. Higher HU values indicate better quality eggs with firm egg whites. Before the 12 hrs. of transportation, all treatment groups exhibited relatively high HU values, T1 (81.83 ± 1.58), T2 (82.18 ± 1.41), T3 (82.59 ± 1.41) and T4 (82.68 ± 1.42). However, as the study conducted after transportation, a decline in HU values was observed in all treatment groups where, T1 decreased to 77.26 ± 1.63 , T2 dropped to 77.21 ± 0.57 , T3 and T4 shown value of 77.87 ± 0.77 and 77.73 ± 0.73 respectively. The decline in HU values became more pronounced by the 6th day, with T1 - 74.32 ± 0.84 , T2 further sharply decreasing to 68.10 ± 1.31 , T3 to 75.99 ± 1.59 and T4 dropping to 69.74 ± 0.87 . This trend of decreasing HU continues till 24th day of the post transportation, where T1 shown value of 69.33 ± 0.57 , T2 reached lowest point i.e. 54.68 ± 2.66 , T3 recorded a value of

70.06±0.84 and T4 recorded 61.59±0.58. Statistical analysis revealed significant ($P<0.05$) differences in Haugh unit values among the treatment groups shows significance ($P<0.05$) across the measurement periods. The results demonstrate a clear trend of declining Haugh unit values over the 24-day period for all treatment groups, with T2 exhibiting the significant ($P<0.05$) reduction in egg quality compared to T1 and T3 which shows less decline in Haugh Unit.

4.2.2 Albumen Index

The results of Albumen Index of treated herbal sprayed eggs after transportation presented in the Table no. 4.8. Albumen index shows no significant ($P>0.05$) effect in the experiment after the transportation, but storage shows significant ($P<0.05$) difference from 06th day to 24th day. The albumen index is an important indicator of egg internal quality, reflecting the thickness and quality of the egg white, which can be influenced by factors such as storage conditions and egg freshness. Before the transportation, all treatment groups exhibited similar albumen index values, with T1 (0.083±0.005), T2 (0.083±0.005), T3 (0.084±0.004) and T4 (0.083±0.005). These initial measurements indicate a consistent baseline across the groups. As the study recorded albumen index after transportation shows, T1 and T3 shown values 0.076±0.003 and 0.079±0.004, respectively, while T2 decreased to 0.076±0.001 and T4 slightly decreased to 0.078±0.004. By the 6th day, T1 recorded a further decline to 0.072±0.003, T2 continued to significant ($P<0.05$) decrease to 0.063±0.001, T3 shown value of 0.077±0.006 and T4 dropped to 0.066±0.002. The trend of decreasing albumen index values continued to 24th day, where T1 had a value of 0.058±0.004, T2 shows the lowest point in all group at 0.028±0.003, T3 have highest value to 0.065±0.003 and T4 recorded 0.038±0.002. Statistical analysis revealed significant ($P<0.05$) differences in the albumen index among the treatment groups across all time points, indicating that the treatments had a substantial impact on the albumen quality throughout the study. Notably, T2 exhibited the significantly ($P<0.05$) highest reduction in albumen index, suggesting that this treatment may have adversely affected the quality of the egg white over the storage period.

4.2.3 Yolk Index

The experimental results of yolk index of treated herbal sprayed eggs after 12 hrs of transportation presented in the table no. 4.9. Yolk index shows the significant ($P<0.05$) effect

Table 4.7: Effect of Transportation on Haugh unit value over the storage time period

	Before Transportation		After Transportation		06 th Day	12 th Day	18 th Day	24 th Day	P value
	Before Transportation	After Transportation	Before Transportation	After Transportation					
T1 Non-Spray (4-7°C)	81.83±1.58 ^A	77.26±1.63 ^A	74.32±0.84 ^{ABab}	71.94±1.10 ^{BCa}	71.20±0.62 ^{BCa}	69.33±0.57 ^{Ca}	0.000		
T2 Non-Spray (26.5 ± 3°C)	82.18±1.41 ^A	77.21±0.57 ^A	68.10±1.31 ^{Bc}	64.28±0.59 ^{Bcb}	60.96±0.88 ^{Cb}	54.68±1.66 ^{Dc}	0.000		
T3 Spray (4-7°C)	82.59±1.41 ^A	77.87±0.77 ^A	75.99±1.59 ^{ABa}	73.80±1.28 ^{ABCa}	72.05±1.58 ^{BCa}	70.06±0.84 ^{Ca}	0.000		
T4 Spray (26.5 ± 3°C)	82.68±1.42 ^A	77.73±0.73 ^A	69.74±0.87 ^{Bbc}	66.85±1.027 ^{BCb}	63.07±1.45 ^{Cb}	61.59±0.58 ^{Db}	0.000		
P value	0.974	0.955	0.000	0.000	0.000	0.000	0.000		

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.8: Effect of Transportation on albumin index value over the storage time period

	Before Transportation		After Transportation		06 th Day	12 th Day	18 th Day	24 th Day	P value
	Before Transportation	After Transportation	Before Transportation	After Transportation					
T1 Non-Spray (4-7°C)	0.083±0.005 ^A	0.076±0.003 ^A	0.072±0.003 ^{ABab}	0.068±0.003 ^{ABa}	0.063±0.001 ^{ABa}	0.058±0.004 ^{Ba}	0.008		
T2 Non-Spray (26.5 ± 3°C)	0.083±0.005 ^A	0.076±0.001 ^A	0.063±0.001 ^{Bb}	0.046±0.001 ^{Cb}	0.032±0.001 ^{Dc}	0.028±0.003 ^{Dc}	0.000		
T3 Spray (4-7°C)	0.084±0.004 ^A	0.079±0.004 ^A	0.077±0.006 ^{ABa}	0.076±0.003 ^{ABa}	0.071±0.002 ^{ABa}	0.065±0.003 ^{Ba}	0.024		
T4 Spray (26.5 ± 3°C)	0.083±0.005 ^A	0.078±0.004 ^A	0.066±0.002 ^{Bab}	0.056±0.001 ^{Cb}	0.041±0.001 ^{Db}	0.038±0.002 ^{Db}	0.000		
P value	0.999	0.915	0.014	0.000	0.000	0.000	0.000		

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

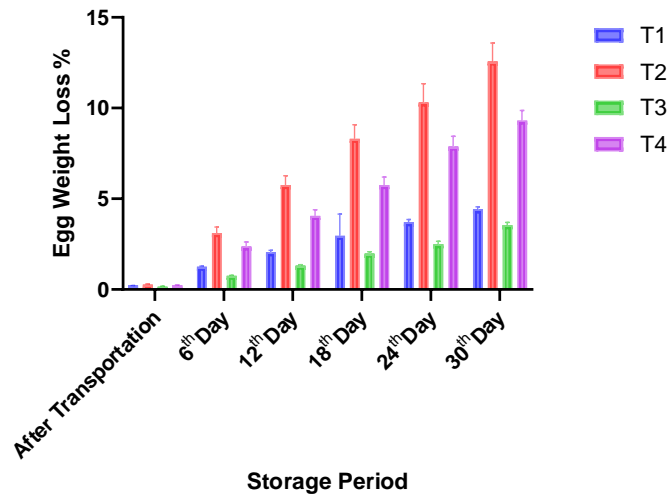


Fig. 14: Loss of egg weight % due to transportation and storage

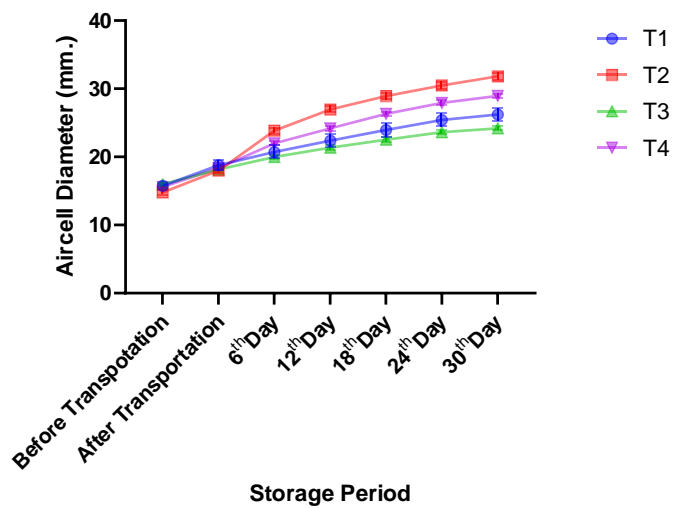


Fig. 15: Increase in air cell due to transportation and storage

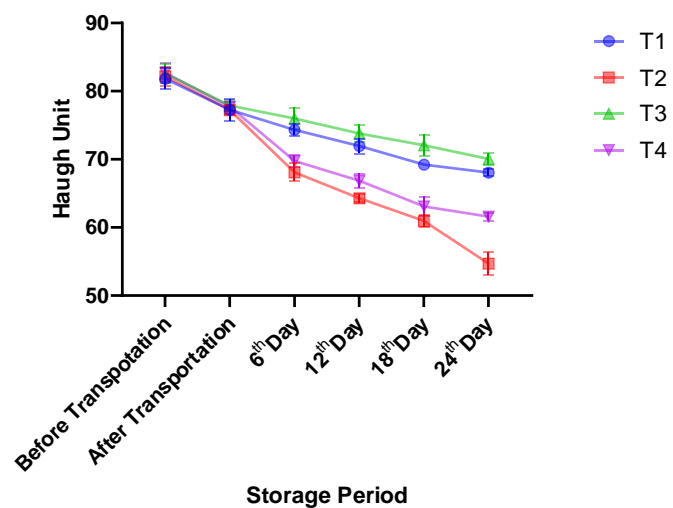


Fig. 16: Haugh Unit value after transportation and storage

in the eggs which are transported for 12 hr and stored till 24th day. The yolk index is a critical measure of egg quality, reflecting the firmness and height of the yolk relative to its width. A higher yolk index indicates a fresher egg with a firmer yolk, which is desirable for both culinary applications and consumer preference. Before transportation, the yolk indices were consistent across all groups, with T1 recording 0.41 ± 0.01 , T2 - 0.42 ± 0.00 , T3 - 0.41 ± 0.01 and T4 - 0.42 ± 0.00 . After transportation no significant ($P > 0.05$) effect were observed. However, as the storage period progressed, significant ($P < 0.05$) changes observed in the yolk index over the 24 days of experiment is observed. After the transportation, reduction in yolk index is seen where T1 shows value - 0.39 ± 0.008 , while T2 showed 0.39 ± 0.008 , T3 - 0.39 ± 0.001 and T4 decreased slightly to 0.39 ± 0.001 . The trend of declining yolk index values became more pronounced by the 24th day T1 recorded a yolk index of 0.36 ± 0.008 , T2 shows least yolk index value of 0.18 ± 0.007 , T3 shows maximum value of 0.37 ± 0.006 and T4 recorded a yolk index of 0.20 ± 0.012 . The results shown that significance ($P < 0.05$) reduction in yolk index values over the 24-day period for all treatment groups, where T2 shows least yolk index value and T3 shows maximum yolk value on 24th day of post-cold storage.

4.2.4 Albumen Weight (%)

The experimental results of Albumen weight percent of treated herbal sprayed eggs after 12 hrs of transportation is presented in the Table no. 4.10. Albumen weight percent values show the comparatively non-significant ($P > 0.05$) difference after the transportation, but over the storage albumen weight percentage shows the significant ($P < 0.05$) difference up to 24th day. Albumen weight is an important indicator of egg quality, as it reflects the freshness and overall integrity of the egg white. Before the transportation, the initial albumen weights for the treatment groups were relatively similar, with T1 measuring 57.6 ± 0.46 %, T2 - 57.12 ± 0.37 %, T3 - 57.04 ± 0.26 % and T4 - 57.34 ± 0.32 %. These values establish a consistent baseline for albumen weight across all groups. However, as the storage period progressed, significant ($P < 0.05$) reduction in albumen weight were observed through 24 days of experiment. after transportation, all groups showed a slight reduction in albumen weight, T1 reduced to 56.78 ± 0.60 %, T2 to 55.84 ± 0.46 %, T3 to 55.86 ± 0.31 % and T4 to 55.31 ± 0.46 %. The reductions in albumen weight at this stage indicate the onset of quality degradation due to

storage. The trend of reduction of albumen weight continued through 06th day to the 24th day, where at 6th day T1 recorded 54.84 ± 0.26 %, T2 at 52.63 ± 0.41 %, T3 maintained a slightly higher value of 55.71 ± 0.36 % and T4 measured 54.05 ± 0.18 %. The differences in albumen weight among the groups began to become more pronounced, 6th day onward. The decline in albumen weight was significant ($P < 0.05$) least for T2, which indicated a considerable loss of quality. By 24th day transportation, T1 recorded an albumen weight of 53.84 ± 0.43 %, T2 showed value of 49.11 ± 0.82 %, T3 measured highest value of 54.63 ± 0.37 % and T4 recorded value 52.76 ± 0.24 %. The significantly ($P < 0.05$) maximum reduction in albumen weight in was observed in T2 group and minimum reduction observed in T3 group.

4.2.5 Yolk Weight (%)

The results of effect of transportation and spray on represented yolk weight percentage and storage over time is presented in Table 4.11. Initially, yolk weight percentage were similar across all treatments, but notable changes emerged as storage progressed. In particular, the non-spray treatment at $26.5 \pm 3^\circ\text{C}$ (T2) showed a remarkable increase in yolk weight, rising from 31.09 ± 0.29 % before the transportation to 37.22 ± 0.15 % by the 24th day, indicating that higher temperatures significantly ($P < 0.05$) enhance yolk retention. The spray treatments showed positive effects, with T4 (spray at $26.5 \pm 3^\circ\text{C}$) increasing from 31.07 ± 0.029 % to 35.44 ± 0.18 %. In contrast, the non-spray treatment at $10-15^\circ\text{C}$ (T1) and the spray treatment at the same temperature (T3) exhibited more modest increases. The statistical analysis highlighted significant ($P < 0.05$) differences in yolk weight from the 6th day onward, particularly in the higher temperature treatments, suggesting that optimizing storage conditions can greatly improve egg quality and reduce post-harvest losses. These findings underscore the importance of managing storage environments to enhance the viability of the egg market.

4.2.6 Yolk Colour

The results of effect of transportation and spray on colour of yolk over storage time is presented in Table 4.12, providing valuable insights into how different treatments impact this important quality parameter. Yolk colour is a key factor in consumer perception and acceptance of eggs and it can be influenced by various factors, including the hens' diet and storage

Table 4.9: Effect of Transportation on yolk index quality over the storage time period

	Before Transportation		After Transportation		06 th Day	12 th Day	18 th Day	24 th Day	P value
	Before Transportation	After Transportation	Before Transportation	After Transportation					
T1 Non-Spray (4-7°C)	0.41±0.01 ^A	0.39±0.008 ^A	0.38±0.006 ^{ABbb}	0.36±0.004 ^{Ba}	0.36±0.004 ^{ABbb}	0.36±0.004 ^{Ba}	0.36±0.008 ^{Cb}	0.011	
T2 Non-Spray (26.5 ± 3°C)	0.42±0.00 ^A	0.39±0.008 ^A	0.33±0.002 ^{Bc}	0.29±0.009 ^{Cc}	0.29±0.009 ^{Cc}	0.20±0.007 ^{Db}	0.18±0.007 ^{Dc}	0.000	
T3 Spray (4-7°C)	0.41±0.01 ^A	0.39±0.01	0.39±0.009 ^a	0.39±0.004 ^a	0.39±0.004 ^a	0.38±0.012 ^a	0.37±0.006 ^a	0.447	
T4 Spray (26.5 ± 3°C)	0.42±0.00 ^A	0.39±0.01 ^A	0.36±0.006 ^{ABb}	0.32±0.015 ^{BCbc}	0.32±0.015 ^{BCbc}	0.29±0.007 ^{Cb}	0.20±0.012 ^{Dc}	0.000	
P value	0.170	0.969	0.000	0.000	0.000	0.000	0.000	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.10: Effect of Transportation on albumin weight (%) over the storage time period

	Before Transportation		After Transportation		06 th Day	12 th Day	18 th Day	24 th Day	P value
	Before Transportation	After Transportation	Before Transportation	After Transportation					
T1 Non-Spray (4-7°C)	57.6±0.46 ^A	56.78±0.6 ^A	54.84±0.26 ^{Bbb}	54.48±0.4 ^{Ba}	54.84±0.4 ^{Ba}	54.39±0.32 ^{Ba}	53.84±0.43 ^{Bbb}	0.000	
T2 Non-Spray (26.5 ± 3°C)	57.12±0.37 ^A	55.84±0.46 ^A	52.63±0.41 ^{Bc}	52.56±0.26 ^{Bb}	52.63±0.41 ^{Bc}	51.39±0.22 ^{Bc}	49.11±0.82 ^{Cc}	0.000	
T3 Spray (4-7°C)	57.04±0.26	55.86±0.31	55.71±0.36 ^a	55.38±0.62 ^a	55.71±0.36 ^a	54.92±0.28 ^a	54.63±0.37 ^a	0.201	
T4 Spray (26.5 ± 3°C)	57.34±0.32 ^A	55.31±0.46 ^A	54.05±0.18 ^{ABb}	53.11±0.54 ^{Bab}	53.11±0.54 ^{Bab}	53.03±0.27 ^{Bb}	52.76±0.24 ^{Bb}	0.000	
P Value	0.991	0.108	0.000	0.012	0.000	0.000	0.000	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.11: Effect of Transportation on yolk weight (%) over the storage time period

	Before Transportation	After Transportation	06 th Day	12 th Day	18 th Day	24 th Day	P value
T1 Non-Spray (4-7°C)	31.07±0.28 ^A	31.73±0.08 ^A	32.15±0.14 ^{ABbc}	32.86±0.25 ^{BCc}	33.46±0.16 ^{CDc}	34.06±0.28 ^{Dc}	0.000
T2 Non-Spray (26.5 ± 3°C)	31.09±0.29 ^A	31.99±0.23 ^A	33.38±0.15 ^{Ba}	34.62±0.12 ^{Ca}	35.75±0.05 ^{Da}	37.22±0.15 ^{Ea}	0.000
T3 Spray (4-7°C)	31.10±0.30 ^A	31.37±0.14 ^A	31.93±0.22 ^{ABc}	32.27±0.24 ^{ABc}	32.58±0.13 ^{BCd}	32.75±0.08 ^{BD}	0.000
T4 Spray (26.5 ± 3°C)	31.07±0.29 ^A	31.55±0.20 ^A	32.8±0.28 ^{Bab}	33.67±0.11 ^{Cb}	34.63±0.1 ^{Db}	35.44±0.18 ^{Eb}	0.000
P Value	0.961	0.114	0.004	0.000	0.000	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P <0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P <0.05)

Table 4.12: Effect of Transportation on yolk color over the storage time period

	Before Transportation	After Transportation	06 th Day	12 th Day	18 th Day	24 th Day	P value
T1 Non-Spray(4-7°C)	8.20±0.26	8.20±0.22	8.00±0.24	8.60±0.18	8.20±0.22	8.40±0.18	0.975
T2 Non-Spray (26.5 ± 3°C)	8.60±0.18	9.00±0.14	8.20±0.17	8.40±0.18	9.00±0.14	8.00±0.20	0.342
T3 Spray (4-7°C)	8.40±0.18	8.00±0.24	8.00±0.24	8.20±0.22	8.20±0.26	8.20±0.22	0.994
T4 Spray (26.5 ± 3°C)	8.20±0.26	8.80±0.17	8.20±0.26	8.80±0.22	8.60±0.18	9.00±0.14	0.771
P value	0.931	0.366	0.992	0.898	0.577	0.395	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P <0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P <0.05)

conditions. The results show that the yolk colour fluctuated within a narrow range across all treatments and time points, with no significant ($P>0.05$) difference was observed. For the non-spray eggs stored at 4-7°C i.e. T1, the yolk colour started at 8.20 ± 0.26 before transportation, decreased slightly to 8.00 ± 0.24 on the 6th day, peaked at 8.60 ± 0.18 on the 12th day, and then returned to 8.20 ± 0.22 and 8.40 ± 0.18 on the 18th and 24th days, respectively. This suggests that the cooler temperatures may have initially caused a slight decrease in yolk colour, but the effect was not sustained over the entire storage duration. The non-spray eggs at $26.5 \pm 3^\circ\text{C}$ i.e. T2 exhibited a more varied pattern, with the yolk colour increasing to 9.00 ± 0.14 after transportation and on the 18th day, while decreasing to 8.00 ± 0.20 on the 24th day. This indicates that the higher temperature had a more pronounced impact on yolk colour compared to the cooler storage conditions. The spray treatments showed a similar pattern, with the yolk colour remaining relatively stable at 8.00 ± 0.24 to 8.40 ± 0.18 for the 4-7°C group (T3) and increasing from 8.20 ± 0.26 to 9.00 ± 0.14 for the $26.5 \pm 3^\circ\text{C}$ group (T4) over the storage period. This suggests that the spraying treatment may have helped maintain a more consistent yolk colour, although the effect was more pronounced at the higher temperature.

4.2.7 Shell Thickness

The effect of transportation on the thickness of eggshells over a storage period IS presented in Table 4.13 & it provides valuable insights into how different treatments impact this crucial quality parameter. The shell thickness is a key indicator of an egg's structural integrity and resistance to damage during handling and storage. The results show that the shell thickness doesn't show significant ($P>0.05$) effect across all treatments and time points, with minor variations observed. For the non-spray eggs stored at 4-7°C (T1), the shell thickness increased slightly from 0.37 ± 0.00 before transportation to 0.38 ± 0.00 after transportation and on the 6th and 12th days, before returning to 0.37 ± 0.00 for the remainder of the storage period. The non-spray eggs at $26.5 \pm 3^\circ\text{C}$ exhibited a similar pattern, with the shell thickness increasing numerically to 0.38 ± 0.00 on the 6th, 18th and 24th days, while remaining at 0.37 ± 0.00 for the other time points. The spray treatments, both at 4-7°C and $26.5 \pm 3^\circ\text{C}$, showed more consistent shell thickness values, remaining at 0.37 ± 0.00 throughout the storage period, except for a slight decrease to 0.37 ± 0.00 after transportation for the $26.5 \pm 3^\circ\text{C}$ group. This suggests

that the spraying treatment may have helped maintain a more stable shell thickness, regardless of temperature.

4.3 pH (Power of Hydrogen)

4.3.1 pH of Whole Egg

The results of effect of transportation and spray on whole egg pH over storage time is presented in Table 4.14 & Fig. 17. Before transportation, the initial pH values across the treatment groups were relatively similar, with T1 (Non-Spray at 4-7°C) recording a pH of 7.16 ± 0.06 , T2 (Non-Spray at $26.5 \pm 3^\circ\text{C}$) at 7.09 ± 0.09 , T3 (Spray at 4-7°C) at 7.09 ± 0.06 and T4 (Spray at $26.5 \pm 3^\circ\text{C}$) at 7.07 ± 0.09 . After 12 hrs of transportation, T1 showed a slight increase to 7.24 ± 0.01 , while T2 rose to 7.24 ± 0.01 . T3 and T4 remained relatively stable at 7.11 ± 0.04 and 7.19 ± 0.03 , respectively. From the 6th day onward, significant ($P < 0.05$) changes were observed in the pH levels. T1 continued to increase, reaching 7.53 ± 0.12 by the 24th day. T2 exhibited the most substantial increase, climbing to 8.13 ± 0.11 by the end of the storage period, demonstrating a strong correlation between higher temperature and pH enhancement. T3 showed a gradual increase in pH from 7.09 to 7.49, while T4 increased from 7.07 to 7.74, showed significant increase. Overall, the findings suggest that cold storage conditions, particularly at higher temperatures and with herbal spray treatments, significantly influence the pH levels of eggs over time, which is crucial for maintaining egg quality during storage.

4.3.2 pH of Albumen

The results of the effect of transportation on albumen pH over the storage period is presented in Table 4.15 & Fig. 18. The 12 hrs. Transportation doesn't show significant effect ($P > 0.05$) on Albumen pH. Before, the initial albumen pH values across the treatment groups were relatively similar, with T1 recording an average pH of 7.79 ± 0.09 , T2 at 7.87 ± 0.07 , T3 at 7.72 ± 0.1 and T4 at 7.76 ± 0.07 . while after transportation, T1, T2, T3, and T4 had pH values of 7.89 ± 0.05 , 7.89 ± 0.05 , 7.93 ± 0.02 and 7.79 ± 0.02 , respectively. After the 6th day onward, significant ($P < 0.05$) changes were observed, particularly in T1 and T2, which continued to show increases in pH. T1 reached a final pH of 8.33 ± 0.10 by the 24th day, with a statistically

Table 4.13: Effect of Transportation in thickness of shell (mm) over the storage time period

	Before Transportation	After Transportation	06 th Day	12 th Day	18 th Day	24 th Day	P value
T1 Non-Spray (4-7°C)	0.37±0.00	0.38±0.00	0.38±0.00	0.37±0.00	0.37±0.00	0.37±0.00	0.561
T2 Non-Spray (26.5 ± 3°C)	0.37±0.00	0.37±0.00	0.38±0.00	0.37±0.00	0.38±0.00	0.38±0.00	0.351
T3 Spray (4-7°C)	0.37±0.00	0.37±0.00	0.37±0.00	0.37±0.00	0.37±0.00	0.37±0.00	0.987
T4 Spray (26.5 ± 3°C)	0.38±0.00	0.37±0.00	0.37±0.00	0.37±0.00	0.37±0.00	0.37±0.00	0.462
P value	0.510	0.547	0.299	0.907	0.698	0.319	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.14: Effect of Transportation on the pH of an egg over the storage time period

	Before Transportation	After Transportation	06 th Day	12 th Day	18 th Day	24 th Day	P value
T1 Non-Spray (4-7°C)	7.16±0.06 ^{BC}	7.24±0.01 ^{BCa}	7.28±0.01 ^{BCb}	7.38±0.09 ^{ABCb}	7.47±0.11 ^{Ab}	7.53±0.12 ^{Ab}	0.012
T2 Non-Spray (26.5 ± 3°C)	7.09±0.09 ^D	7.24±0.01 ^{Da}	7.41±0.03 ^{CDa}	7.55±0.03 ^{Ca}	7.89±0.10 ^{Ba}	8.13±0.11 ^{Aa}	0.000
T3 Spray (4-7°C)	7.09±0.06 ^B	7.19±0.03 ^{Bb}	7.11±0.04 ^{ABc}	7.27±0.10 ^{ABc}	7.35±0.06 ^{Ab}	7.49±0.05 ^{Ab}	0.000
T4 Spray (26.5 ± 3°C)	7.07±0.09 ^C	7.19±0.03 ^{Cb}	7.26±0.03 ^{Cb}	7.49±0.07 ^{Bb}	7.66±0.05 ^{ABab}	7.74±0.07 ^{Ab}	0.000
P value	0.800	0.249	0.000	0.000	0.000	0.000	0.000

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

significant ($P < 0.05$), indicating a strong correlation between treatment and pH increase. T2 also demonstrated a significant increase, reaching 8.88 ± 0.17 by the end of the storage period. While T3 showed pH of 8.23 ± 0.06 on day 24). The T4 group exhibited significant ($P < 0.05$) increase in pH from 7.76 to 8.74 by the 24th day. Overall, the results indicate that cold storage significantly affects the albumen pH of eggs over time, with T2 and T4 showing the most substantial increases, while T3 maintained a relatively stable pH throughout the study.

4.3.3 pH of Yolk

The results presented in Table 4.16 & Fig. 19 shown the effect of transportation on the yolk pH of eggs over time. Effect of 12hrs. transportation showed no significant ($P > 0.05$) effect on the yolk pH of egg & continued same trend till 12th day of storage post transportation. Before transportation, the initial yolk pH values across the treatment groups were relatively similar, with T1 (Non-Spray at 4-7°C) at 6.21, T2 (Non-Spray at $26.5 \pm 3^\circ\text{C}$) at 6.17, T3 (Spray at 4-7°C) at 6.17, and T4 (Spray at $26.5 \pm 3^\circ\text{C}$) at 6.16, indicating a consistent baseline. After transportation, T1, T2, T3, and T4 had pH values of 6.24, 6.25, 6.19 and 6.19, respectively. Till 12th day, no significant ($P > 0.05$) difference was observed, particularly in T1 and T2, which continued to show increases in pH. The T1 group reached a final pH of 6.57 by the 24th day, indicating a strong correlation between treatment and pH increase. The T2 group also demonstrated a significant ($P < 0.05$) increase, reaching 7.05 by the end of the storage period. The T3 showed increase throughout the study, ending with a pH of 6.52 on day 24 and with significance ($P < 0.05$) T4 exhibited a significant increase in pH from 6.16 to 6.85 by the 24th days. Overall, the results indicate that cold storage significantly affects the yolk pH of eggs over time, with T2 and T4 showing the most substantial increases, while T3 maintained a relatively stable pH throughout the study.

4.4 MICROBIAL PARAMETER

4.4.1 Total Plate Count (TPC)

The results of the Total Plate Counts (TPC) of transported eggs are illustrated in Figure 20. Before transportation, the initial TPC values across the treatment groups were relatively low, with T1 (Non-Spray at 4-7°C) recording 1.98 ± 0.05 , T2 (Non-Spray at 26.5

$\pm 3^{\circ}\text{C}$) at 1.87 ± 0.04 , T3 (Spray at $4-7^{\circ}\text{C}$) at 2.13 ± 0.04 , and T4 (Spray at $26.5 \pm 3^{\circ}\text{C}$) at 1.92 ± 0.04 . After transportation, TPC values increased significantly ($P<0.05$) for all groups, with T1 at 2.87 ± 0.04 , T2 at 2.76 ± 0.03 , T3 at 2.25 ± 0.06 and T4 at 2.19 ± 0.05 . Notably, from the 6th day onward, significant ($P<0.05$) increases in TPC were observed across all treatments, particularly in T2, which reached 6.20 ± 0.04 by the 24th day, indicating a strong correlation between higher storage temperatures and microbial growth. The T1 also showed a substantial increase, reaching 5.10 ± 0.03 by the end of the storage period. T3 maintained the lowest TPC values throughout the experiment, ending at 4.50 ± 0.03 , while T4 increased to 5.73 ± 0.05 by day 24. The statistical analysis revealed significant ($P<0.05$) differences in TPC among the treatments, particularly evident from the 6th day onward, suggesting that both storage temperature and the application of herbal sprays play a crucial role in controlling microbial growth in eggs during transport. Overall, the findings highlight the importance of managing storage conditions to maintain egg quality and safety during transportation.

4.4.2 *Escherichia Coli*

The results of *E. coli* count in transported eggs are depicted in Figure 21. Before transportation, the initial *E. coli* levels were low across all treatment groups, with T1 (Non-Spray at $4-7^{\circ}\text{C}$) showing 0.24 ± 0.04 , T2 (Non-Spray at $26.5 \pm 3^{\circ}\text{C}$) at 0.23 ± 0.04 , T3 (Spray at $4-7^{\circ}\text{C}$) at 0.25 ± 0.04 , and T4 (Spray at $26.5 \pm 3^{\circ}\text{C}$) at 0.23 ± 0.03 . After transportation, slight increases were observed in all groups, with T1 at 0.61 ± 0.05 , T2 at 0.64 ± 0.04 , T3 at 0.59 ± 0.04 , and T4 at 0.52 ± 0.04 . As the storage period progressed, particularly from the 6th day onward, significant ($P<0.05$) increases in *E. coli* counts were noted. T1 reached 2.30 ± 0.04 by the 24th day, while T2 increased to 2.89 ± 0.04 , indicating that higher storage temperatures significantly ($P<0.05$) promote bacterial growth. T3 maintained lower *E. coli* levels throughout the storage period, ending at 1.92 ± 0.04 by day 24, whereas T4 also showed a notable increase to 2.62 ± 0.03 . The statistical analysis revealed significant ($P<0.05$) differences in *E. coli* counts among the treatments, particularly from the 6th day onwards, suggesting that both the storage temperature and the application of herbal sprays play a crucial role in controlling *E. coli* growth in eggs during transport. Overall, these findings underscore the importance of effective storage conditions to ensure the microbiological safety of eggs during transportation.

Table 4.15: Effect of Transportation on the albumin pH over the storage time period

	Before Transportation	After Transportation	06 th Day	12 th Day	18 th Day	24 th Day	P value
T1 Non-Spray (4-7°C)	7.79±0.09 ^C	7.89±0.05 ^C	7.97±0.07 ^{BC}	8.08±0.04 ^{BCbc}	8.20±0.01 ^{ABb}	8.33±0.10 ^{ABc}	0.000
T2 Non-Spray (26.5 ± 3°C)	7.87±0.07 ^E	7.89±0.05 ^E	8.12±0.03 ^{DE}	8.39±0.07 ^{Ca}	8.63±0.03 ^{Ba}	8.88±0.17 ^{Aa}	0.000
T3 Spray (4-7°C)	7.72±0.1 ^B	7.79±0.02 ^B	7.83±0.04 ^B	7.91±0.03 ^{Bc}	8.01±0.05 ^{Ab}	8.23±0.06 ^{Ac}	0.000
T4 Spray (26.5 ± 3°C)	7.76±0.07 ^D	7.79±0.02 ^D	8.03±0.18 ^{CD}	8.28±0.12 ^{BCab}	8.57±0.08 ^{ABa}	8.74±0.10 ^{ab}	0.000
P Value	0.813	0.762	0.237	0.002	0.00	0.003	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P <0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P <0.05)

Table 4.16: Effect of Transportation on the yolk pH over the storage time period

	Before Transportation	After Transportation	06 th Day	12 th Day	18 th Day	24 th Day	P value
T1 Non-Spray(4-7°C)	6.21±0.05 ^B	6.24±0.02 ^B	6.29±0.02 ^{AB}	6.44±0.10 ^{AB}	6.51±0.12 ^{ABab}	6.57±0.07 ^{Ab}	0.013
T2 Non-Spray (26.5 ± 3°C)	6.17±0.02 ^E	6.25±0.02 ^E	6.45±0.13 ^{DE}	6.62±0.05 ^{CD}	6.82±0.04 ^{BCa}	7.05±0.11 ^{Aa}	0.000
T3 Spray (4-7°C)	6.17±0.05 ^B	6.19±0.04 ^B	6.21±0.04 ^{AB}	6.31±0.08 ^{AB}	6.40±0.03 ^{ABb}	6.52±0.04 ^{Ab}	0.000
T4 Spray (26.5 ± 3°C)	6.16±0.02 ^D	6.19±0.04 ^D	6.34±0.08 ^{CD}	6.53±0.08 ^{BC}	6.71±0.11 ^{ABab}	6.85±0.04 ^{Aa}	0.000
P Value	0.774	0.381	0.248	0.067	0.017	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P <0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P <0.05)

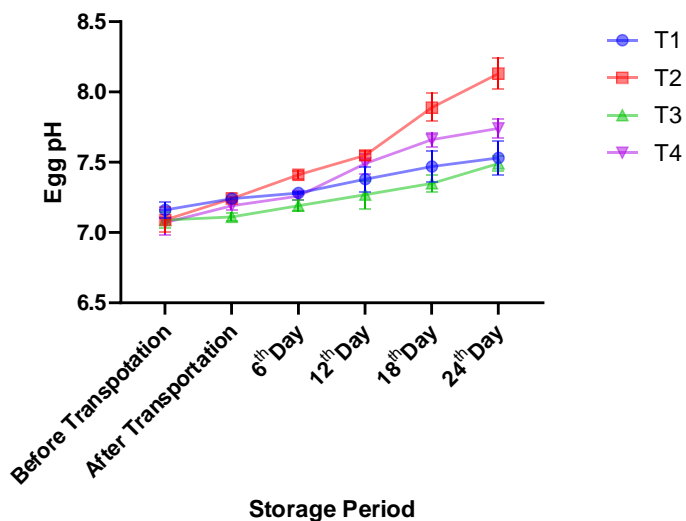


Fig. 17: Egg pH after the transportation and storage

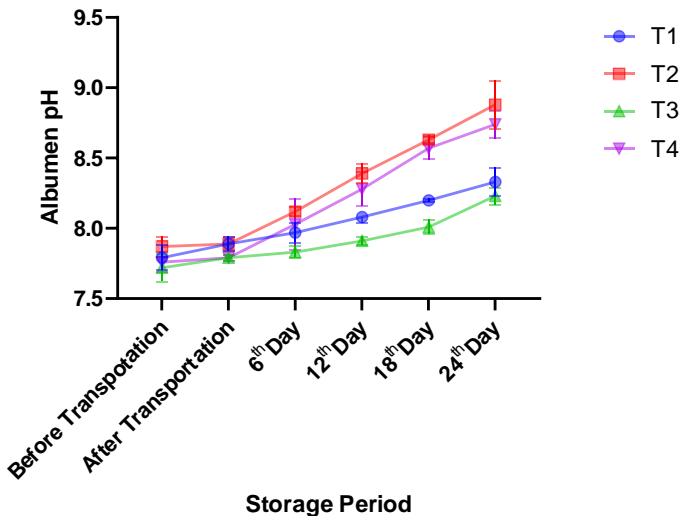


Fig. 18: Albumen pH after the transportation and storage

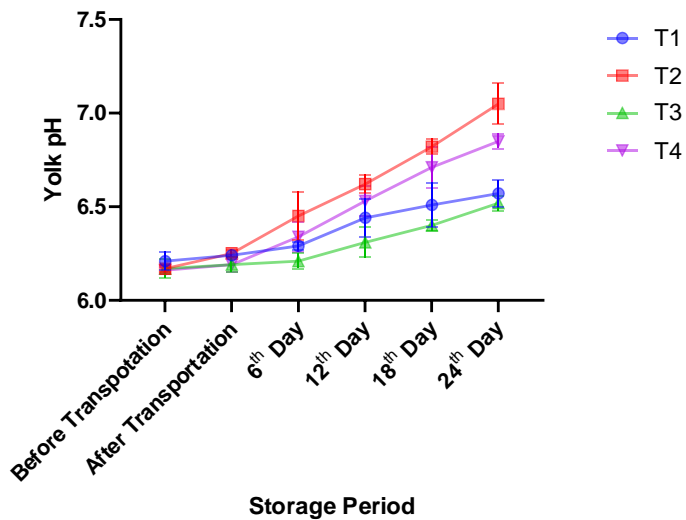


Fig. 19: Yolk pH after the transportation and storage

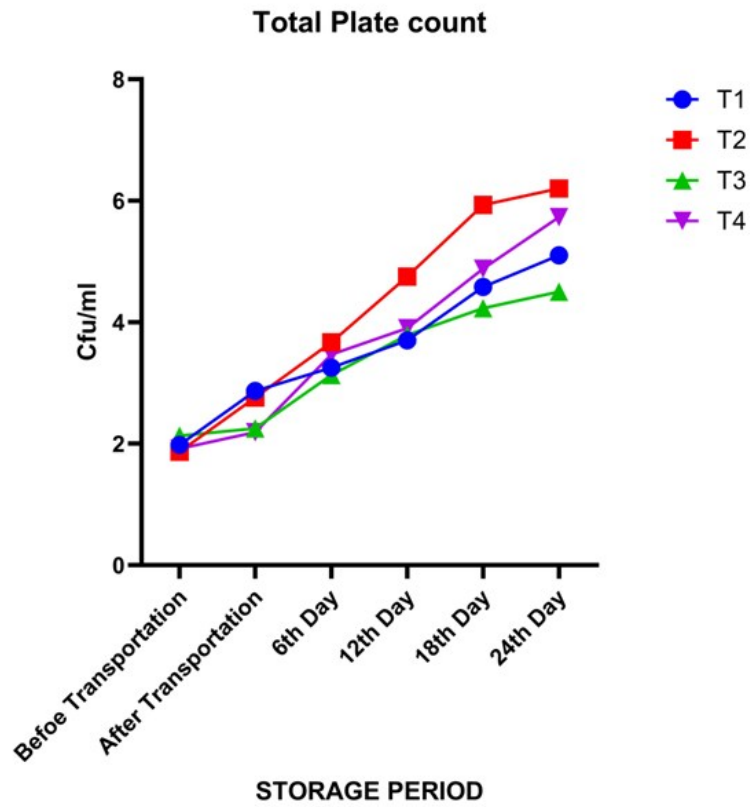


Fig. 20: Results of Total Plate Counts of transported eggs

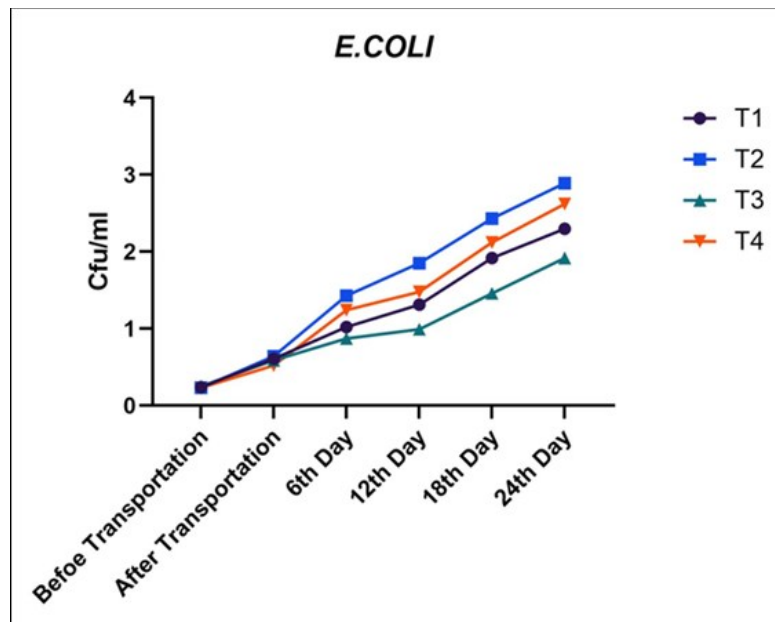


Fig. 21: Results of E.Coli of transported eggs

Objective 02: To study the effect of herbal-based egg spray on cold stored eggs for improving shelf life

4.5 EXTERNAL PARAMETERS:

4.5.1 Egg Weight

The result of effect of herbal sprayed and one month of cold storage on egg weight is presented in Table no. 4.17. Post one month of cold storage *i.e.* 30th and 36th to 60th day there was no Significance ($P>0.05$) difference in the egg weight of different treatment group. This trend was changed continued from 30th day post cold storage till 60th day of storage. On the 0th day, the initial weights of the eggs across the treatment groups were comparable, with T1 recording an average weight of 51.95 ± 0.87 g, T2 - 51.31 ± 0.53 g, T3 - 51.82 ± 0.59 g and T4 - 52.11 ± 0.97 g. after 30th day of cold storage, T1, T2, T3 and T4 had weights of 50.43 ± 0.94 g, 49.05 ± 0.63 g, 49.60 ± 0.67 g and 50.06 ± 0.97 g respectively. From the 30th to the 60th day, T2 continued to show a significant ($P<0.05$) decline, reaching a final weight of 41.68 ± 1.15 g on day 60. As the storage period increases, significant ($P<0.05$) comparative weight loss was observed in all groups. T2 group had the lowest weights recorded throughout the study and demonstrated a statistically significant ($P<0.05$) difference, indicating a strong correlation between treatment and weight loss. Another side T3 shows maximum a relatively stable weight throughout the duration of the experiment, ending with a weight of 48.17 ± 0.99 g on day 60. The T1 and T4 also showed a gradual decline in weight, with 48.13 ± 0.51 & 45.26 ± 1.39 g values respectively on day 60. This indicates statistically significant ($P<0.05$) differences in weight loss compared to the control group. Overall, the results indicate that the treatments shown significant ($P<0.05$) effect egg weight over the time, with T2 showing the most substantial weight loss, while T3 maintained the highest average weight throughout the study.

4.5.2 Egg Weight Loss (%)

The results presented in the Table no. 4.18 & Fig. 22 shows the changes in egg weight loss percentage of herbal sprayed eggs after the one month of cold storage. Post one month of cold storage on the 30th day, T1 recorded an egg weight loss percentage of 2.22 ± 0.13 %, which was comparatively lower than that of T2, which had the highest percentage at 2.26 ± 0.25 %. The T3 and T4 displayed intermediate values, with T3 - 1.53 ± 0.31 % and T4

- 2.05 ± 0.35 %. As the storage period progressed to the 36th day, T2 continued to show a significant ($P < 0.05$) increase in egg weight loss percentage, reaching 3.52 ± 0.41 %, while T1 shows shown loss of 2.44 ± 0.13 %. T3 and T4 also exhibited increase in Egg weight loss, with 1.98 ± 0.36 % and 2.63 ± 0.35 % value respectively. By the 60th day of experiment, similar trend of significant ($P < 0.05$) increasing egg weight loss percentage was observed where T2 recorded a highest egg weight loss percentage of 9.63 ± 0.91 % followed by T4 - 6.85 ± 1.19 %. During this complete experiment least increase in egg weight loss percentage seen in T1 which ended to 3.78 ± 0.10 %, T3 - 3.69 ± 0.50 %. The statistical analysis indicated significant ($P < 0.05$) differences among all the treatments, where T2 shows highest egg weight loss percentage at the 60th day.

4.5.3 Air cell Diameter

The result of effect of herbal sprayed and one month of cold storage on Air Cell Diameter is presented in Table no. 4.19 & Fig. 23. The air cell diameter shows comparatively significant ($P < 0.05$) difference over the 60 days of experimental period. On the 0th day of cold storage, the air cell sizes for the treatment groups were relatively similar, with T1 measuring 16.79 ± 0.56 mm, T2 - 16.73 ± 0.39 mm, T3 - 17.25 ± 0.20 mm and T4 - 17.66 ± 0.51 mm. These initial measurements indicate a consistent baseline across all treatment groups. As the study progressed to the post one month of cold storage on 30th day, increases in air cell diameter were observed across all treatment groups. T1 increased to 26.39 ± 0.51 mm, T2 to 27.47 ± 0.34 mm, T3 to 25.44 ± 0.11 mm and T4 to 26.18 ± 0.70 mm. More increased air cell diameter found in T1 and T2 which are non-sprayed eggs than sprayed eggs *i.e.* T3 and T4 eggs. On the 36th day, T1 continued to show an increase in Air cell diameter to 27.26 ± 0.44 mm, while T2 further sharply expanded to 29.19 ± 0.33 mm, T3 showed a slight increase to 25.58 ± 0.17 mm and T4 reached 26.91 ± 0.71 mm. The trend of increasing air cell size continued to the 60th day showed where maximum significant ($P < 0.05$) air cell value observed in T2 - 35.25 ± 0.37 followed by T4 - 32.33 ± 0.95 , T1 - 29.73 ± 0.33 and then T3 - 27.93 ± 0.34 . Statistical analysis revealed significant ($P < 0.05$) differences in air cell size indicating that the treatments had a significant ($P < 0.05$) impact on the size of the air cell throughout the study period. The findings demonstrate a clear trend of increasing air cell size over the 60-day period for all treatment groups, with T2 exhibiting the highest increase.

Table 4.17: Effect of cold storage on weight of an egg (%) over the storage time period

	Cold Storage (10-15°C)							P Value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	60 th Day	
T1 Non-Spray (10-15°C)	51.95±0.87 ^A	50.43±0.94 ^{AB}	49.97±0.95 ^{AB}	49.75±0.95 ^{AB}	48.89±0.66 ^{Bab}	48.47±0.56 ^{Bab}	48.13±0.51 ^{Bab}	0.003
T2 Non-Spray (26.5 ± 3°C)	51.31±0.53 ^A	49.05±0.63 ^{AB}	47.79±0.73 ^{ABC}	46.33±0.8 ^{BCD}	44.47±0.94 ^{DEB}	43.64±1.22 ^{EFA}	41.68±1.15 ^{Fe}	0.000
T3 Spray (10-15°C)	51.82±0.59	49.6±0.67	49.38±0.67	49.31±0.68	49.15±0.96 ^a	48.77±0.96 ^a	48.17±0.99 ^a	0.135
T4 Spray (26.5 ± 3°C)	52.11±0.97 ^A	50.06±0.97 ^{AB}	49.48±0.93 ^{AB}	48.38±1.1 ^{AB}	47.36±1.18 ^{ABb}	46.32±1.27 ^{Bb}	45.26±1.39 ^{BCab}	0.001
P value	0.892	0.667	0.288	0.050	0.005	0.004	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d,e} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.18: Effect of cold storage in percentage of egg weight loss (%) over the storage time period

	30 th Day Cold Storage (10-15°C)							P Value
	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	60 th Day		
T1 Non-Spray (10-15°C)	2.22±0.13 ^D	2.44±0.13 ^{Dbb}	2.51±0.12 ^{CDb}	2.93±0.08 ^{BCb}	3.35±0.04 ^{ABb}	3.78±0.1 ^{Ab}	0.00	
T2 Non-Spray (26.5 ± 3°C)	2.26±0.25 ^E	3.52±0.41 ^{Da}	4.98±0.48 ^{Ca}	6.85±0.66 ^{BCa}	7.67±1.02 ^{ABa}	9.63±0.91 ^{Aa}	0.000	
T3 Spray (10-15°C)	1.53±0.31 ^B	1.98±0.36 ^{ABb}	2.2±0.37 ^{ABCb}	2.81±0.4 ^{ABCb}	3.19±0.41 ^{ABb}	3.69±0.5 ^{Ab}	0.002	
T4 Spray (26.5 ± 3°C)	2.05±0.35 ^C	2.63±0.35 ^{BCab}	3.73±0.63 ^{ABab}	4.75±0.81 ^{ABab}	5.79±1 ^{ABab}	6.85±1.19 ^{Aa}	0.000	
P value	0.226	0.018	0.000	0.000	0.000	0.000		

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

4.5.4 Specific Gravity

The effect of herbal spray & one month of cold storage of egg on results of specific gravity is presented in the Table no. 4.20. It shows significant ($P < 0.05$) difference among all treatments over the period of 60 days. Specific gravity is an important parameter that can provide insights into the quality and freshness of eggs, as it is influenced by factors such as air cell size and egg weight. On the 0th day, all treatment groups exhibited similar specific gravity values, with T1 - 1.080 ± 0.028 , T2 - 1.080 ± 0.003 , T3 - 1.083 ± 0.002 and T4 - 1.080 ± 0.003 . These initial measurements indicate a consistent baseline across the groups. As the study progressed till one month of cold storage on 30th day shows significant ($P < 0.05$) reduction in specific gravity, T1 decreased slightly to 1.073 ± 0.002 , while T2 shows reduction in specific gravity to 1.069 ± 0.002 . T3 shown a value of 1.077 ± 0.002 and T4 recorded a specific gravity of 1.072 ± 0.003 . By the 36th day, a significant ($P < 0.05$) decline was observed in T2 at 1.05 ± 0.003 followed by T1 - 1.067 ± 0.002 , T4 - 1.064 ± 0.002 & T3 - 1.070 ± 0.003 . The trend of decreasing specific gravity on 36th day continued through the measuring period of experiment *i.e.* 60th day, where T1 reached 1.047 ± 0.002 , T2 sharply decrease to 1.030 ± 0.003 , T3 shown a value of 1.053 ± 0.002 and T4 recorded 1.043 ± 0.002 . The sharp reduction in specific gravity was seen in the T2 group versus T3 group which shows the value of 1.053 ± 0.002 by the end of experiment on 60th day. Statistical analysis indicated significant ($P < 0.05$) differences in specific gravity among the treatment groups across all time points.

4.5.5 Shape Index

The result of effect of herbal sprayed and one month of cold storage on Shape index is presented in Table no. 4.21. Throughout the study, the shape indices for each treatment group remained non-significant ($P > 0.05$) over the time. On the 0th day, the shape indices for the treatment groups were as follows: T1 recorded a shape index of 75.49 ± 1.05 , T2 measured 74.48 ± 0.53 , T3 had a shape index of 75.71 ± 0.96 and T4 registered 74.27 ± 0.59 . Notably all groups exhibited very little variation in their shape indices, maintaining their initial values across all measurement days. The shape index is a critical parameter for assessing the overall quality and appearance of eggs, as it reflects their physical form.

4.5.6 Surface Area

The effect of herbal spray & one month of cold storage of egg on results of Surface Area (mm^2) is presented in the Table no. 4.22. There is no significance ($P>0.05$) difference was observed because these values remained unchanged across all measurement days, from the 0th day through to the 60th day of experiment. Each treatment group exhibited consistent values throughout the study, indicating stability in the measured parameter. On the 0th day, the average values for each treatment group were as follows: T1 recorded 65.08 ± 0.86 , T2 measured 65.98 ± 0.86 , T3 had a value of 64.84 ± 0.73 and T4 registered 65.87 ± 0.87 . On the 60th day Surface area remains same as T1 - 65.08 ± 0.86 , T2 - 65.98 ± 0.86 , T3 - 64.84 ± 0.73 and T4 - 65.87 ± 0.87 . This lack of variation suggests that the experimental conditions did not affect the parameter indicating a high level of stability and consistency across all groups through the period.

4.6 INTERNAL PARAMETER

4.6.1 Haugh Unit

The effect of herbal spray & one month of cold storage of egg on results of Haugh Unit is presented in the Table no. 4.23 & Fig. 24. The HU values show the significant ($P<0.05$) difference throughout the experimental period of 54 days. The HU is a critical measurement of egg quality, reflecting the freshness and thickness of the egg white. Higher HU values indicate better quality eggs with firm egg whites. On the 0th day i.e. before the cold storage, all treatment groups exhibited relatively high HU values, with T1 - 81.83 ± 1.58 , T2 - 82.18 ± 1.41 , T3 - 82.59 ± 1.41 and T4 - 82.68 ± 1.42 . However, after time of one month of cold storage, a decline in HU values was observed in all treatment groups. By the 30th day i.e. post one month of cold storage, T1 decreased to 73.74 ± 0.58 , T2 dropped to 72.84 ± 1.36 , T3 and T4 shown value to 80.23 ± 1.54 and 80.57 ± 1.38 respectively. The decline in HU values became more pronounced by the 36th day, with T1 - 72.02 ± 1.42 , T2 further sharply decreasing to 63.78 ± 1.29 , T3 records decrease to 72.62 ± 1.64 and T4 dropping to 66.04 ± 3.7 . This trend of decreasing HU continues to the 54th day of the post-cold storage, where T1 ended at 65.85 ± 0.42 , T2 reached lowest point at 48.14 ± 0.66 , T3 shown a value of 66.75 ± 0.74 and

Table 4.19: Effect of cold storage on the air cell diameter over the storage time period

	Cold Storage (10-15°C)							P Value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	60 th Day	
T1 Non-Spray (10-15°C)	16.79±0.56 ^A	26.39±0.51 ^{ABab}	27.26±0.44 ^{ACb}	27.42±0.45 ^{BCab}	27.91±0.35 ^{BCC}	28.84±0.49 ^{Cc}	29.73±0.33 ^{Dc}	0.000
T2 Non-Spray (26.5 ± 3°C)	16.73±0.39 ^A	27.47±0.34 ^{Ba}	29.19±0.33 ^{BCa}	30.91±0.38 ^{Ca}	32.3±0.25 ^{Da}	33.73±0.36 ^{Ea}	35.25±0.37 ^{fa}	0.000
T3 Spray (10-15°C)	17.25±0.2 ^A	25.44±0.11 ^{Ab}	25.58±0.17 ^{Bb}	26.14±0.17 ^{Bc}	26.16±0.23 ^{Bc}	27.23±0.22 ^{Bc}	27.93±0.34 ^{Cc}	0.000
T4 Spray (26.5 ± 3°C)	17.66±0.51 ^A	26.18±0.7 ^{ABab}	26.91±0.71 ^{ABCb}	28.15±0.72 ^{BCDb}	29.4±0.66 ^{CDb}	30.96±0.84 ^{Db}	32.33±0.95 ^{Eb}	0.000
P value	0.411	0.033	0.000	0.000	0.000	0.000	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d,e} are Significantly Different (P <0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P <0.05)

Table 4.20: Effect of cold storage on specific gravity of an egg over the storage time period

	Cold Storage (10-15°C)							P Value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	60 th Day	
T1 Non-Spray (10-15°C)	1.080±0.028 ^A	1.073±0.002 ^{ABab}	1.067±0.002 ^{BCa}	1.060±0.003 ^{BCDa}	1.057±0.002 ^{CDb}	1.053±0.002 ^{CDab}	1.047±0.002 ^{bab}	0.000
T2 Non-Spray (26.5 ± 3°C)	1.080±0.003 ^A	1.069±0.002 ^{Bc}	1.050±0.003 ^{Cb}	1.047±0.002 ^{CDb}	1.040±0.003 ^{CDcc}	1.037±0.002 ^{Dcc}	1.030±0.003 ^{Ec}	0.000
T3 Spray (10-15°C)	1.083±0.002 ^A	1.077±0.002 ^{ABa}	1.070±0.003 ^{BCa}	1.067±0.002 ^{Ca}	1.064±0.002 ^{Ca}	1.057±0.002 ^{Da}	1.053±0.002 ^{Da}	0.000
T4 Spray (26.5 ± 3°C)	1.080±0.003 ^A	1.072±0.003 ^{ABab}	1.064±0.002 ^{BCa}	1.060±0.003 ^{BCa}	1.053±0.002 ^{CDb}	1.047±0.002 ^{Db}	1.043±0.002 ^{Db}	0.000
P value	0.999	0.026	0.000	0.000	0.000	0.000	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d,e} are Significantly Different (P <0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P <0.05)

Table 4.21: Effect of cold storage on shape index of an egg over the storage time period

	Cold Storage (10-15°C)						P Value	
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day		60 th Day
T1 Non-Spray (10-15°C)	75.49±1.05	75.49±1.05	75.49±1.05	75.49±1.05	75.49±1.05	75.49±1.05	75.49±1.05	1.00
T2 Non-Spray (26.5 ± 3°C)	74.48±0.53	74.48±0.53	74.48±0.53	74.48±0.53	74.48±0.53	74.48±0.53	74.48±0.53	1.00
T3 Spray (10-15°C)	75.71±0.96	75.71±0.96	75.71±0.96	75.71±0.96	75.71±0.96	75.71±0.96	75.71±0.96	1.00
T4 Spray (26.5 ± 3°C)	74.27±0.59	74.27±0.59	74.27±0.59	74.27±0.59	74.27±0.59	74.27±0.59	74.27±0.59	1.00
P value	0.765	0.765	0.765	0.765	0.765	0.765	0.765	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.22: Effect of cold storage on surface area (mm²) of egg over the storage time period

	Cold Storage (10-15°C)						P Value	
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day		60 th Day
T1 Non-Spray (10-15°C)	65.08±0.86	65.08±0.86	65.08±0.86	65.08±0.86	65.08±0.86	65.08±0.86	65.08±0.86	1.00
T2 Non-Spray (26.5 ± 3°C)	65.98±0.86	65.98±0.86	65.98±0.86	65.98±0.86	65.98±0.86	65.98±0.86	65.98±0.86	1.00
T3 Spray (10-15°C)	64.84±0.73	64.84±0.73	64.84±0.73	64.84±0.73	64.84±0.73	64.84±0.73	64.84±0.73	1.00
T4 Spray (26.5 ± 3°C)	65.87±0.87	65.87±0.87	65.87±0.87	65.87±0.87	65.87±0.87	65.87±0.87	65.87±0.87	1.00
P value	0.697	0.765	0.765	0.765	0.765	0.765	0.765	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

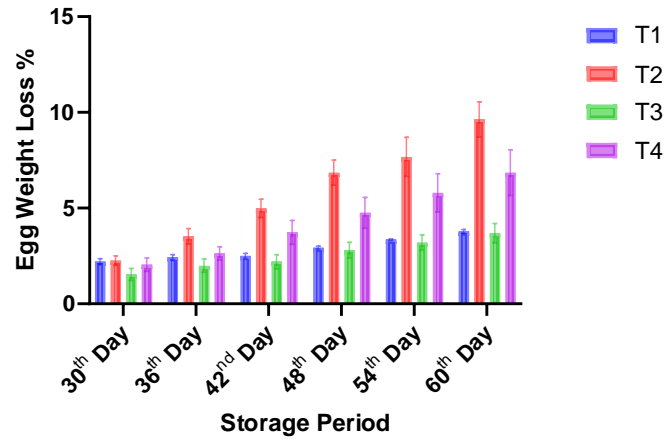


Fig. 22: Loss of egg weight % after one month of cold stored eggs

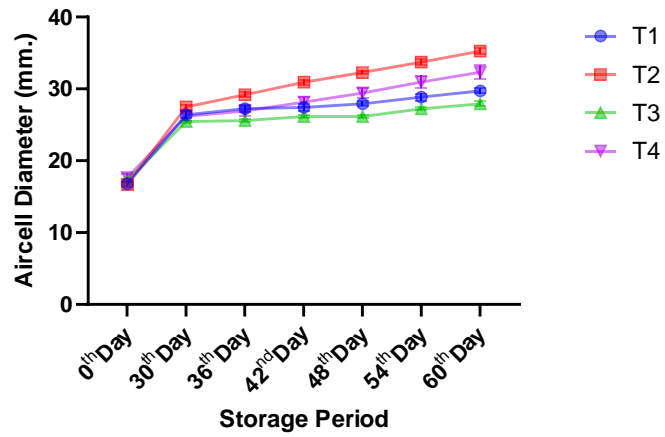


Fig. 23: Increase in air cell after one month of cold stored eggs

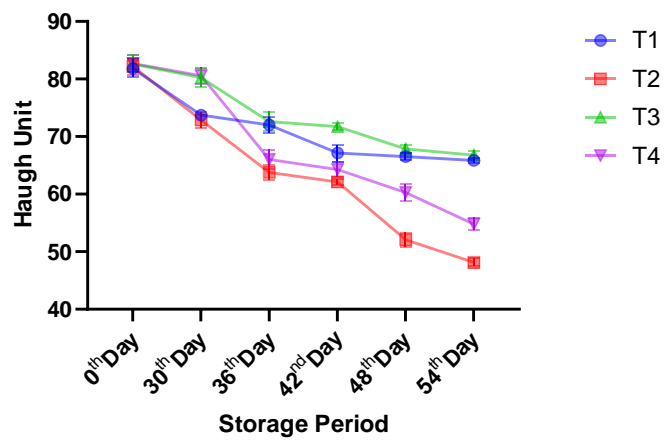


Fig. 24: Increase in air cell after one month of cold stored eggs

T4 recorded 54.75 ± 1.05 . Statistical analysis revealed significant ($P < 0.05$) differences in Haugh unit values among the treatment groups shows significance ($P < 0.05$) across the measurement periods. The results demonstrate a clear trend of declining Haugh unit values over the 54-day period for all treatment groups, with T2 exhibiting the significant ($P < 0.05$) reduction in egg quality compared to T1 and T3 which shows less decline in Haugh Unit.

4.6.2 Albumen Index

The effect of herbal spray & one month of cold storage of egg on results of Albumen Index is presented in the Table no. 4.24. Albumen index shows the significant ($P < 0.05$) effect in the experiment after the cold storage to 54th day. The albumen index is an important indicator of egg internal quality, reflecting the thickness and quality of the egg white, which can be influenced by factors such as storage conditions and egg freshness. On the 0th day before the cold storage, all treatment groups exhibited similar albumen index values, with T1 - 0.083 ± 0.005 , T2 also - 0.083 ± 0.005 , T3 - 0.084 ± 0.004 and T4 - 0.083 ± 0.005 . These initial measurements indicate a consistent baseline across the groups. As the study progressed to the 30th day *i.e.* post one month of cold storage, T1 and T3 shown their values at 0.077 ± 0.002 and 0.081 ± 0.005 , respectively, while T2 decreased to 0.078 ± 0.003 and T4 decreased to 0.082 ± 0.005 . By the 36th day, T1 recorded a further decline to 0.063 ± 0.000 , T2 continued to decrease to 0.049 ± 0.001 , T3 shown value of 0.068 ± 0.006 and T4 dropped to 0.063 ± 0.007 . The trend of decreasing albumen index values continued to 54th day, where T1 shown a value of 0.056 ± 0.004 , T2 shows the lowest point in all group at 0.019 ± 0.001 , T3 - 0.061 ± 0.002 and T4 recorded 0.031 ± 0.003 . Statistical analysis revealed significant ($P < 0.05$) differences in the albumen index among the treatment groups across all time points, indicating that the treatments had a substantial impact on the albumen quality throughout the study. Notably, T2 exhibited the significantly ($P < 0.05$) highest reduction in albumen index, suggesting that this treatment may have adversely affected the quality of the egg white over the storage period.

4.6.3 Yolk Index

The effect of herbal spray & one month of cold storage of egg on results of Yolk Index is presented in the Table no. 4.25. Yolk index shows the significant ($P < 0.05$) effect in the

experiment throughout the cold storage to 54th day. The yolk index is a critical measure of egg quality, reflecting the firmness and height of the yolk relative to its width. A higher yolk index indicates a fresher egg with a firmer yolk, which is desirable for both culinary applications and consumer preference. On the 0th day *i.e.* before cold storage, the yolk indices were consistent across all groups, with T1 recording 0.41 ± 0.01 , T2 - 0.42 ± 0.00 , T3 - 0.41 ± 0.01 and T4 - 0.42 ± 0.00 . However, as the storage period progressed, significant ($P < 0.05$) changes observed in the yolk index over the 54 days of experiment is observed. By the 30th day *i.e.* after the one of cold storage, reduction in yolk index is seen where T1 shows value to 0.36 ± 0.01 , while T2 showed to 0.33 ± 0.01 , T3 to 0.40 ± 0.00 and T4 - 0.39 ± 0.01 . The trend of declining yolk index values became more pronounced by the 54th day T1 recorded a yolk index of 0.33 ± 0.01 , T2 shows least yolk index value at 0.15 ± 0.01 , T3 shows maximum value to 0.38 ± 0.01 and T4 recorded a yolk index of 0.29 ± 0.01 . The results show that significance ($P < 0.05$) reduction in yolk index values over the 54-day period for all treatment groups, where T2 shows least yolk index value and T3 shows maximum yolk value on 54th day of post-cold storage.

4.6.4 Albumen Weight (%)

The effect of herbal spray & one month of cold storage of egg on results of Albumen Weight percent is presented in the Table no. 4.26. Albumen weight percent values show the comparatively significant ($P < 0.05$) difference throughout the experimental period of 54 days. Albumen weight is an important indicator of egg quality, as it reflects the freshness and overall integrity of the egg white. On the 0th day *i.e.* before the one month of cold storage, the initial albumen weights for the treatment groups were relatively similar, with T1 measuring 57.60 ± 0.46 %, T2 - 57.12 ± 0.37 %, T3 - 58.04 ± 0.26 % and T4 - 58.34 ± 0.32 %. These values establish a consistent baseline for albumen weight across all groups. However, as the storage period progressed, significant ($P < 0.05$) reduction in albumen weight were observed through 54 days of experiment. By the 30th day *i.e.* post one month of cold storage, all groups showed a reduction in albumen weight, T1 reduced to 55.79 ± 0.84 %, T2 to 55.83 ± 0.80 %, T3 to 57.12 ± 0.45 % and T4 to 57.16 ± 0.46 %. The reductions in albumen weight at this stage indicate the onset of quality degradation due to storage. The trend of reduction of albumen weight continued through to the 36th day, where T1 recorded 55.72 ± 0.68 %, T2 - 54.80 ± 0.64

Table 4.23: Effect of cold storage on Haugh unit value over the storage time period

	Cold Storage (10-15°C)								P Value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	60 th Day		
T1 Non-Spray (10-15°C)	81.83±1.58 ^A	73.74±0.58 ^{Bb}	72.02±1.42 ^{Bab}	67.13±1.44 ^{Cab}	66.52±0.63 ^{Ca}	65.85±0.42 ^{Ca}		0.000	
T2 Non-Spray (26.5 ± 3°C)	82.18±1.41 ^A	72.84±1.36 ^{Bab}	63.78±1.29 ^{Cc}	62.11±0.49 ^{Cc}	52.05±1.22 ^{Dc}	48.14±0.66 ^{Dc}		0.000	
T3 Spray (10-15°C)	82.59±1.41 ^A	80.23±1.54 ^{Aa}	72.62±1.64 ^{Ba}	71.74±0.57 ^{Ba}	67.86±0.75 ^{Ba}	66.75±0.74 ^{Ca}		0.000	
T4 Spray (26.5 ± 3°C)	82.68±1.42 ^A	80.57±1.38 ^{Aa}	66.04±1.7 ^{Bab}	64.29±1.36 ^{Bcab}	60.28±1.44 ^{Bcb}	54.75±1.05 ^{Cb}		0.000	
P value	0.974	0.000	0.026	0.031	0.000	0.000		0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.24: Effect of cold storage on albumin index value over the storage time period

	Cold Storage (10-15°C)								P Value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	60 th Day		
T1 Non-Spray (10-15°C)	0.083±0.005 ^A	0.077±0.002 ^A	0.063±0.000 ^{Bab}	0.062±0.001 ^{Ba}	0.059±0.002 ^{Ba}	0.056±0.004 ^{Ba}		0.000	
T2 Non-Spray (26.5 ± 3°C)	0.083±0.005 ^A	0.078±0.003 ^A	0.049±0.001 ^{Cb}	0.036±0.001 ^{Db}	0.031±0.001 ^{Dc}	0.019±0.001 ^{Ec}		0.000	
T3 Spray (10-15°C)	0.084±0.004 ^A	0.081±0.005 ^A	0.068±0.006 ^{ABa}	0.068±0.002 ^{ABa}	0.064±0.002 ^{Ba}	0.061±0.002 ^{Ba}		0.000	
T4 Spray (26.5 ± 3°C)	0.083±0.005 ^A	0.082±0.005 ^A	0.063±0.007 ^{ABab}	0.054±0.007 ^{Ba}	0.044±0.002 ^{Bcb}	0.031±0.003 ^{Cb}		0.000	
P value	0.999	0.053	0.030	0.000	0.000	0.000		0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.25: Effect of cold storage on yolk index quality over the storage time period

	Cold Storage (10-15°C)						P value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	
T1 Non-Spray (10-15°C)	0.41±0.01 ^A	0.36±0.01 ^{Bb}	0.36±0.00 ^{Bb}	0.36±0.01 ^{Ba}	0.34±0.02 ^{Bcb}	0.33±0.01 ^{Cb}	0.000
T2 Non-Spray (26.5 ± 3°C)	0.42±0.00 ^A	0.33±0.01 ^{Bc}	0.33±0.01 ^{Bc}	0.25±0.00 ^{Cc}	0.16±0.00 ^{Dc}	0.15±0.01 ^{Dc}	0.000
T3 Spray (10-15°C)	0.41±0.01 ^A	0.40±0.00 ^{ABa}	0.40±0.00 ^{ABa}	0.39±0.00 ^{ABa}	0.37±0.00 ^{BCa}	0.38±0.01 ^{Ca}	0.000
T4 Spray (26.5 ± 3°C)	0.42±0.00 ^A	0.39±0.01 ^{Aa}	0.39±0.01 ^{Aa}	0.30±0.02 ^{Bb}	0.30±0.02 ^{Bb}	0.29±0.01 ^{Bb}	0.000
P value	0.170	0.000	0.000	0.000	0.000	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P <0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P <0.05)

Table 4.26: Effect of cold storage on albumin weight (%) over the storage time period

	Cold Storage (10-15°C)						P value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	
T1 Non-Spray (10-15°C)	57.6±0.46 ^A	55.79±0.84 ^{Ab}	55.72±0.68 ^{ABb}	55.51±0.64 ^{ABa}	54.39±0.52 ^{ABa}	53.26±0.42 ^{Ba}	0.004
T2 Non-Spray (26.5 ± 3°C)	57.12±0.37 ^A	55.83±0.8 ^{Ab}	54.8±0.64 ^{Ab}	52.59±0.35 ^{Bb}	50.18±0.36 ^{Bbb}	48.45±0.31 ^{Cc}	0.000
T3 Spray (10-15°C)	58.04±0.26 ^A	57.12±0.45 ^{Aa}	56.45±0.62 ^{Aa}	55.02±0.27 ^{Ba}	54.63±0.46 ^{Ba}	53.93±0.11 ^{Ba}	0.000
T4 Spray (26.5 ± 3°C)	58.34±0.32 ^A	57.16±0.46 ^{Aa}	56.25±0.57 ^{Ab}	54.13±0.49 ^{ABb}	52.59±4.21 ^{ABb}	51.75±0.24 ^{Bb}	0.000
P value	0.991	0.013	0.037	0.000	0.017	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P <0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P <0.05)

%, T3 maintained a slightly higher value of 56.45 ± 0.62 % and T4 measured 56.25 ± 0.57 %. The differences in albumen weight among the groups began to become more pronounced, 36th day onward. The decline in albumen weight was highest for T2, which indicated a considerable loss of quality. By 54th day of one-month cold storage, T1 recorded an albumen weight of 53.26 ± 0.42 %, T2 showed its lowest point of 48.45 ± 0.31 %, T3 measured highest point at 53.93 ± 0.11 % and T4 recorded 51.75 ± 0.24 %. The significantly ($P < 0.05$) maximum reduction in albumen weight in was observed in T2 group and minimum reduction observed in T3 group.

4.6.5 Yolk Weight (%)

The effect of herbal spray & one month of cold storage of egg on results of Yolk Weight percent is presented in the Table no. 4.27. Initially, yolk weights percent were similar across all treatments, but notable changes emerged as storage progressed. In particular, the non-spray treatment *i.e.* $26.5 \pm 3^\circ\text{C}$ (T2) showed a remarkable increase in yolk weight, rising from 31.09 ± 0.29 % on the 0th day to 37.97 ± 0.19 % by the 54th day, indicating that higher temperatures significantly ($P < 0.05$) enhance yolk retention. Similarly, the spray treatments also demonstrated positive effects, with T4 (spray at $26.5 \pm 3^\circ\text{C}$) shown increasing from 31.07 ± 0.28 % to 36.13 ± 0.23 %. The non-spray treatment at $10-15^\circ\text{C}$ (T1) and the spray treatment at the same temperature (T3) exhibited more modest increases. The statistical analysis highlighted significant ($P < 0.05$) differences in yolk weight from the 36th day onward, particularly in the higher temperature treatments, suggesting that optimizing storage conditions can greatly improve egg quality and reduce post-harvest losses. These findings underscore the importance of managing storage environments to enhance the viability of the egg market.

4.6.6 Yolk Colour

The effect of herbal spray & one month of cold storage of egg on results of Yolk Colour is presented in the Table no. 4.28. Yolk colour is an important quality attribute that can be influenced by factors such as hen diet, storage conditions, and age of the egg. No significant ($P > 0.05$) changes were seen in the yolk colour change during the 54-day experimental period. On the 0th day *i.e.* before cold storage, the yolk colours varied slightly among the treatment groups, with T1 - 8.60 ± 0.51 , T2 - 9.20 ± 0.37 , T3 - 8.20 ± 0.58 and T4 - 8.40 ± 0.51 . By the

30th day *i.e.* after the one month of cold storage, T1 showed yolk colour value to 8.40 ± 0.51 , while T2 to 7.80 ± 0.37 . T3 to 8.60 ± 0.51 and T4 to 8.60 ± 0.51 . The changes in yolk colour became the 36th day, with T1 showed to 8.60 ± 0.51 , T2 to 8.60 ± 0.51 , T3 to 9.20 ± 0.37 and T4 to 8.60 ± 0.51 . This trend of irregular values observed in the complete 54th day experiment. Statistical analysis revealed that the no differences in yolk colour among the treatment groups were seen.

4.6.7 Shell Thickness

The experimental results of shell thickness (in mm.) of treated herbal sprayed eggs after one-month of cold storage presented in the Table no. 4.29. There was no significance ($P > 0.05$) difference was observed across all measurement days, from the 0th day through to the 60th day of experiment. Shell thickness is an important quality parameter that can affect the overall integrity and protection of the egg contents. On the 0th day *i.e.* before the cold storage, all treatment groups exhibited similar shell thicknesses, with T1 - 0.35 ± 0.003 , T2 - 0.35 ± 0.008 , T3 - 0.35 ± 0.009 and T4 - 0.36 ± 0.002 . These initial measurements indicate a consistent baseline across the groups. As the study progressed to the 30th day post one-month of cold storage, T1 showed a slight decrease in shell thickness to 0.31 ± 0.021 , while T2, T3, and T4 maintained their initial values at 0.35. This trend of non-uniform changes in the eggshell thickness recorded on the 54th day, T1 shell thickness - 0.34 ± 0.006 , T2 - 0.37 ± 0.004 , T3 - 0.35 ± 0.007 and T4 - 0.35 ± 0.009 . This shows that the treatments did not have a significant ($P > 0.05$) impact on the shell thickness of the eggs throughout the 54-day period.

4.7 pH (POWER OF HYDROGEN)

4.7.1 pH of Whole Egg

The effect of herbal spray & one month of cold storage of egg on results of pH of Whole Egg is presented in the Table no. 4.30 & Fig. 25. On the 0th day, the initial pH values across the treatment groups were relatively similar, with T1 (Non-Spray at $10-15^{\circ}\text{C}$) recording a pH of 7.16 ± 0.06 , T2 (Non-Spray at $26.5 \pm 3^{\circ}\text{C}$) - 7.09 ± 0.09 , T3 (Spray at $10-15^{\circ}\text{C}$) - 7.09 ± 0.06 and T4 (Spray at $26.5 \pm 3^{\circ}\text{C}$) - 7.07 ± 0.09 . By the 30th day of cold storage, T1 showed a slight increase to 7.20 ± 0.07 , while T2 rose to 7.44 ± 0.04 . T3 and T4 remained

Table 4.27: Effect of cold storage on yolk weight (%) over the storage time period

	Cold Storage (10-15°C)						P value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	
T1 Non-Spray (10-15°C)	31.07±0.28 ^A	32.00±0.61 ^A	32.47±0.56 ^{AB}	33.02±0.51 ^{ABbc}	33.51±0.26 ^{ABc}	33.86±0.11 ^{Cc}	0.038
T2 Non-Spray (26.5 ± 3°C)	31.09±0.29 ^A	31.96±0.57 ^A	33.65±0.48 ^A	35.21±0.25 ^{Ba}	36.69±0.17 ^{Ca}	37.97±0.19 ^{Da}	0.000
T3 Spray (10-15°C)	31.10±0.30 ^A	31.73±0.51 ^A	32.1±0.3 ^{AB}	32.56±0.23 ^{ABc}	32.86±0.15 ^{Cc}	33.56±0.09 ^{Cc}	0.001
T4 Spray (26.5 ± 3°C)	31.07±0.29 ^A	31.7±0.42 ^A	33.13±0.36 ^{AB}	34.03±0.26 ^{BCab}	34.95±0.22 ^{Cb}	36.13±0.23 ^{Db}	0.000
P value	0.961	0.967	0.075	0.000	0.000	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.28: Effect of cold storage on yolk color over the storage time period

	Cold Storage (10-15°C)						P value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	
T1 Non-Spray (10-15°C)	8.60±0.51	8.40±0.51	8.60±0.51	8.60±0.51	8.60±0.51	8.20±0.58	0.991
T2 Non-Spray (26.5 ± 3°C)	9.20±0.37	7.80±0.37	8.60±0.51	9.00±0.55	8.60±0.51	8.40±0.51	0.407
T3 Spray (10-15°C)	8.20±0.58	8.60±0.51	9.20±0.37	8.20±0.58	8.60±0.51	8.60±0.51	0.744
T4 Spray (26.5 ± 3°C)	8.40±0.51	8.60±0.51	8.60±0.51	8.60±0.51	8.40±0.51	8.60±0.51	0.999
P value	0.54	0.61	0.761	0.777	0.99	0.94	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.29: Effect of cold storage in thickness of shell over the storage time period

	Cold Storage (10-15°C)						P value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	
T1 Non-Spray (10-15°C)	0.35±0.003 ⁺	0.31±0.021	0.33±0.009	0.35±0.008	0.37±0.015	0.34±0.006	0.117
T2 Non-Spray (26.5 ± 3°C)	0.35±0.008	0.35±0.009	0.36±0.008	0.35±0.008	0.37±0.007	0.37±0.004	0.522
T3 Spray (10-15°C)	0.35±0.009	0.35±0.005	0.35±0.007	0.34±0.002	0.35±0.003	0.35±0.007	0.373
T4 Spray (26.5 ± 3°C)	0.36±0.002	0.35±0.005	0.36±0.007	0.33±0.003	0.36±0.011	0.35±0.009	0.210
P value	0.376	0.272	0.107	0.437	0.367	0.237	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.30: Effect of cold storage on the pH of an egg over the storage time period

	Cold Storage (10-15°C)						P value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	
T1 Non-Spray (10-15°C)	7.16±0.06 ^{BC}	7.20±0.07 ^{Bb}	7.29±0.06 ^{ABbc}	7.37±0.08 ^{ABb}	7.53±0.08 ^{Ab}	7.59±0.10 ^{ABc}	0.008
T2 Non-Spray (26.5 ± 3°C)	7.09±0.09 ^D	7.44±0.04 ^{Ca}	7.62±0.06 ^{BCa}	7.73±0.03 ^{Ba}	8.39±0.12 ^{ABa}	8.62±0.04 ^{Aa}	0.00
T3 Spray (10-15°C)	7.09±0.06 ^B	7.09±0.04 ^{Bb}	7.14±0.04 ^{ABc}	7.30±0.02 ^{ABb}	7.45±0.07 ^{Ab}	7.51±0.03 ^{Ac}	0.00
T4 Spray (26.5 ± 3°C)	7.07±0.09 ^C	7.15±0.05 ^{Ca}	7.44±0.04 ^{Bab}	7.63±0.04 ^{Ba}	7.72±0.03 ^{ABb}	7.82±0.04 ^{Ab}	0.00
P value	0.800	0.00	0.00	0.00	0.00	0.00	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

relatively stable at 7.09 ± 0.04 and 7.15 ± 0.05 , respectively. From the 36th day onward, significant ($P < 0.05$) changes were observed in the pH levels. T1 continued to increase, reaching 7.59 ± 0.10 by the 54th day. T2 exhibited the most substantial increase, climbing to 8.62 ± 0.04 by the end of the storage period, demonstrating a strong correlation between higher temperature and pH enhancement. T3 showed a gradual increase in pH from 7.09 ± 0.06 to 7.51 ± 0.03 , while T4 increased from 7.07 ± 0.09 to 7.82 ± 0.04 , showed significant ($P < 0.05$) results. Overall, the findings suggest that cold storage conditions, particularly at higher temperatures and with herbal spray treatments, significantly influence the pH levels of eggs over time, which is crucial for maintaining egg quality during storage.

4.7.2 pH of Albumen

The effect of herbal spray & one month of cold storage of egg on results of pH of Albumen is presented in the Table no. 4.31 & Fig. 26. One-month cold storage doesn't show significant effect ($P > 0.05$). On the 0th day, the initial albumen pH values across the treatment groups were relatively similar, with T1 recording an average pH of 7.87 ± 0.07 , T2 - 7.79 ± 0.09 , T3 - 7.86 ± 0.07 and T4 - 7.78 ± 0.10 . By the 30th day of cold storage, T1, T2, T3 and T4 had pH values of 8.16 ± 0.09 , 8.20 ± 0.17 , 7.93 ± 0.08 and 8.16 ± 0.16 , respectively. From the 36th day onward, significant ($P < 0.05$) changes were observed, particularly in T1 and T2, which continued to show increases in pH. T1 reached a final pH of 8.64 ± 0.09 by the 54th day, with a statistically significant, indicating a strong correlation between treatment and pH increase. T2 also demonstrated a significant increase, reaching 9.19 ± 0.20 by the end of the storage period. While T3 showed minimal change throughout the study, ending with a pH of 8.22 ± 0.06 on day 54 which is non-significant ($P > 0.05$). T4 exhibited a substantial increase in pH from 7.78 ± 0.10 to 8.99 ± 0.16 by the 54th day, with a highly significant ($P < 0.05$). Overall, the results indicate that cold storage significantly affects the albumen pH of eggs over time, with T2 and T4 showing the most substantial increases, while T3 maintained a relatively stable pH throughout the study.

4.7.3 pH of Yolk

The effect of herbal spray & one month of cold storage of egg on results of pH of Yolk is presented in the Table no. 4.32 & Fig. 27. One-month cold storage showed no significant

($P > 0.05$) effect on the yolk pH of egg due to the cold storage. On the 0th day, the initial yolk pH values across the treatment groups were relatively similar, with T1 (Non-Spray at 10-15°C) - 6.21 ± 0.05 , T2 (Non-Spray at $26.5 \pm 3^\circ\text{C}$) - 6.17 ± 0.02 , T3 (Spray at 10-15°C) - 6.17 ± 0.05 and T4 (Spray at $26.5 \pm 3^\circ\text{C}$) - 6.16 ± 0.02 , indicating a consistent baseline. By the 30th day of cold storage, T1, T2, T3 and T4 had pH values of 7.21 ± 0.05 , 7.44 ± 0.04 , 7.09 ± 0.03 and 7.17 ± 0.06 , respectively. From the 36th day onward, significant ($P < 0.05$) changes were observed, particularly in T1 and T2, which continued to show increases in pH. T1 reached a final pH of 7.60 ± 0.10 by the 54th day, indicating a strong correlation between treatment and pH increase. T2 also demonstrated a significant increase, reaching 8.57 ± 0.04 by the end of the storage period. The T3 showed a slower increase throughout the study, ending with a pH of 7.53 ± 0.02 on day 54 and with significance ($P < 0.05$). T4 exhibited a substantial increase in pH from 6.16 ± 0.02 to 7.89 ± 0.4 by the 54th days. Overall, the results indicate that cold storage significantly affects the yolk pH of eggs over time, with T2 and T4 showing the most substantial increases, while T3 maintained a relatively stable pH throughout the study.

4.8 MICROBIAL PARAMETER

4.8.1 Total Plate Count (TPC)

The results of the Total Plate Counts (TPC) of eggs stored under cold conditions are depicted in Figure 28. On the 0th day, the initial TPC values across the treatment groups were relatively low, with T1 (Non-Spray at 10-15°C) recording 1.98 ± 0.04 , T2 (Non-Spray at $26.5 \pm 3^\circ\text{C}$) - 1.87 ± 0.04 , T3 (Spray at 10-15°C) - 2.13 ± 0.05 , and T4 (Spray at $26.5 \pm 3^\circ\text{C}$) - 1.91 ± 0.04 . By the 30th day of cold storage, TPC values increased for all groups, with T1 and T2 reaching 4.27 ± 0.03 and 4.27 ± 0.06 , respectively, while T3 and T4 showed count of 3.43 ± 0.04 and 3.43 ± 0.03 , respectively. Notably, from the 36th day onward, significant ($P < 0.05$) increases in TPC were observed across all treatments, particularly in T2, which reached 7.2 ± 0.03 by the 54th day, indicating a strong correlation between higher storage temperatures and microbial growth. T1 also showed a substantial increase, reaching 5.6 ± 0.04 by the end of the storage period. The T3 maintained the lowest TPC values throughout the experiment, ending to 4.98 ± 0.03 , while T4 increased to 6.49 ± 0.04 by day 54. The statistical

Table 4.31: Effect of cold storage on the albumin pH over the storage time period

	Cold Storage (10-15°C)						P value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	
T1 Non-Spray (10-15°C)	7.87±0.07 ^B	8.16±0.09 ^B	8.28±0.09 ^{ABab}	8.39±0.09 ^{ABb}	8.51±0.09 ^{ABab}	8.64±0.09 ^{Ab}	0.002
T2 Non-Spray (26.5 ± 3°C)	7.79±0.09 ^D	8.20±0.17 ^C	8.43±0.07 ^{BCa}	8.70±0.01 ^{Ba}	8.94±0.07 ^{ABa}	9.19±0.20 ^{Aa}	0.007
T3 Spray (10-15°C)	7.86±0.07	7.93±0.08	7.97±0.16 ^c	8.06±0.04 ^c	8.13±0.10 ^c	8.22±0.06 ^c	0.721
T4 Spray (26.5 ± 3°C)	7.78±0.1 ^C	8.16±0.16 ^B	8.36±0.06 ^{Bab}	8.56±0.06 ^{ABa}	8.76±0.06 ^{ABab}	8.99±0.16 ^{Ab}	0.000
P value	0.813	0.784	0.0432	0.018	0.046	0.019	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

Table 4.32: Effect of cold storage on the yolk pH over the storage time period

	Cold Storage (10-15°C)						P value
	0 th Day	30 th Day	36 th Day	42 nd Day	48 th Day	54 th Day	
T1 Non-Spray (10-15°C)	6.21±0.05 ^C	7.21±0.05 ^{BC}	7.32±0.05 ^{Bb}	7.30±0.04 ^{Bb}	7.53±0.05 ^{ABb}	7.60±0.10 ^{Ab}	0.001
T2 Non-Spray (26.5 ± 3°C)	6.17±0.02 ^E	7.44±0.04 ^D	7.39±0.21 ^{Ca}	7.67±0.04 ^{Ba}	8.35±0.09 ^{Aa}	8.57±0.04 ^{Aa}	0.000
T3 Spray (10-15°C)	6.17±0.05 ^C	7.09±0.03 ^B	7.15±0.04 ^{Bb}	7.29±0.03 ^{ABb}	7.40±0.05 ^{ABb}	7.53±0.02 ^{Ab}	0.000
T4 Spray (26.5 ± 3°C)	6.16±0.02 ^D	7.17±0.06 ^{CD}	7.41±0.03 ^{BCa}	7.53±0.08 ^{Ba}	7.72±0.17 ^{ABa}	7.89±0.04 ^{Aa}	0.000
P value	0.774	0.348	0.000	0.000	0.000	0.000	

Mean ± SE the mean values between Column with different Superscript ^{a,b,c,d} are Significantly Different (P < 0.05) mean values between Rows with different Superscript _{A,B,C,D} are Significantly Different (P < 0.05)

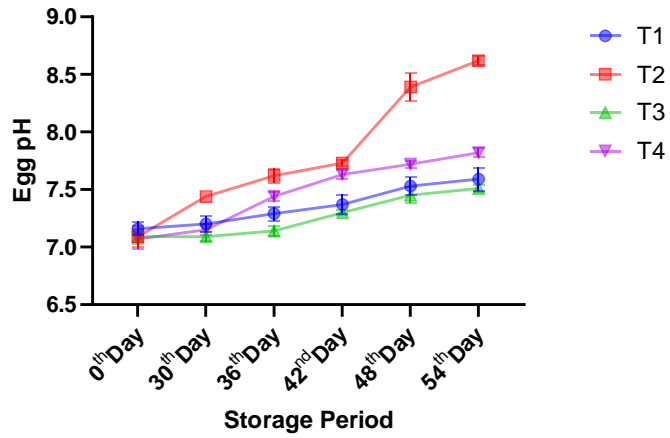


Fig. 25: Egg pH after one month of cold stored eggs

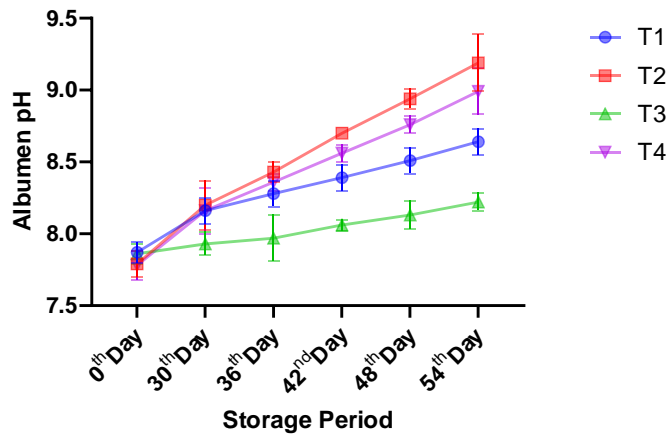


Fig. 26: Albumen pH after one month of cold stored eggs

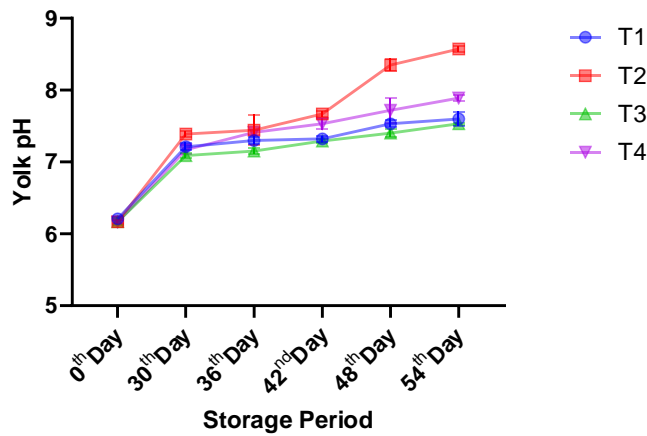


Fig. 27: Yolk pH after one month of cold stored eggs

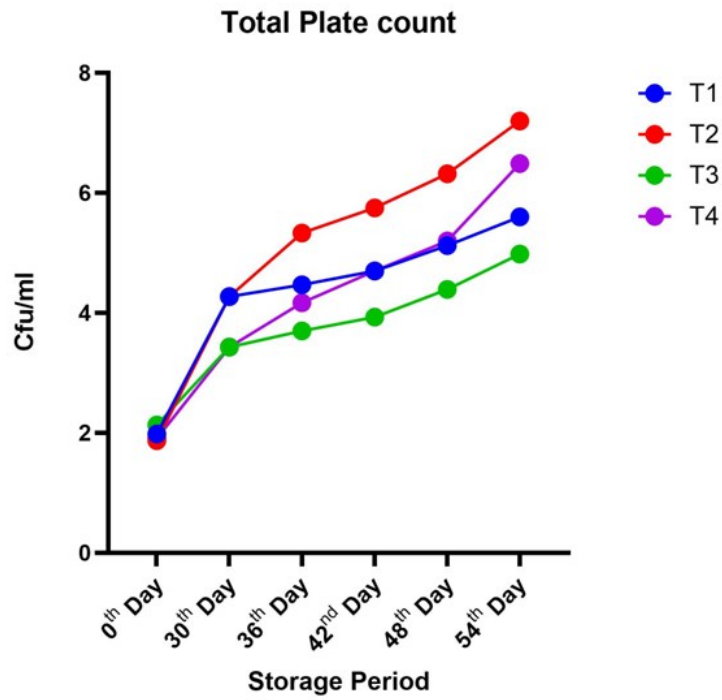


Fig. 28: Results of Total Plate Counts of cold stored eggs

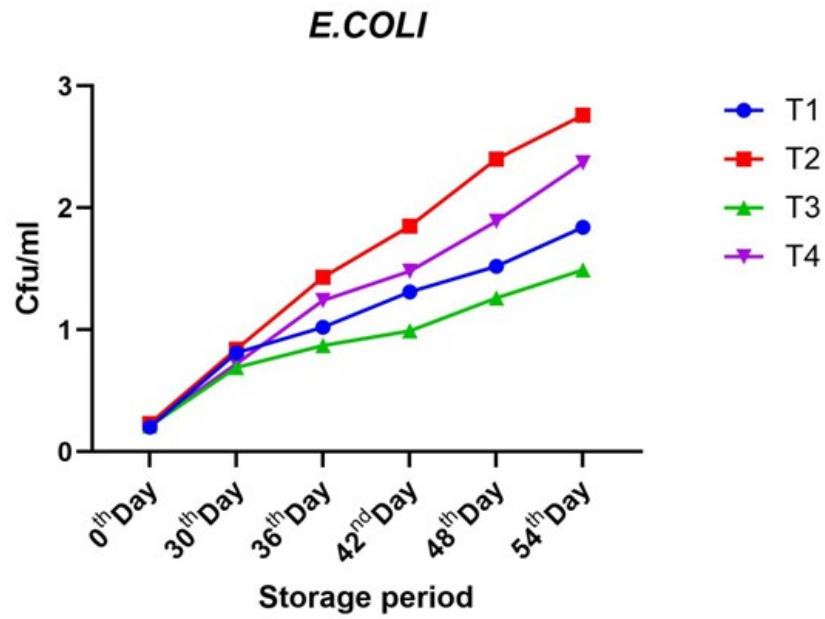


Fig. 29: Results of *E. Coli* of cold stored eggs

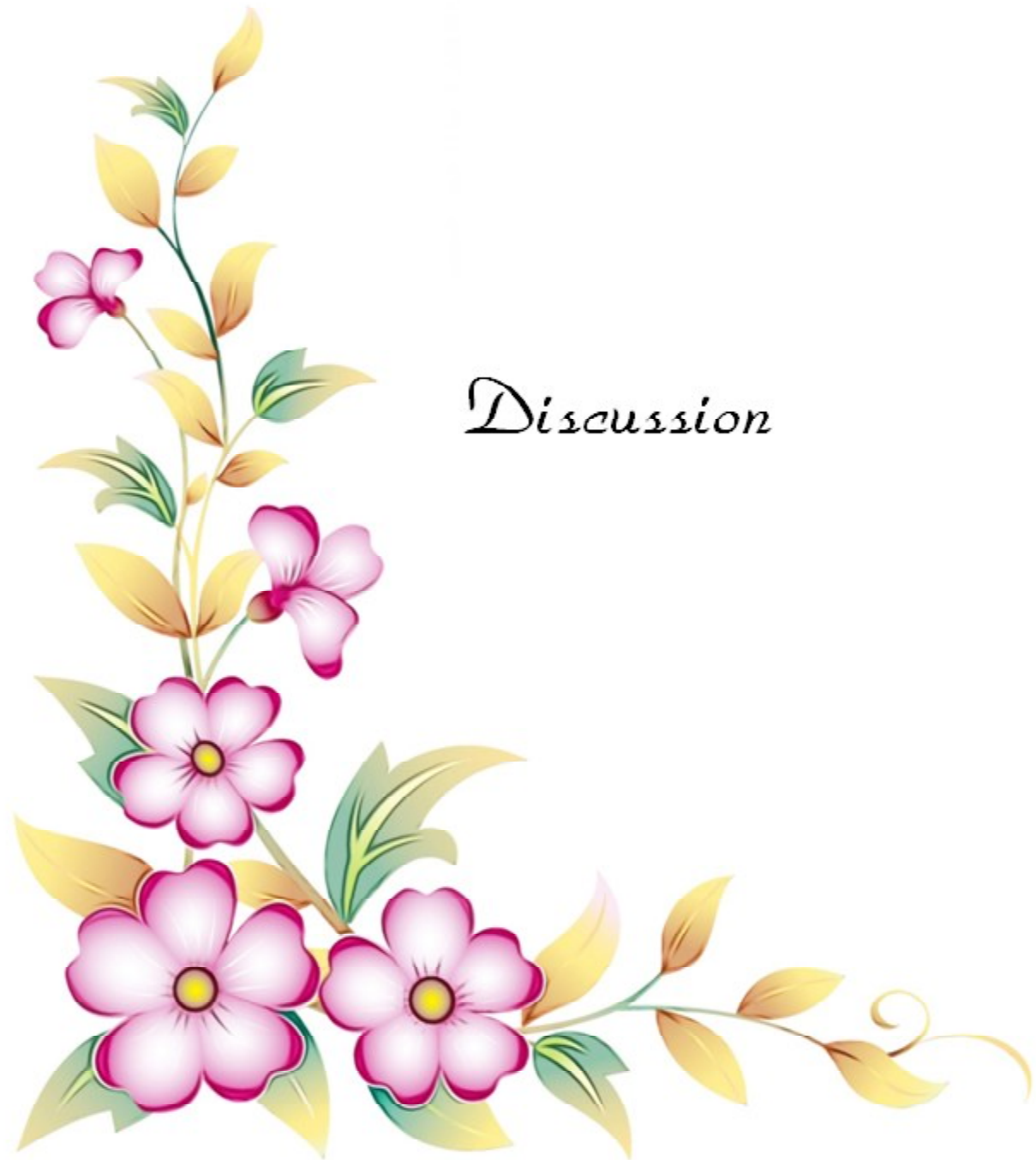
analysis revealed significant differences in TPC among the treatments, particularly evident from the 36th day onward, suggesting that both storage temperature and the application of herbal sprays play a crucial role in controlling microbial growth in eggs during cold storage. Overall, the findings highlight the importance of maintaining optimal storage conditions to ensure the microbiological quality of eggs throughout the cold chain.

4.8.2 *Escherichia Coli* Count

The effect of herbal spray & one month of cold storage of egg on results of *Escherichia Coli* Count is presented in the Table no. Figure 29. On the 0th day, the initial *E. coli* levels were low across all treatment groups, with T1 (Non-Spray at 10-15°C) recording to 0.2 ± 0.04 , T2 (Non-Spray at $26.5 \pm 3^\circ\text{C}$) - 0.23 ± 0.04 , T3 (Spray at 10-15°C) - 0.21 ± 0.04 and T4 (Spray at $26.5 \pm 3^\circ\text{C}$) - 0.22 ± 0.04 . By the 30th day of cold storage, *E. coli* counts increased slightly for all groups, with T1 - 0.81 ± 0.04 , T2 - 0.84 ± 0.05 , T3 at 0.69 ± 0.04 and T4 at 0.72 ± 0.04 . Notably, from the 36th day onward, significant ($P < 0.05$) increases in *E. coli* were observed across all treatments, particularly in T2, which reached 2.76 ± 0.04 by the 54th day, indicating a strong correlation between higher storage temperatures and bacterial growth. T1 also showed a substantial increase, reaching 1.84 ± 0.04 by the end of the storage period. In contrast, T3 maintained the lowest *E. coli* counts throughout the experiment, ending - 1.49 ± 0.04 , while T4 increased to 2.37 ± 0.04 by day 54. The statistical analysis revealed significant ($P < 0.05$) differences in *E. coli* among the treatments, particularly evident from the 36th day onward, suggesting that both storage temperature and the application of herbal sprays play a crucial role in controlling *E. coli* growth in eggs during cold storage. These findings underscore the importance of maintaining optimal storage conditions to ensure the microbiological safety of eggs throughout the cold chain.

This finding indicates that both the herbal spray treatment and the cold storage conditions effectively preserved the structural integrity of the eggshell, which is crucial for maintaining the overall quality and safety of the eggs.





Discussion

India ranks as the world's third-largest egg producer, with an annual output of 138.80 billion eggs in 2022-23. However, the country faces significant post-harvest losses in the egg supply chain, leading to substantial economic setbacks. The southern states, particularly Andhra Pradesh and Tamil Nadu, are the primary egg producers in India. To meet the demand in northern regions, eggs are transported over long distances. However, this process is fraught with challenges, as the cultural diversity across India results in fluctuating market demand for eggs, especially in the northern states. To mitigate spoilage and maintain freshness, eggs are often stored in cold conditions. However, the transportation process itself can compromise egg quality, with vibrations during transit and temperature variations leading to deterioration in the physical and chemical properties of eggs. To address these challenges, our team at the ICAR-Central Avian Research Institute (ICAR-CARI) have conducted studies to evaluate the impact of transportation, cold storage, and storage at different temperatures on egg quality. The research aims to determine optimal storage conditions and explore the efficacy of herbal sprays in enhancing the viability of the egg market. By addressing post-harvest losses and improving storage and transportation methods, India can maximize the potential of its thriving egg production sector and ensure the availability of high-quality eggs to consumers across the country.

5.1 External Parameters

5.1.1 Egg Weight

The effect of transportation on egg weight reduction was non-significant ($P>0.05$) till 18th day of post transportation storage in all the groups. Results of cold storage shows no

significant ($P>0.05$) difference in egg weight throughout all groups till 42nd day, after onwards the significant effect was seen because of varied storage temperature. But in both experiments egg weight reduction shows significant ($P<0.05$) effect through all over the groups excluding T3 which is herbal spray treated and stored under lower temperature. Weight loss in eggs is primarily attributed to the evaporation of solvents from the egg contents through the shell. These findings align with previous studies by Altan et al. (1998), Fasenکو *et al.* (2001), Tilki and Inal (2004), Hassan *et al.* (2005), Reijrink et al. (2010), Gonzalez-Redondo *et al.* (2010) and Alsobayel and Albadry (2011), which reported that increased storage duration correlates with greater egg weight loss egg but coating minimises the egg weight reduction. Furthermore, egg weight loss is significantly influenced by storage temperature. Eggs stored at 4°C exhibited significantly lower weight loss ($P<0.05$) compared to those stored at room temperature. This reduced weight loss at lower temperatures can be attributed to decreased solvent loss (water and other gaseous products) from the egg contents compared to eggs stored at ambient temperatures. These observations are consistent with findings from Shanawa (1994), Samli *et al.* (2005) and Hasan and Okur (2009), who noted a decrease in egg weight within ten days of storage at 29°C. Their results indicate that while cold storage effectively preserves egg weight in the short term, the treatment applied to the eggs, along with the storage temperature, significantly influences weight retention over time. The application of herbal sprays appears to mitigate weight loss, particularly under cold storage conditions, while non-treated eggs stored at higher temperatures exhibit accelerated weight loss. These findings underscore the importance of optimal storage conditions and treatment methods in maintaining egg quality during storage.

5.1.2 Percentage of egg weight

The effect of transportation on egg weight loss percentage was non-significant ($P>0.05$) until the 18th day of post-transportation storage in all groups. Results of cold storage showed no significant ($P>0.05$) difference in egg weight throughout all groups until the 42nd day, after which a significant effect was observed due to varied storage temperatures. However, in both experiments, egg weight reduction (%) showed a significant ($P<0.05$) effect across all groups, excluding T3, which received herbal spray treatment and was stored under lower temperatures. Weight loss in eggs is primarily attributed to the evaporation of moisture and gases from the

egg contents through the shell pores. These findings align with previous studies by Altan *et al.* (1998), Fasenko *et al.* (2001), Tilki and Inal (2004), Hassan *et al.* (2005), Reijrink *et al.* (2010), Gonzalez-Redondo *et al.* (2010), and Alsobayel and Albadry (2011), which reported that increased storage duration correlates with greater egg weight loss percentage but that coating minimizes this reduction. Furthermore, egg weight loss is significantly influenced by storage temperature, with eggs stored at 4°C exhibiting significantly lower weight loss ($P < 0.05$) compared to those stored at room temperature. This reduced weight loss at lower temperatures can be attributed to decreased moisture and gas loss from the egg contents compared to eggs stored at ambient temperatures. While cold storage effectively preserves egg weight in the short term, the treatment applied to the eggs, along with the storage temperature, significantly influences weight retention over time. The application of herbal sprays appears to mitigate weight loss, particularly under cold storage conditions, while non-treated eggs stored at higher temperatures exhibit accelerated weight loss. These findings underscore the importance of optimal storage conditions and treatment methods in maintaining egg quality during storage.

5.1.3 Air Cell size

The result of transportation doesn't show significant ($P > 0.05$) effect on air cell and cold storage of one month showed significant ($P < 0.05$) effect on air cell due to prolonged storage. These results agree with Akyurek and Okur (2009), who observed the size of the air cell exceeded 5 mm in 7 days at all storage temperatures. The increase in Air-cell size of transported study shows significant difference from 6th day onwards. This is because of reduction in egg weight due to moisture causes the shrinkage of egg content and increase in the gap between inner and outer shell membrane. This finding implies that the deterioration of egg quality was increased by storage time in nonlinear manner. Therefore, one should bear in mind that deterioration of internal egg quality is a function of storage time and temperature. Under storage temperature up to 29°C, the air cell size of eggs stored 10 days increased rapidly according to storage time and temperature (Hasan *et al.*, 2005).

5.1.4 Specific Gravity

The specific gravity of eggs is a critical indicator of their quality and it typically changes over time due to various factors such as storage conditions and moisture loss. This might be

due to the size of the air cell because with increase of storage time and temperature the size of the air cell increased. In experiment one of transportation eggs shows significant ($P > 0.05$) difference in specific gravity from 12th day onwards in all group, where the maximum decrease was found in the non-sprayed eggs stored at $26.5 \pm 3^\circ\text{C}$ where refrigerated condition records less decrease in specific gravity. In cold storage experiment 30th day significant ($P < 0.05$) difference was observed in the specific gravity, throughout the experiment the maximum decrease were found in the non-sprayed eggs stored at $26.5 \pm 3^\circ\text{C}$ where refrigerated condition records less decrease in specific gravity. Research indicates that as eggs are stored, their specific gravity tends to decrease, reflecting changes in internal composition and air cell size. In a study by Maynard L. Milks (2002) examining the effects of storage duration on egg quality, it was found that specific gravity significantly decreased over time. For instance, eggs stored for 35 days showed variations in specific gravity based on their physical condition, with eggs without defects exhibiting the highest values. Conversely, eggs with external cracks consistently recorded the lowest specific gravity, indicating a correlation between shell integrity and egg quality. Another study highlighted that specific gravity is influenced by storage temperature and time, with eggs stored at room temperature showing a more significant decline in specific gravity compared to those kept in refrigerated conditions. This decline is attributed to moisture loss through the porous eggshell, which leads to an increase in air cell size and a subsequent decrease in egg weight (Woodard, 1982; Song *et al.*, 2000). The specific gravity of eggs stored at higher temperatures was notably lower, demonstrating that prolonged storage at suboptimal conditions adversely affects egg quality. Furthermore, the interaction between storage time and temperature was shown to significantly impact specific gravity, with significant differences observed as early as two weeks into storage (Caner *et al.*, 2015). The degradation of albumen quality and the increase in air cell size due to moisture loss were closely linked to the observed changes in specific gravity, emphasizing the importance of maintaining proper storage conditions to preserve egg quality. In summary, the specific gravity of eggs decreases over time due to factors such as moisture loss and changes in internal composition, with significant variations observed based on storage conditions and the physical integrity of the eggs. Maintaining optimal storage temperatures is crucial for minimizing quality deterioration during the storage period (Obanu and Mpieri 1984; Stadelman 1986).

5.1.5 Shape Index

Results of both experiment shows no significance ($P>0.05$) change in the shape index of egg during experimental period of both transported and cold storage conditions. These findings are validated by previous studies conducted by Woodard (1982) and Song *et al.* (2000), they reported a lack of significant influence from storage time and temperature on the egg shape index. This suggests that, within the parameters tested, the structural integrity of the eggs in terms of their shape remains stable despite variations in storage conditions. Overall, the data indicate that the morphological parameters of eggs, particularly their shape index, are resilient to the impacts of transportation and storage variables within the studied range. These findings are consistent with the studies conducted by Yeasmin Akter (2014), which also showed no effect of time and temperature on the shape index of eggs. The adaptability of egg shape index to storage conditions and herbal spray treatment suggests that the structural integrity of the eggs remains stable despite variations in temperature and storage parameters. The data presented in this study demonstrate that both experiments followed by storage at varying temperatures does not significantly impact the shape index of eggs, regardless of herbal spray treatment.

5.1.6 Surface Area

The results of our study indicate that neither transportation nor cold storage had a significant ($P>0.05$) effect on the length and width of eggs. This finding is consistent with previous research conducted by Doyon (1985), Shafey *et al.* (2002), Anderson *et al.* (2004) and Alsobayel *et al.* (2003), which also reported that the physical dimensions of eggs are not the conditions under which they are transported or stored. It suggests that these factors do not adversely affect the structural integrity of eggs within the evaluated time frames. Previous studies have similarly indicated that eggs can maintain their dimensions when subjected to standard transportation and refrigeration practices. For instance, Shafey *et al.* (2002) observed that eggs stored under controlled conditions exhibited stable dimensions over time, reinforcing the notion that storage duration is a more critical factor than the specific storage conditions. The findings highlight the importance of managing storage duration to maintain egg quality.

While transportation and cold storage conditions are essential for preserving other quality parameters, such as albumen height and pH, they appear to have a negligible impact on egg dimensions. This aligns with the conclusions drawn by Anderson *et al.* (2004), who emphasized that prolonged storage could lead to deterioration in egg quality, but the physical dimensions remain relatively stable. Similarly, Alsobayel *et al.* (2003) reported that while egg quality metrics such as weight and internal quality may decline with extended storage, the external dimensions of the eggs are less affected.

5.2 Internal Parameters

5.2.1 Haugh Unit

Haugh unit reduction happened due to the decrease in thick albumen height, during storage the ovomucin-lysozyme complex breaks down, which helps to increase the pH of eggs. The result of transport study shows no significant ($P > 0.05$) effect on the HU, but the slight reduction effect was observed due to transportation vibration and environmental effect. The cold storage of the one month results showed significant effect on HU due to prolonged effect. That states that storage time and temperature significantly ($P < 0.05$) affect the HU. These results of this study were supported by Morais *et al.* 1997 who observed the reduction in the Haugh unit of eggs at 21 days of storage. Similarly, storage temperatures can affect the HU of eggs. High storage temperatures promote the breakdown of ovomucin-lysozyme complex. As a result, HU of eggs stored at room temperature was reduced significantly ($P < 0.05$) compared to refrigeration. The results agree with Santos, 2009; Sauveur, 1993 and Samli *et al.* 2005, that storage time and temperature adversely affected HU of eggs. Consequently, other researchers like Tona *et al.* 2009 and Akyurek and Okur 2004 reported that the rate of water loss from egg is influenced by the rate of evaporation from egg content. Previous studies have demonstrated that oil coating, a current practice used to extend shelf life of eggs, was effective in preserving albumen quality of eggs (Stadelman and Wilson 1958; Homler and Stadelman 1963; Sabrani and Payne 1978). For example, Sabrani and Payne (1978) observed that the Haugh unit of oil-coated eggs decreased from an initial value of 89.0 to 65.9 (for 28 wk old hen) and 76.3 to 59.5 (for 60 wk old hen), respectively, after 24 d of storage at 28 °C. coating with oil coating for its effectiveness in preserving the internal quality of eggs

since egg quality may differ with initial egg quality, egg size, and storage conditions (temperature and period) (Sabrani and Payne 1978; Scott and Silversides 2000).

5.2.2 Albumin Index

The findings related to the albumen index during transportation indicated no significant effect ($P>0.05$). Similarly, cold storage for one month did not result in any significant differences ($P>0.05$) in the albumen index. However, the storage duration of eggs beyond one month did have a significant impact ($P<0.05$) on the albumen index in both experimental setups. Specifically, the T3 group maintained a relatively consistent albumen index throughout the experimental period. The observed decrease in thick albumen height can be attributed to the breakdown of the ovomucin-lysozyme complex during storage, which leads to a reduction in the albumen index. These findings align with the work of Morais *et al.* (1997), who reported a decline in the albumen index of eggs after 21 days of storage. Additionally, storage temperatures play a crucial role in affecting the albumen index. Elevated storage temperatures can accelerate the breakdown of the ovomucin-lysozyme complex, resulting in a significant reduction ($P<0.05$) in the albumen index of eggs stored at room temperature compared to those kept in refrigeration. This is consistent with the observations of Sauveur (1988) and Samli *et al.* (2005), who found that both storage time and temperature negatively impact the albumen index of eggs. Furthermore, research by Tona *et al.* (2009) and Akyurek and Okur (2004) highlighted that the rate of water loss from eggs is influenced by the evaporation rate of the egg contents. Previous studies have also shown that oil coating, a common practice to extend the shelf life of eggs, effectively preserves the quality of the albumen (Stadelman and Wilson, 1958; Schwall *et al.*, 1961).

5.2.3 Yolk index

In our study transportation doesn't affect significantly ($P>0.05$) on the yolk index of the egg. After the 12th day of storage onwards, significant ($P<0.05$) effect was observed in all group. The beyond one-month cold storage significant ($P<0.05$) effect on yolk index due to the prolonged storage. A yolk index value, calculated as yolk height/yolk width, is an indication of freshness of eggs (Stadelman, 1986). A decrease in a yolk index value during storage

indicates a progressive weakening of the vitelline membranes and liquefaction of the yolk caused mainly by diffusion of water from the albumen (Obanu and Mpieri, 1984). Several studies revealed that during the storage, osmotic diffusion of water in albumin due to microbial invasion during storage will lead to a weakening of the lecithin membrane, reduction in total solids, and liquefaction of the yolk, ultimately leading to a reduction in total solids and liquefaction of the yolk (Zang *et al.*, 2019).

5.2.4 Albumin and Yolk Weight

Experimental results of transportation not show any significant ($P > 0.05$) effect on the weight of albumin, but the further storage showed significant ($P < 0.05$) difference on egg albumin weight. In T3 group i.e. sprayed and stored at 4-7°C shows no significant ($P > 0.05$) difference in albumin weight throughout experimental period. Cold storage of one month showed significant ($P < 0.05$) decrease in the egg albumin weight. These results are inconsistent with Siyar *et al.*, 2007 and Tabidi, 2011, who reported that the loss in albumen weight is attributed to loss of humidity from inside the egg due to evaporation. Consequently, albumen weight loss was significantly ($p < 0.05$) higher at room temperature than in refrigeration at 28 days of storage. This may be due to the higher amount of water loss from the albumen to the yolk. Similar results were demonstrated by Tona *et al.*, 2004 and Akyurek and Okur, 2009, that water loss from eggs may be influenced by storage time, temperature, relative humidity and porosity of the shell. A decrease of albumen weight with storage was due to the evaporation of water and loss of carbon dioxide from the albumen through the shell (Obanu and Mpieri 1984; Stadelman 1986). Scott and Silversides (2000) and Silversides and Scott (2001) also reported that, when measured as a percentage of the whole egg, albumen weight decreased, and yolk weight increased with storage.

Experimental results of transportation not show any significant ($P > 0.05$) effect on the weight of yolk, but the further storage showed significant ($P < 0.05$) differences on yolk weight. In T3 group i.e. sprayed and stored at 4-7°C shows least increase in yolk weight through experimental period. Cold storage of one month showed significant ($P < 0.05$) increase in the egg yolk weight. These results concur with and Barbosa *et al.*, 2004. On the other hand, when

the storage temperature was higher, the rate of increase in yolk weight was significantly ($P < 0.05$) higher than in refrigeration (4°C). These results are supported by Davis and Stephenson, 1991; Morais *et al.*, 1997 and Leandro *et al.*, 2005, who reported that the most important factors that affect egg quality during storage are temperature and relative humidity. Diffusion of water from the albumen to the yolk (Obanu and Mpieri, 1984) may be partly responsible for the increase of yolk weight during storage. The yolk gains moisture and the albumen lose it as storage progresses (Obanu and Mpieri, 1984).

5.2.5 Yolk Color

The study of transportation and cold storage doesn't affect yolk color significantly ($P > 0.05$) at any temperature or condition. This proves that the temperature did not influence the yolk pigmentation. This might be due to the antioxidant content of layer ration, because layer diet was formulated by using crude palm oil (CPO), which was rich in carotenoids and vitamin E, which delayed or prevented the oxidation of carotenoid pigments contained in feed and yolk Mohiti *et al.*, (2010); while in another study, it was demonstrated that the addition of vitamin E (20 and 40 mg/kg) to hen diets reduced yolk color intensity, in comparison with the control group El-Mallah *et al.*, (2011). Spada *et al.*, (2008) found increased pigmentation of the red in yolks after 28 days of storage at room temperature (25°C) and stabilizing on the 36th day. No recent data was found regarding the relationship between yolk color and storage temperature or time.

5.2.6 Shell Weight and Thicknesses

No significant ($P < 0.05$) effect of transportation and cold storage on the shell thickness and its weight (in grams). Because no effect of storage was seen on the calcification process. over the Previous studies with other coating materials showed that the weight gain of eggs by coating with oil or alginate was negligible (Murray and Rutherford, 1963) and that increase in shell thickness ranged from 0.001 to 0.013 mm by coating eggs with soy protein isolate, whey protein isolate, carboxymethyl cellulose, and wheat gluten (Xie and others, 2002). Wong and others (1996) observed significant differences in shell thickness between noncoated eggs and eggs coated with wheat gluten and corn zein, but reported no differences between noncoated

eggs and eggs coated with mineral oil, egg albumen, and soy protein isolate. Rhim and others (2004) reported that a single coating of eggs with soy protein did not significantly affect the shell thickness, but double coating significantly increased the shell thickness (0.405 mm) compared with that (0.387 mm) of non-coated eggs. These findings on shell thickness are also in agreement with Dudusola, who did not find any effect of storage time and temperature on shell thickness in partridges and Japanese quail eggs. These findings are in line with Silversides and Scott, 2001; Tilki and Inal, 2004 and Akyurek and Okur, 2009, who reported no effect of storage time on eggshell weight. In contrast, Samli *et al.*, 2004 noticed significant ($P < 0.05$) change in shell weight during storage at different time and temperature. The reason for this result may be the disinfectant or coating agent has some effect on the eggshell weight, but the exact cause needs further study.

5.3 pH

5.3.1 pH of an Egg

In addition to weight loss, Haugh units, yolk index, and pH can serve as quality indices for eggs (Scott and Silversides, 2000; Caner *et al.*, 2015). The impact of transportation on egg pH showed no significant ($P > 0.05$) reduction until the sixth day of storage post-transportation across all groups. Conversely, the results of cold storage indicated significant ($P < 0.05$) differences in egg pH across all groups after prolonged cold storage, with this trend continuing throughout the experimental period. The increase in pH after 14 and 28 days can be attributed to the relative evaporation of water, carbon dioxide, hydrogen, and hydrogen sulfide gases due to the lower storage temperatures. Additionally, microbial activity, which metabolizes acids, is inhibited under low-temperature storage conditions. However, findings from Caner *et al.*, (2015) and Sheng *et al.*, (2021) suggest that the albumen pH of coated groups initially decreased before increasing with storage time. This trend was not uniform across all storage experiments and contrasts with our results. This difference may be because of the disinfectant or anti-microbial coating agent on the egg albumen through the eggshell; however, further investigation is necessary to elucidate the exact causes. Regardless, it is noteworthy that, relative to the initial measurements, albumen pH values for all groups increased by the end of the storage period.

5.3.2 pH of Albumen

The pH of egg albumen is significantly influenced by both storage time and temperature. Our results indicate that albumen pH was significantly higher ($P < 0.05$) at room temperature compared to refrigeration throughout the storage period. This difference may be attributed to increased evaporation from the eggs at ambient temperatures. Furthermore, the effects of transportation on albumen pH were not significant ($P > 0.05$) until the sixth day of storage, after which a notable increasing trend in albumen pH was observed. The highest pH values were recorded in the T2 group, which consisted of non-sprayed eggs stored at ambient temperature. Notably, one month of cold storage of fresh eggs did not significantly affect albumen pH ($P > 0.05$); however, a significant difference ($P < 0.05$) was observed starting from the 36th day of storage. These findings align with previous studies by Moula *et al.*, (2009) and Silversides and Budgell (2004), which also reported an increase in albumen pH with extended storage. In contrast, Walsh *et al.*, (1995) found that neither temperature nor storage time influenced egg albumen pH. Additionally, AEB (2007) noted that refrigeration significantly slows down pH changes in egg albumen. Freshly laid eggs typically contain approximately 0.5% carbon dioxide, which diminishes during storage (Knight *et al.*, 1972). The resultant chemical changes, initiated by this loss, lead to thinning of the albumen and an increase in pH values, reaching between 9.4 and 9.5 (Kim *et al.*, 1997; Scott and Silversides, 2000; Silversides and Scott, 2001; Caner *et al.*, 2005).

5.3.3 pH of Yolk

The experimental results demonstrated a significant ($P < 0.05$) difference in yolk pH between sprayed and non-sprayed eggs, as well as in relation to their storage temperature. Notably, transportation vibrations and cold storage did not exhibit a significant ($P > 0.05$) effect on yolk pH. The literature suggests that lower temperatures contribute to a slower increase in yolk pH; however, the application of a coating also helps preserve yolk pH at its original level. The observed increase in egg yolk pH aligns with findings by Jin *et al.*, (2011), who reported a significant ($P < 0.05$) increase in both albumen and yolk pH with rising temperature and storage time. When comparing yolk pH to that of fresh liquid egg yolk, the difference remained

relatively small, and the values were still classified as indicative of good quality. According to Barutu (2016), the pH of high-quality egg yolk is approximately 6.0. Typically, egg yolks have a pH of about 6.0, which increases to a range of 6.4 to 6.9 during storage, remaining relatively constant if there is no loss of carbon dioxide (Caner *et al.*, 2005). The increase in egg pH is consistent with the assertions of Samli *et al.*, (2005) and Akyurel and Okur (2009), who indicated that storage time significantly influences egg pH. This increase is attributed to the loss of carbon dioxide resulting from the breakdown of carbonic acid in egg yolks (Wardy *et al.*, 2014).

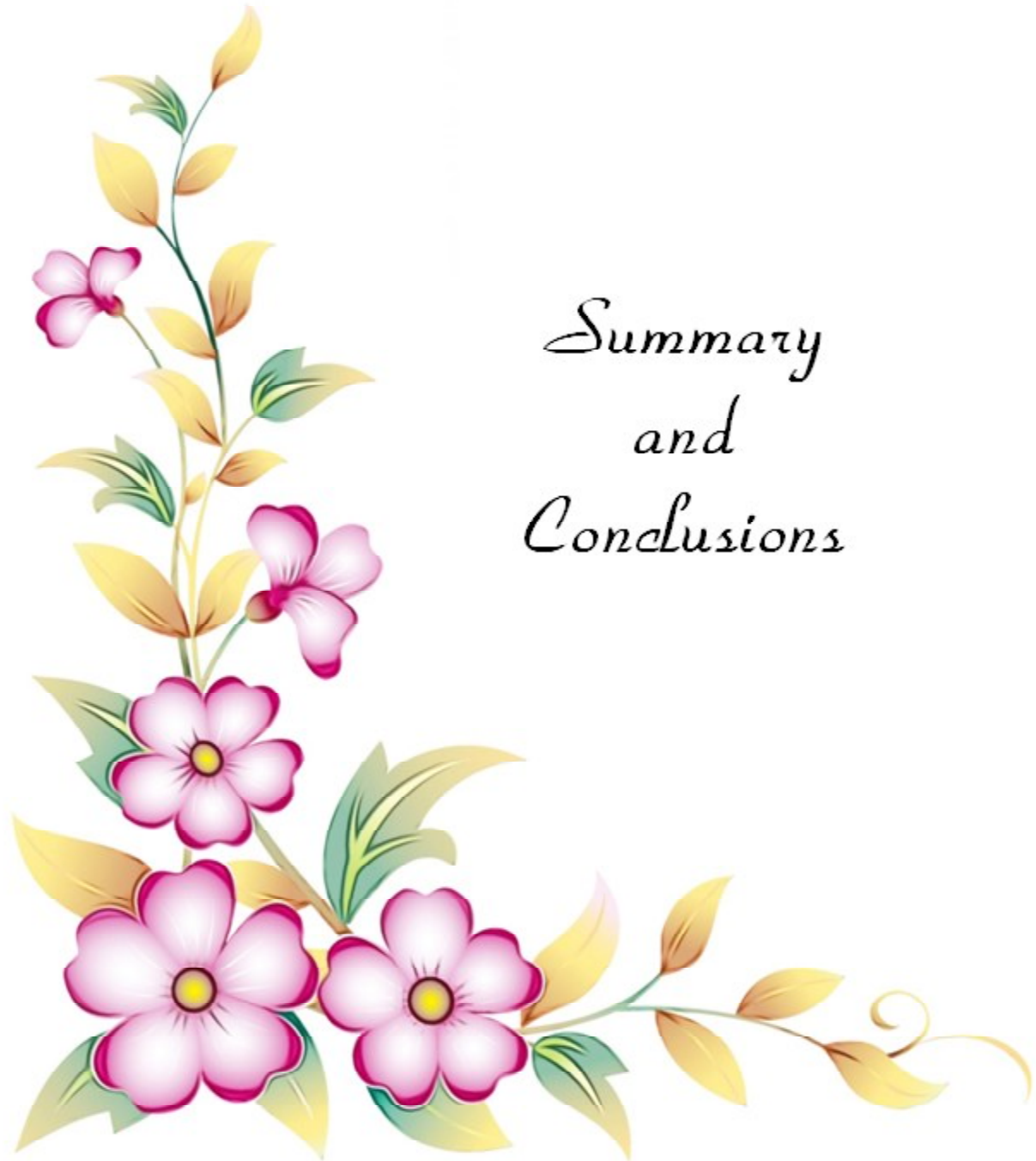
5.4 Microbial Study

The results from our experimental studies on bacterial growth during the transportation and cold storage of eggs align with the established microbiological principles outlined in the previous studies. Experimental findings indicate that bacterial growth during transportation is likely due to exogenic contamination, which occurs when eggshells encounter environmental microorganisms. The at eggs can be contaminated externally by fecal microorganisms or other environmental sources, and that this type of contamination is significantly more common than endogenic contamination, which occurs during egg formation in the hen. The contamination levels can vary widely, with studies showing mesophilic aerobic microbiota levels ranging from 10^3 to 10^6 CFU/egg, depending on various factors including the sanitary conditions during transportation (Baron and jan, 2011). Despite the protective barriers provided by the eggshell and membranes, results suggest that bacterial penetration can occur, especially in cases of compromised eggshell integrity. The cuticle and shell membranes serve as barriers, they can be ineffective if the eggshell is cracked or if the contamination levels are high. This aligns with your observations of bacterial growth, suggesting that compromised eggshells during transport may have facilitated microbial entry (Samli *et al.*, 2005). The experimental findings of bacterial growth after one month of cold storage can be explained by the survival mechanisms of bacteria within the egg white. The article by Akyurel and Okur (2009) discusses how egg white contains antimicrobial properties, such as lysozyme and Ovo transferrin, which inhibit bacterial growth. However, it also highlights that these defenses can be overcome, particularly under certain storage conditions. For instance, the growth of Salmonella is notably inhibited at temperatures

below 8°C, but can proliferate at higher temperatures, especially between 20°C and 30°C, where significant growth can occur (Akyurel and Okur, 2009). The storage duration and temperature are critical factors influencing bacterial growth. Our results indicate that after one month of cold storage, the conditions may have favored bacterial growth due to potential alterations in egg quality, such as changes in the vitelline membrane and egg white viscosity. Previous studies of Caner *et. al.*, (2015) suggests that these changes can enhance nutrient migration from the yolk to the egg white, creating a more favorable environment for bacterial proliferation. In conclusion, the discussion of our findings in the context of the literature highlights the importance of managing both transportation and storage conditions to minimize bacterial contamination and growth in eggs. Understanding the mechanisms of contamination and the conditions that favor bacterial survival can inform better practices in the egg production and handling industry (Scott and Silversides, 2000; Caner *et. al.*, 2015).



*Summary
and
Conclusions*



The research titled “A Novel Strategy for Enhancing the Shelf-Life Stability of Table Eggs Under Varied Storage Conditions” explores the use of a herbal-based spray, known as “CARI EGG SHIELD,” to improve the preservation and quality of table eggs. This study is crucial as it addresses significant issues related to post-harvest egg loss during storage and transportation, which is a growing concern in the poultry industry, particularly in countries with diverse climatic conditions like India. The study was conducted in response to the challenges faced in maintaining the quality and shelf life of eggs during transportation and storage. Eggs are highly perishable, and factors such as temperature variations and microbial contamination can lead to significant post-harvest losses. The primary purpose of this research was to develop and evaluate the effectiveness of herbal-based egg spray that could reduce microbial spoilage and improve the shelf life of eggs stored under different temperature conditions.

The research was conducted in two phases. In the first Objective, 800 eggs were collected, these eggs were transported for 12 hours and divided into four groups based on different storage and treatment conditions:

1. Refrigerated storage without spray (T1),
2. Refrigerated storage with spray (T2),
3. Ambient temperature storage without spray (T3) and
4. Ambient temperature storage with spray (T4).

In the second Objective, 1200 eggs were collected, out of which 600 were treated with the spray and all eggs stored in cold storage for one month, after which they were evaluated

for changes in internal and external quality parameters. The study utilized a range of measurements to assess egg quality, including egg weight, weight loss, Air cell size, Haugh Unit, yolk index, albumen index and microbial load (total plate count and *E. coli* count). Statistical analyses were performed to determine the significance of the findings.

Objective 1: To evaluate the efficacy of herbal-based egg spray on transported eggs for reducing microbial spoilage and improving shelf life at different storage temperature.

The experimental results regarding the weight of herbal-sprayed transported eggs indicate a significant reduction in egg weight during the storage period. Non-sprayed eggs stored at ambient temperature (T2) exhibited the greatest weight loss due to increased moisture evaporation. In contrast, T4 eggs, which were sprayed and stored at ambient temperature, showed less weight loss compared to T2. The least weight loss was observed in the T3 group, where eggs were sprayed and stored at low temperatures.

The air cell size in the eggs increased with storage duration and temperature. Non-sprayed eggs at ambient temperature (T2) exhibited the largest air cell size by the end of the experiment compared to the sprayed group (T4) at the same temperature. Conversely, the sprayed group stored at low temperature (T3) showed minimal increase in air cell size compared to T1.

Both herbal-sprayed and non-sprayed eggs demonstrated a decrease in specific gravity as a result of reduced egg weight and increased air content due to moisture loss. The maximum reduction in egg weight was observed in T2, attributed to high temperatures and significant moisture loss. This rapid reduction in specific gravity was also noted in eggs stored at ambient temperatures (T2 & T4), whereas the low-temperature group (T1 & T3) exhibited less reduction. Among these, T3, the sprayed group, showed minimal reduction in specific gravity compared to non-sprayed counterparts.

The Haugh Unit, an important parameter for assessing internal egg quality, decreased across all groups following transportation. The most significant decline was noted in T2 (non-sprayed at ambient temperature). In contrast, T3 did not show a notable reduction by the end

of the experiment due to the effects of herbal spray and lower storage temperatures. The threshold level for Haugh Units was surpassed by T2 on day 12, while cold-stored eggs crossed this threshold between days 6 and 12 post-storage. The herbal spray coating significantly delayed quality deterioration.

Prolonged storage of both non-sprayed and herbal-sprayed eggs resulted in a reduction of albumin index due to protein denaturation. The T2 group exhibited the highest reduction in albumin index by the end of the storage period compared to non-sprayed eggs stored at lower temperatures (T1). Higher temperatures denature proteins more rapidly than lower temperatures due to bond breakage and moisture loss. Sprayed groups (T3 & T4) experienced minimal reductions in albumin quality.

The yolk index also decreased with prolonged storage time, paralleling declines in albumin quality. The maximum reduction in yolk index was observed in T2 (non-sprayed at ambient temperature), while T4 (sprayed at ambient temperature) fared slightly better. The highest yolk index values were recorded for T3 eggs.

The study revealed that albumin weight decreased over time as storage progressed, primarily due to moisture loss through the eggshell pores. This moisture loss is directly related to temperature and storage duration. A sharp decline in albumen weight was noted for T2 compared to T1 (stored at low temperature). Sprayed eggs (T3 & T4) maintained better albumen weight than non-coated counterparts, indicating that spraying helps delay moisture loss from albumin. As albumin weight decreases over time, yolk weight tends to increase due to reverse osmotic pressure affecting the vitelline membrane, ultimately leading to its rupture. Notably, T2 showed a significant increase in yolk weight by the end of the experimental period, while T3 had minimal increase.

The study also found that pH levels of whole eggs increased over storage time for both herbal-sprayed and non-sprayed groups as time and temperature rose. The highest pH value was recorded for T2 at the end of the experiment compared to other groups (T1, T3 & T4). Sprayed eggs stored at lower temperatures (T3) exhibited the least pH increase. The application of herbal sprays appears to delay pH elevation by reducing moisture loss and CO₂ exchange, which contributes to protein denaturation.

The increase in egg pH correlates with changes in albumin pH. Non-sprayed ambient storage (T2) showed maximum CO₂ exchange, leading to increased albumen pH levels. High-temperature storage caused pH levels to rise from 7.5 to between 9.4-9.7 during the storage period. In comparison, sprayed groups (T3 & T4) demonstrated less increase in albumen pH than non-sprayed groups (T1 & T2).

An increase in pH indicates a rise in microbial growth, specifically total plate count (TPC) and E. coli levels. Non-sprayed groups (T1 & T2) exhibited higher bacterial growth than sprayed groups (T3 & T4), with T2 showing maximum contamination throughout the experimental period due to open pores allowing bacterial entry and CO₂ release. The breakdown of Ovomucin-lysozyme bonds during storage at ambient temperatures further diminished antimicrobial activity in egg whites. Conversely, T3 demonstrated minimal microbial contamination throughout the study period when stored at low temperatures compared to non-sprayed refrigerated eggs.

Objective 2: To study the effect of herbal-based egg spray on cold stored eggs for improving shelf life

Results from a study on the weight of herbal-sprayed eggs after one month of cold storage indicate a notable reduction in weight over the storage period. Non-sprayed eggs stored at ambient temperature (T2) exhibited the highest weight loss due to significant moisture evaporation. In contrast, T4 eggs, which were sprayed and also stored at ambient temperature, experienced less weight loss compared to T2. The T3 group, consisting of sprayed eggs stored at lower temperatures, showed the least weight reduction.

Air cell size, an increase was observed as storage duration and temperature rose. The largest air cell size was recorded in the non-sprayed eggs at ambient temperature (T2), while the sprayed group stored at low temperature (T3) had the smallest air cell increase compared to T1 at the end of the experiment.

The study also revealed a decrease in specific gravity for both herbal-sprayed and non-sprayed eggs, attributed to moisture loss and reduced egg weight. The most significant reduction in specific gravity occurred in T2 due to high temperatures and moisture loss. Conversely, T3 exhibited minimal reduction in specific gravity compared to non-sprayed eggs.

The Haugh Unit, a critical measure of internal egg quality, declined across all groups after one month of cold storage, with T2 showing the most substantial decrease. Notably, T3 did not display significant reductions due to the combination of herbal spray and low storage temperatures. The threshold level for Haugh Units was surpassed by T2 on day 12, whereas cold-stored eggs crossed this threshold between days 6 and 12. The herbal spray significantly delayed the deterioration of egg quality.

After one month of cold storage, both non-sprayed and herbal-sprayed eggs showed a reduction in albumin index due to protein denaturation. The T2 group exhibited the highest decline in albumin index compared to non-sprayed eggs stored at lower temperatures (T1). Higher temperatures accelerate protein denaturation more than lower temperatures due to bond breakage and moisture loss. In contrast, sprayed groups (T3 & T4) demonstrated minimal reductions in albumin quality.

The yolk index also decreased with prolonged storage time, paralleling the decline in albumin quality. Maximum reduction was noted in T2 (non-sprayed at ambient temperature), while T4 (sprayed at ambient temperature) showed slightly better results. The highest yolk index values were recorded for T3 eggs.

The study highlighted that egg weight loss during storage leads to a decrease in albumin weight over time due to moisture evaporation through the eggshell pores. This moisture loss correlates with increased storage temperature and duration. The sharpest decline in albumen weight was observed in T2 compared to T1 (stored at low temperature). Sprayed eggs (T3 & T4) maintained better albumen weight than non-coated counterparts, indicating that spraying helps mitigate moisture loss from albumin. As albumen weight decreases over time, yolk weight tends to increase due to reverse osmotic pressure affecting the vitelline membrane, ultimately leading to its rupture. Notably, T2 showed the greatest increase in yolk weight by the end of the experiment, while T3 had minimal yolk weight increase.

Additionally, pH levels of whole eggs increased during storage for both herbal-sprayed and non-sprayed groups as time and temperature rose. The highest pH value was recorded for T2 at the end of the study compared to other groups (T1, T3 & T4). Sprayed eggs stored

at lower temperatures (T3) exhibited the least pH increase. The application of herbal sprays appears to delay pH elevation by reducing moisture loss and CO₂ exchange, which contributes to protein denaturation and increased pH values.

The increase in pH correlates with microbial growth, specifically total plate count (TPC) and *E. coli* levels. Non-sprayed groups (T1 & T2) showed higher bacterial growth than sprayed groups (T3 & T4), with T2 experiencing maximum contamination throughout the experimental period due to open pores allowing bacterial entry and CO₂ release. The breakdown of Ovomucin-lysozyme bonds during storage at ambient temperatures further diminished antimicrobial activity in egg whites. Conversely, T3 demonstrated minimal microbial contamination over the study period when stored at low temperatures compared to non-sprayed refrigerated eggs.

These sprayed eggs kept at Refrigerated temperature (T3) less weight loss, higher Haugh Unit scores and lower microbial contamination levels. Conversely, eggs stored at ambient temperature without the spray (T2) showed the most significant decline in the egg quality.

The results revealed that the herbal spray, particularly when used in combination with lower temperature (T3), significantly improved the shelf life of eggs maintained higher quality over time compared to untreated eggs (T1 & T2). The findings demonstrate that the “CARI EGG SHIELD” spray effectively preserves the internal and external quality of eggs, reduces microbial spoilage and extends shelf life by delaying the egg deterioration, especially under refrigerated conditions. This study concludes that the use of the herbal-based “CARI EGG SHIELD” spray can play a vital role in enhancing the shelf life and quality of table eggs during cold storage and transportation. The spray’s antimicrobial properties significantly reduce microbial growth, thereby improving egg safety and quality. These results have important implications for the poultry industry, as they suggest a practical solution to reduce post-harvest losses and improve product sustainability.

While the study provides valuable insights, it is limited to specific storage conditions and egg types. Future research could explore the spray’s effectiveness across different poultry breeds and under varying environmental conditions. Additionally, long-term studies could assess

the economic benefits of implementing this technology on a commercial scale. This research offers a novel approach to addressing post-harvest egg losses by introducing an environmentally friendly and effective method for enhancing egg shelf life. The development and application of the “CARI EGG SHIELD” spray represent a significant contribution to the field of poultry science, with potential benefits for both producers and consumers in maintaining egg quality during distribution. By addressing a critical issue in the poultry industry, this study not only provides a solution to a practical problem but also contributes to the broader understanding of food preservation and sustainability in the context of global food security.

Conclusion

The current study investigated how time, temperature and herbal sprays affect the shelf life of transported and cold stored eggs. As we know temperature, duration of storage, opening of pores etc. are very important factors for quality of eggs but in Indian scenario data regarding the shelf life of transported or cold stored (30days) eggs is lacking. In our study we confirmed that storing transported & herbal sprayed eggs at a low temperature of 4-7°C significantly improves their shelf life by 2 weeks and storage of same eggs at ambient temperature $26.5 \pm 3^\circ\text{C}$ shows improvement in shelf life by a week. Where in second study, cold storage (one month) & herbal sprayed eggs kept at a low temperature of 10-15°C post cold storage period significantly improves shelf life by 2 weeks. Based on our findings, we recommend that 12 hr. transported Herbal sprayed eggs stored at 4-7°C should consumed within 60 days and non-sprayed eggs should consume in 42 days. If stored at $26.5 \pm 3^\circ\text{C}$, they should be consumed within 18 and 12 days respectively. The 30-day cold stored non sprayed eggs at 10-15°C are safe to consume until the 54th day (24 day post cold storage) and Herbal sprayed eggs to 66th day (36 day post cold storage), while non sprayed eggs stored at $26.5 \pm 3^\circ\text{C}$ can be consumed within the 6th day after the 30 days of cold storage i.e. 36th day and Herbal sprayed eggs within 42 days.





Mini Abstract

India's poultry industry ranks 3rd in egg and 5th in meat production, contributing 30% to Agricultural GDP. The Indian poultry sector, worth \$28.18B in 2022, aims for \$44.97B by 2028. The southern part of India is known as the Egg Basket, producing a significant portion of the country's eggs. To fulfil the demand of the rest of the country, eggs are stored and transported over thousands of kilometres. Inadequate infrastructure like cold storage facilities, roads, and packaging, compounded by the effects of climate change, leads to significant post-harvest deterioration and loss. Improper infrastructure causes 10-25% post-harvest egg losses, creating One Health issues. Additionally, accountability by Indian regulatory bodies is lacking. To understand and address the post-harvest loss in the egg sector, we carried out two experiments. We studied the effect of an Herbal-Based Spray named CARI EGG SHIELD (Patent Application No. 202311066448) on internal, external, and microbial parameters of transported and cold storage eggs. Fresh eggs were collected from ICAR-CARI and went under spray. After the 12-hour transportation at a speed of 50-60 km/hr, analysis was carried out to assess the loss. The eggs were then stored under different temperatures. Test analyses were carried out at intervals of every 6 days until deterioration, where internal, external, and microbial parameters were recorded. In another experimental study, we collected 1,200 fresh eggs, of which 600 were sprayed with our Herbal-Based Spray. After that all the eggs were cold stored for one-month period, these eggs then post cold storage period were further stored at different temperature conditions and analysed every 6 days until deterioration. The analysis of both Transported and cold stored experimental eggs revealed significant differences ($P < 0.05$) in various quality parameters of eggs, including egg weight loss percentage, air cell diameter, Haugh Unit (HU), Yolk Index (YI), Albumin Index (AI), pH, Yolk Weight, and Albumin Weight. Herbal sprayed eggs stored at lower temperatures exhibited superior quality compared to non-sprayed eggs. Conversely, in both experimental parameters such as shell thickness, shape index, and surface area showed no significant differences ($P > 0.05$), indicating that transportation and cold storage did not cause any physical changes, thus maintaining the structural integrity of the eggs throughout the study. In our study, we found that herbal sprays and low temperatures (4-7°C) significantly enhance egg shelf life, extending it by two weeks compared to non-sprayed eggs. Sprayed eggs stored at room temperature (26.5°C) lasted one week longer.



लघु सारांश

भारत का कुक्कुट उद्योग अण्डा उत्पादन में तीसरे और मांस उत्पादन में पांचवे स्थान पर है, जो कृषि सकल घरेलू उत्पाद में 30% का योगदान देता है। वर्ष 2022 में भारतीय कुक्कुट क्षेत्र का मूल्य \$28.18 अरब था और वर्ष तक 2024 इसका लक्ष्य \$44.97 अरब का है। भारत के दक्षिणी हिस्से को 'अण्डों की टोकरी' कहा जाता है, जो देश के बड़े हिस्से के लिए अण्डे का उत्पादन करता है। देश के अन्य हिस्सों की मांग को पूरा करने के लिए, अण्डों को संग्रहित किया जाता है और हजारों किलोमीटर तक परिवहन किया जाता है। ठण्डे भंडारण सुविधाओं, सड़कों और संवेष्टन जैसी अपर्याप्त बुनियादी ढांचे, और जलवायु परिवर्तन के प्रभावों के कारण फसलोपरान्त में महत्वपूर्ण गिरावट और नुकसान होता है। अनुचित बुनियादी ढांचे के कारण अण्डों में 10-25% फसलोपरान्त नुकसान होता है, जिससे 'एक स्वास्थ्य' समस्याएं उत्पन्न होती हैं। इसके अलावा, भारतीय नियामक निकायों की जबवाबदेही की कमी भी समस्या का हिस्सा है। अण्डा क्षेत्र में फसलोपरान्त नुकसान को समझने और संबोधित करने के लिए हमने दो प्रयोग किए। हमने एक हर्बल-आधारित स्प्रे (पेटेंट आवेदन संख्या 20311066448) का अण्डों पर आवरण के रूप में प्रयोग किया (CARI EGG SHIELD) और परिवहन और ठण्डे भंडारण के दौरान अण्डों की आंतरिक, बाहरी और सूक्ष्मजीवी मापदंडों पर सड़के प्रभाव का अध्ययन किया। ताजे अंडों को भारतीय कृषि अनुसंधान परिषद – केन्द्रीय पक्षी अनुसंधान संस्थान से एकत्र किया गया और यादृच्छिक रूप से स्प्रे किया गया। 50-60 किमी/घंटा की गति पर 12 घण्टे के परिवहन के दौरान तथा परिवहन के तुरंत बाद नुकसान का आकलन किया गया। इसके बाद अण्डों को विभिन्न तापमानों पर संग्रहित किया गया। क्षय तक, हर 6 दिनों के अंतराल पर परीक्षण विश्लेषण किए गए, जिसमें आंतरिक, बाहरी और सूक्ष्मजीवी मापदंडों को दर्ज किया गया। अन्य प्रयोगात्मक अध्ययन में, हमने 1200 ताजे अंडों को एकत्र किया, जिनमें से 600 अंडों को हमारे हर्बल-आधारित स्प्रे से स्प्रे किया गया। इस स्प्रे ने एक महीने के ठंडे भंडारण के दौरान अंडों के गिरावट को कम करने में प्रभावी सिद्ध किया। एक महीने के ठंडे भंडारण के बाद, इन अंडों को विभिन्न तापमान स्थितियों में संग्रहित किया गया और हर 6 दिनों के अंतराल पर क्षय तक विश्लेषण किया गया। दोनों प्रयोगों में परिवहन और ठंडे भंडारण किए गए अंडों के विश्लेषण से पता चला कि अंडों के विभिन्न गुणवत्ता मापदंडों में महत्वपूर्ण अंतर ($P < 0.05$) था, जिसमें अंडों के वजन का नुकसान प्रतिशत, वायु कोशिका व्यास, हांग इकाई (HU), जर्दी सूचकांक (YI), अल्ब्यूमिन सूचकांक (AI), pH, जर्दी का वजन और अल्ब्यूमिन का वजन शामिल थे। ठंडे तापमान पर संग्रहित हर्बल स्प्रे किए गए अंडों की गुणवत्ता, गैर-स्प्रे किए गए अंडों की तुलना में बेहतर पाई गई। इसके विपरीत, शेल की मोटाई, आकार सूचकांक और सतह क्षेत्र जैसे मापदंडों में कोई महत्वपूर्ण अंतर ($P > 0.05$) नहीं देखा गया, जिससे यह पता चलता है कि परिवहन और ठंडे भंडारण ने अंडों की भौतिक संरचना पर कोई प्रभाव नहीं डाला, जिससे अध्ययन के दौरान अंडों की संरचनात्मक अखंडता बनी रही। हमारे अध्ययन में, हमने पाया कि हर्बल स्प्रे और कम तापमान (4-7°C) अंडों के निधानी आयु को काफी हद तक बढ़ाते हैं, जिससे यह गैर-स्प्रे किए गए अंडों की तुलना में दो सप्ताह अधिक समय तक सुरक्षित रहते हैं। कमरने के तापमान (26.5°C) पर संग्रहित स्प्रे किए गए अंडों एक सप्ताह अधिक समय तक चले हैं।



References

- A Berardinelli, V Donati, A Giunchi, L Ragni. 2003. Effects of Transport Vibrations on Quality Indices of Shell Eggs. *86*(4):495-502.
- AbdulAzeez, J.A. and Akbay, C., 2018. An economic analysis of broiler chicken production for different production rotations in the Northern Region of Iraq. *Tarým Ekonomisi Arařtırmaları Dergisi*, *7*(2): 76-89.
- Abeyrathne, E. D. N. S., A. Lee, and J. Ahn. 2013. Egg white proteins and their potential use in food processing or as nutraceutical and pharmaceutical agent. *Poult. Sci.* *92*(12): 3292-3299.
- Adams, J.L. and Skinner, J.L. 1963. Effects of management, strain and truck shipment on albumen quality of eggs. *Poult. Sci.* *42*(5): 1076-1081.
- Adarkwa, I., 2011. Assessment of the postharvest handling of six major vegetables in two selected Districts in Ashanti Region of Ghana (Doctoral dissertation).
- Adel A. Kader. 2002. Postharvest Technology of Horticultural Crops. *Ethiop. J. Appl. Sci. Technol.* *1*: 1–8.
- AEB (American Egg Board). 2007. pH stability. <https://www.aeb.org/food-manufacturers/eggproduct-overview/egg-product-advantages/39-functional-eroperties/219-ph>
- Ahmadi, E. 2012. Bruise Susceptibilities of Kiwifruit as Affected by Impact and Fruit Properties. *Res. Agric. Eng.* *58* (3): 107–113.
- Akyurek, H. And Okur, A.A. 2009. Effect of storage time, temperature and hen age on egg quality in free-range layer hens. *J. Anim. Vet. Adv.* *8*(10): 1953-1958.
- Alakali, J. S., and Adekunle, O. K. 2019. Post-harvest loss mitigation in the poultry industry. *Food. Energy. Secur.* *8*(3): e00175.

- Alsobayel, A. A. and Albadry, M. A. 2011. Effect of storage period and strain of layer on internal and external quality characteristics of eggs marketed in Riyadh area. *J. Saudi Soc. Agric. Sci.* **10**:41-45.
- Alsobayel, A.A., Almarshade, M.A. and Albadry, M.A. 2013. Effect of breed, age and storage period on egg weight, egg weight loss and chick weight of commercial broiler breeders raised in Saudi Arabia. *J. Saudi Soc. Agric. Sci.* **12**(1): 53-57.
- Altan, O., Dguz, L. and Akbas, Y. 1998. Effect of selection for high body weight and age of hen on egg characteristics in Japanese quail (*Coturnix coturnix japonica*). *Turk. J. Vet. Anim. Sci.* **22**: 67-473.
- Altuntas, E. And Sekeroglu, A. 2008. Effect of shape index on mechanical properties of chicken eggs. *J. Food. Eng.* **85**: 606–612.
- Altuntas, E. And Sekeroglu, A. 2010. Mechanical behavior and physical properties of chicken egg as affected by different egg weights. *J. Food. Process. Eng.* **33**(1): 115-127.
- Ananey-Obiri, D., Matthews, L., Azahrani, M.H., Ibrahim, S.A., Galanakis, C.M. and Tahergorabi, R. 2018. Application of protein-based edible coatings for fat uptake reduction in deep-fat fried foods with an emphasis on muscle food proteins. *Trends. Food. Sci. Technol.* **80**: 167-174.
- Anderson, K.E., Tharrington, J.B., Curtis, P.A. and Jones, F.T. 2004. Shell characteristics of eggs from historic strains of single comb white leghorn chickens and the relationship of egg shape to shell strength. *Int. J. Poult. Sci.* **3**(1): 17-19.
- Anton, M., P. Gandemer, and A. Masson. 2002. Composition and pH of hen eggs as a function of hen age and shell colour. *Worl. Poult. Sci. J.* **58** (2): 219-228.
- Aristocrat, Martin Dworkin, David Gutnick, Sergei Winogradsky 2007. A founder of modern microbiology and the first microbial ecologist, *FEMS Microbiology Reviews*, **3**(2): 364–379.
- Babalola, D. A., Y. O. Makinde, B. T. Omonona, and M. O. Oyekanmi. 2010. Determinants of Postharvest Losses in Tomato Production: A Case Study of Imeko-Afon Local Government Area of Ogun State. *Acta Satech* **3** (2): 14–18.
- BAHS, 2023. Basic Animal Husbandary Statistics by Department of Animal Husbandry & Dairying Govt. of India.
- Bain, M. M., I. Mcdade, D. G. Burchmore, M. A. Law, M. J. Wilson, C. Schmutz, and J. A. Preisinger. 2016. Enhancing the egg's natural defence against bacterial penetration by increasing cuticle deposition. *Anim. Genet.* **47** (1): 3-11.

- Banjo, T. A., 2018. Effect of different levels of layer feed diets on egg quality characteristics. *Asian J. Adv. Res. Rep.* **2**(2): 1-8.
- Baran, F. and Jan, S., 2011. Egg and Egg Product Microbiology. In: Nys, Y., Bain, M. and van Immerseel, F., Eds., *Improving the Safety and Quality of Eggs and Egg Products: Egg Chemistry, Production and Egg Products*, Woodhead Publishing Ltd., Cambridge, Great Britain, **1**: 330-350.
- Barbosa, N. A. A., Freitas, E. R., Sakomura, N. K. and Wada, M. T. 2004. Efeito da temperatura e do tempo de armazenamento na qualidade interna de ovos de poedeiras comerciais. *Braz. J. Poult. Sci.* **60**(6): 60-65.
- Baron, F. J. S. 2011. Egg and egg product microbiology. *Improving the Safety and Quality of Eggs and Egg Products*. **1**: 330–350.
- Baron, F., 2007. Biochemical characterization of eggshell cuticle degradation during embryonic development. *Poult. Sci.* **86** (6): 1049-1053.
- Barska, A., and J. Wyrwa. 2016. Consumer Perception of Active and Intelligent Food Packaging. *Probl. Agric. Econ.* **4** (349): 138–159.
- Barutu, E. M. S. 2016. *Kualitas dan Masa Simpan Telur Ayam Konsumsi pada Suhu Ruang*. Skripsi, IPB. Bogor. **2016**
- Berardinelli, A., Donati, V., Giunchi, A., Guarnieri, A., and Ragni, L. 2003. Effects of Transport Vibrations on Quality Indices of Shell Eggs. *Biosyst. Eng.* **86** (4): 495–502.
- Biladeau, A. M., and Keener, K. M. 2009. The effects of edible coatings on chicken egg quality under refrigerated storage. *Poult. Sci.* **88** (6): 1266–1274.
- BIS, 2023. Bureau of Indian Standardization: Annual Report 2023 by Gov. India.
- Board R.G. 2000. *Eggs and Egg Products*. In Lund B., Baird-Parker T.C., Gould G.W. (Eds), *Microbiological Safety and Quality of Food*, Aspen Publisher, Maryland.
- Board R.G. and Ayres J. 1965. Influence of temperature on bacterial infection of the hen's egg. *Appl. Microbiol.* **13**(3): 358–364.
- Board RG and Fuller R. 1994. *Microbiology of the Avian Egg*. London: Chapman and Hall. :117–138.
- Board, R. And H. Tranter 2017. *The microbiology of eggs*. Egg science and technology. CRC Press, 4th: 81-104.

- Board, R. G., and Halls, N. A. 1973. The cuticle: A barrier to liquid and particle penetration of the shell of hen's egg. *Br. Poult. Sci.* **14**: 67-97.
- Board, R. G., and Tranter. H. S. 1986. *The Microbiology of Eggs. Egg Science and Technology.* 75–96.
- Board, R. J. J. O. A. B. 1966. The course of microbial infection of the hen's egg. *Br Poult Sci.* **29**(2): 319-341.
- Board, R.G., and H.S. Tranter, 1995. *The microbiology of eggs. Egg Science and Technology.* The Haworth Press Inc., New York
- Bond, M., Meacham, T., Bhunnoo, R. and Benton, T. 2013. *Food waste within global food systems.* Swindon, UK: Global Food Security.
- Bovskova, Helena., Mikova, Kamila and Panovska, Zdenica. 2014. Evaluation of Egg Yolk Colour. *Czech J. Food Sci.* **32**: 213-217.
- Caglayan, T., Alapahan, S., Kýrýkçý, K. and Günlü, A. 2009. Effect of different egg storage periods on some egg quality characteristics and hatchability of partridges (*Alectoris graeca*). *Poult. Sci.* **88**(6):1330-1333.
- Campos, E.J. and Baião, N.C., 1975. Efeitos da temperatura, período e posição durante o armazenamento sobre a qualidade interna de ovos de consumo. In *Congresso Brasileiro de avicultura.* **4**: 179-182.
- Caner C. 2005. The effect of edible eggshell coatings on egg quality and consumer
- Caner Cengiz, Muhammed Yüceer 2015. Efficacy of various protein-based coating on enhancing the shelf life of fresh eggs during storage, *Poul. Sci.*, **94**(7): 1665-1677
- Caner, C., and Cansiz, Ö. 2008. Chitosan coating minimises eggshell breakage and improves egg quality. *J. Sci. Food Agric.* **88**(1): 56–61.
- Chandrasekara, A., and Shahidi, F. 2012. Bioaccessibility and antioxidant potential of millet grain phenolics as affected by simulated in vitro digestion and microbial fermentation, *J. Funct. Foods.* **4**(1): 226-237.
- Cyrille B. K. Rathgeber, Gonzalo Pérez-de-Lis and Laura Fernández-de-Uña. 2022. Anatomical, Developmental and Physiological Bases of Tree-Ring Formation in Relation to Environmental Factors. *Tree Physiology Book Series.* **8**: 61–99.
- Daniel Fromm, Sally U. Gammon, 1967. Specific Gravity and Volume of the Hen's Egg Yolk as Influenced by Albumen pH and Storage Age of the Egg, *Poul. Sci.* **47**(4): 1191-1196

- Davis, B. H. and Stephenson, H. P. 1991. Egg quality under tropical conditions in north Queensland. *Food Aust.* **43**:496-499.
- Davis, B. H. and Stephenson, H. P. 1991. Egg quality under tropical conditions in north Queensland. *Food. Aust.* **43**: 496-499.
- Denton, J. H., D. B. Mellor and F. A. Gardner. 1979. The effect of egg carton and case type on egg shell damage. *Poult. Sci.* **60**: 145–150.
- Dong, X., Dong, J., Peng, Y., and Tang, X. 2017. Comparative study of albumen pH and whole egg pH for the evaluation of egg freshness. *Spectrosc. Lett.* **50**:(9) 463–469. <https://doi.org/10.1080/00387010.2017.1360357>
- Doyon, G., Bernier-Cardou, M., Hamilton, R.M.G., Castaigne, F. and MacLean, H. 1985. Egg quality. 1. Shell strength of eggs from five commercial strains of white leghorn hens during their first laying cycle. *Poult. Sci.* **64**(9): 1685-1695.
- Dudusola, I.O. 2009. Effects of storage methods and length of storage on some quality parameters of Japanese quail eggs. *Tropicultura.* **27**: 45-48.
- E.F.S.A., 2005. European food Safety Authority. Regulation, (1333).
- Eddin, A. S. 2019. Egg quality and safety with an overview of edible coating application for egg preservation. *Food Chem.* **296**: 29-39.
- Eke, I. E., Mohammed, S. G., Ali, T. S., Baba, M. A. and Karim, I. A. 2013. Proximate, Mineral, Amino Acid and Vitamin Composition of Four Unripe Plantains and Matured Banana. *Green. J. Phys. Sci.*, **3**(5), 182-186.
- El-Mallah, G. M., Yassein, S. A., Magda, M., Abdel-Fattah, M. M. and El-Ghamry, A. A. 2011. Improving performance and some metabolic response by using some antioxidants in laying diets during summer season. *Am. J. Sci.* **7**:217-224.
- Etches, R.J. 1992. The Influence of Housing Aspect of Egg Quality. In: Proceedings of 19th Worlds Poultry Congress. Amsterdam, Netherlands. Worlds Poultry Congress. Amsterdam, Netherlands. *World's Poult. Sci. Assoc.* **3**: 164-167 and *J. Food Sci.* **78**(2): S 329-35.
- F. Baron, S. J. 2011. Egg and egg product microbiology. *Food Sci. Technol. Nutr.* **14**: 330–350.
- Falguera, V., Quintero, J. P., Jiménez, A., Muñoz, J. A. and Ibarz, A. 2011. Edible films and coatings: Structures, active functions and trends in their use. *Trends Food Sci. Technol.* **22**(6): 292–303.

- FAO. 2011. Global food losses and food waste – Extent, causes and prevention. Rome
- FAO. 2022. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO.
- Farrell Jr, D. J. 1998. The biophysics of eggshell structure and function. *J. Exp. Biol.* **201**(18): 2745-2759.
- Fasenko, G. M., Robinson, F. E., Whelan, A. I., Kremeniuk, K. M. and Walker, J. A. 2001. Prestorage incubation of long-term stored broiler eggs: 1. Effect on hatchability. *Poult. Sci.* **80**(10): 1406-1411.
- Flashes S.N. and Board J.J. 1985. Comparison of environmental and egg microbiology associated with conventional and free-range laying hen management. *Poult. Sci.*, **90**(9): 2063-2068.
- Fox, S., 2013. Health online 2013. Pew Internet & American Life Project.
- Funk, E. M. 1948. A method for measuring shape and condition of egg yolks. *Poult. Sci.* **27**(6), 795-796.
- Gantois, I., Ducatelle, R., Pasmans, F., Haesebrouck, F., Gast, R., Humphrey, T. J. and Van Immerseel, F. 2009. Mechanisms of egg contamination by *Salmonella* Enteritidis. *FEMS microbiology REV.* **33**(4): 718-738.
- Garibaldi, J. A. 1960. Factors in egg white which control growth of bacteria. *Food Res.* **25**: 337-344. 29.
- Garibaldi, J. A. 1970. Methods for enumeration of microorganisms. In J. R. Norris and D. W. Ribbons (Eds.), Academic Press. *Methods in Microbiology* **3** (B): 375-423.
- Garibaldi, J. A. and H. G. Bayne. 1960. The effect of iron on *Pseudomonas* spoilage of experimentally infected eggs. *Poult. Sci.* **39**:1517-1520. 30.
- Garibaldi, J. A., and H. G. Bayne. 1962. Iron and the bacterial spoilage of shell eggs. *J. Food Sci.* **27**: 57-59. 31.
- Garibaldi, J.A. and Bayne, H.G. 1962. The effect of iron on the *Pseudomonas* spoilage of farm washed eggs. *Poult. Sci.* **41**(3): 850-853.
- Giraffa G. 2002. Enterococci from foods. *FEMS Microbiol. Rev.* **26**(2): 163–171.
- Gonzalez-Redondo, P. 2010. Effect of long-term storage on the hatchability of red-legged partridge (*Alectoris rufa*) eggs. *Poult. Sci.* **89**(2): 379-383.

- Goodwin TL, Wilson ML, Stadelman WJ. 1962. Effects of oiling time, storage position, and storage time on the condition of shell eggs. *Poult. Sci.* **41**:840–4.
- Gulati, A., Das, R. And Winter-Nelson, A.. 2024. Reducing Post-Harvest Losses in India: Farmer-Level Interventions and Grain Management Strategies (No. 24-r-03). Indian Council for Research on International Economic Relations (ICRIER), New Delhi, India.
- Haines, R. B. and Moran, T. 1940. Porosity and bacterial invasion through the shell of hen's egg. *J. Hyg.* **37**: 453-456.
- Hargis, P. S. 1988. Modifying egg yolk cholesterol in the domestic fowl—a review. *World's Poult. Sci. J.* **44**(1): 17-29.
- Harry E. 1963. The relationship between egg spoilage and the environment of the egg when laid. *Br. Poult. Sci.*, **4**(1)91–100
- Hasan, A. and Okur, A. A. 2009. Effect of storage time, temperature and hen age on egg quality in free-range layer hen. *Asian. J. Anim. Vet. Adv.* **8**(10):1953-1958.
- Hassan, S. M., Siam, A. A., Mady, M. E. and Cartwright, A. L. 2005. Egg storage period and weight effects on hatchability of ostrich (*Struthio camelus*) eggs. *Poult. Sci.* **84**(12):1908-1912.
- Haugh, R. R. 1937. The Haugh unit for measuring egg quality. *United States Egg and Poultry Magazine* **43**(11):552-555, 572-573.
- Heath, J. L. 1977. Chemical and related osmotic changes in egg albumen during storage. *Poult. Sci.* **56**(3): 822-828.
- Hegazi, M. 2016. Evaluation of pre-or postharvest application of some minerals and organic agents on the growth, flowering and vase life of *Rudbeckia hirta* L. *J. Agric. Sci.* **8**: 226-236.
- Hegazy, I. 2016. Postharvest Losses and their Causes in the Supply Chain of Fresh Fruits and Vegetables in India. *Int. J. Innov. Res. Sci. Eng. Technol.* **5**(5): 7365-7374.
- Heiman, S. W. and Carver, J. D. 1936. The Albumen Index as a Measure of Egg Quality. *Poult Sci.* **15**(3): 199-203.
- Hempe J. M., R. C. Lauxen, and J. E. Savage. 1987. Rapid Determination of Egg Weight and Specific Gravity Using a Computerized Data Collection System.

- Hisasaga, Cirenio and Griffin, Sara and Tarrant, Katy. 2020. Survey of egg quality in commercially available table eggs. *Poult. Sci.* **99**: 7202-7206.
- Homler, BE and Stadelman WJ. 1963. The effect of oiling before and after cleaning in maintaining the albumen condition. *Poult. Sci.* **42**:190–4.
- Humphrey, J. A., & Alcorn, B. J. 1994. *So You Want To Be an Interpreter. An Introduction to Sign Language Interpreting.* Amarillo, TX: H & H Publishers.
- Hunton, P. 2005. Research on eggshell structure and quality: an historical overview. *Revista Brasileira de Ciência Avícola.* **7**(2): 67–71.
- Hurnik, G. 1978. Relationship between albumen quality and hatchability in fresh and stored hatching eggs. *Poult. Sci.* **57**(4): 854-857.
- ICAR-CIPHET, 2015. *ICAR-Central Institute of Post Harvest Engineering & Technology (CIPHET): Annual Report.* ISBN: 978-81-931450-2-9
- ICMSF, 1996. Preventing abuse of foods after processing. In *Micro-Organisms in Foods: Microbial Ecology of Food Commodities.* Boston, MA: Springer US. 577-597
- Jayathilakan, K., Sultana, K., Radhakrishna, K. and Bawa, A. S. 2012. Utilization of by products and waste materials from meat, poultry and fish processing industries: a review. *J. Food Sci. Technol.* **49**: 278-293.
- Jha, S. N., Vishwakarma, R. K., Ahmad, T., Rai, A., and Dixit, A. K. 2015. Report on assessment of quantitative harvest and post-harvest losses of major crops and commodities in India. All India Coordinated Research Project on Post-Harvest Technology, ICAR-CIPHET: 130.
- Ji-Hoon, An., Youngmin, Hwang., Sumin, Hwang., H., Kwon., Hye-Yoon, Gu., Kihwan, Park., Changsun, Choi. 2023. Comparative evaluation of egg quality in response to temperature variability: From farm to table exposure scenarios. *Food. Sci. Anim. Resour. Food. Sci. Anim. Resour.* **43**(6):1002-1016
- Jin, Y.H., K. T. Lee, W. I. Lee dan. and Y. K. Han. 2011. Effects of Storage Temperature and Time on the Quality of Eggs from Laying Hens at Peak Production. *Asian-Aust. J. Anim. Sci.* **24**(2):279 –284.
- Jirangrat, W., P. W. C. S. Compton, and D. G. C. R. Deeming. 2010. The application of three commercial egg coatings and their effects on hatchability. *Poult. Sci.* **89**(5): 1004-1009.

- Jones, D. and M. J. P. S. Musgrove. 2005. Effects of extended storage on egg quality factors. *Poult Sci.* **84**(11): 1774-1777.
- Jones, D. R., J. D. Simmons, A. E. Cox, and C. C. Coufal. 2018. Effect of pullet-hen interval and storage time on internal egg quality and hatchability. *Poult Sci.* **97**(11): 3883-3888.
- Jones, D. R., K. B. Odom, and C. C. Coufal. 2016. Effect of pullet-hen interval, storage temperature, and storage time on internal egg quality and hatchability. *J. Appl. Poult. Res.* **25**(3): 330-336.
- Kader, A. A. 2005. Increasing Food Availability by Reducing Post-Harvest Losses of Fresh Produce. *Acta Horticulturae.* **682**: 2168–2175.
- Kader, A.A., 2002. *Small-scale postharvest handling practices: a manual for horticultural crops*. California: University of California, Davis, Postharvest Technology Research and Information Center.
- Kamel, B., Bond, C., and Diab, M. 1980. Egg Quality as Affected by Storage and Handling Methods. *J. Food Qual.* **3**(4): 261–273.
- Karwowska, M., Łaba, S. and Szczepański, K. 2021. Food loss and waste in meat sector - why the consumption stage generates the most losses. *Sustainability.* **13**(11): 6227.
- Kassaify, Z. G., K. M. Abdel Massih, M. N. Younes, M. M. Hilan and M. F. Hamadeh. 2020. Microbiological quality of table eggs: A comparative study of local and imported commercial eggs in Lebanon. *J. Food Saf.* **40**(1): 127-132.
- Keener K.M., mcavoy K.C., Foegeding J.B., Curtis P.A., Anderson K.E., Os -borne J.A. and Bush D.J. 2006. Effect of testing temperature on internal egg quality measurements. *Poult. Sci.* **85**: 550–555.
- Keener, K. 2000. The influence of rapid air cooling and carbon dioxide cooling and subsequent storage in air and carbon dioxide on shell egg quality. *Poult Sci.* **79**(7): 1067-1071.
- Kell, G. S. 1975. Density, thermal expansivity, and compressibility of liquid water from 0° to 150° C: Correlations and tables for atmospheric pressure and saturation reviewed and expressed on 1968 temperature scale. *J. Chem. Eng. Data.* 20:97-105.
- Khalifa and Mahmoud. 2010. Breast muscle oxidative changes induced by transport stress in broilers. *Poult Sci.* **97**(5): .1554-1563.

- Kiaya. 2014. Post-harvest losses and strategies to reduce them. *ACF International*. **01**: 1–25.
- Kim, S. H., No, H. K., Kim, S. D., and Prinyawiwatkul, W. 2006. Effect of Plasticizer Concentration and Solvent Types on Shelf life of Eggs Coated with Chitosan. *J. Food Sci.* **71**(4).
- Kim, S. H., Youn, D. K., No, H. K., Choi, S. W. and Prinyawiwatkul, W. 2009. Effects of chitosan coating and storage position on quality and shelf life of eggs. *Int. J. Food Sci. Technol.* **44**(7): 1351–1359.
- Kim, T.W., Pettingell, W.H., Jung, Y.K., Kovacs, D.M. and Tanzi, R.E., 1997. Alternative cleavage of Alzheimer-associated presenilins during apoptosis by a caspase-3 family protease. *Science*, **277**(5324): 373-376.
- Kim, Y.B., Lee, S.Y. and Yum, K.H. 2024. Effects of storage temperature and egg washing on egg quality and physicochemical properties. *Discov. Appl. Sci.* **6**: 111.
- Kitinoja, L., and J. R. Gorny. 1999. Post-Harvest Technology for Small-Scale Produce Marketers: Economic Opportunities, utility and Food Safety. *Post-Harvest Technology for Small-Scale Produce Marketers: Economic Opportunities*. *Qual. Food. Saf.* **21**: viii–v 365.
- Knight DW, Bowrey M and Cooke DJ. 1972. The preservation of internal egg quality using silicone fluids. *Br. Poult. Sci.* **13**:587–93.
- Knight, D. W., Bowrey, M. and Cooke, D. J. 1972. The preservation of internal egg quality using silicone fluids. *Bri. Poult. Sci.* **13**(6): 587–593.
- Knox, C.W. and Olsen, M.W. 1936. The effect of tremulous air cells upon the hatchability of eggs. *Poult. Sci.* **15**(4): 345-348.
- Kocetkovs, V., Radenkovs, V., Juhnevica-Radenkova, K., Jakovlevs, D. and Muizniece-Brasava, S. 2022. The impact of eggshell thickness on the qualitative characteristics of stored eggs produced by three breeds of laying hens of the cage and cage-free housed systems. *Appl. Sci.* **12**(22): 11539.
- Komarnicki, P., R. Stopa, D. Szyjewicz, and M. Mlotek. 2016. Evaluation of Bruise Resistance of Pears to Impact Load. *Postharvest Biol. Technol.* **114**: 36–44.
- Koppel, K., Sosa, M., Gutierrez, N. G., Cardinal, P., Godwin, S. L., Cates, S. C., and Chambers, E. 2016. Consumer practices for purchase, storage, and preparation of poultry and eggs in selected north and south american countries: a pilot study. *Rev. Vitae.* **23**(1).

- Koppel, K., Suwonsichon, S., Chitra, U., Lee, J., and Chambers IV, E. 2014. Eggs and Poultry Purchase, Storage, and Preparation Practices of Consumers in Selected Asian Countries. *Foods*. **3**(1): 110–127.
- Kumar, N., Singh, D., and Kumar, S. 2017. Post-harvest losses in Indian fruits and vegetables: An overview. *Int. J. Curr. Microbiol. Appl. Sci.* **6**(8): 2648-2659.
- Lapao, C. 1999. Effects of broiler breeder age and length of egg storage on albumen characteristics and hatchability. *Poult. Sci.* **78**(5): 640-645.
- Lat, A., and J. D. Reyes. 2017. Analysis of Post-Harvest Handling of Table Eggs Produced in San Jose, Batangas, Phillipines. *J. Int. Soc. Southeast Asian Agric. Sci.* **23** (2): 169–181.
- Leandro, N. S. M., Deus, H. A. B., Stringhini, J. H., Café, M. B., Andrade, M. A. and Carvalho, F. B. 2005. Aspectos de qualidade interna externa de ovos comercializados em diferentes estabelecimentos na região de Goiânia. *Ciênc. Anim. Bras.* **6**(2):71-78.
- Leandro, N. S. M., Deus, H. A. B., Stringhini, J. H., Café, M. B., Andrade, M. A. and Carvalho, F. B. 2005. Aspectos de qualidade interna e externa de ovos comercializados em diferentes estabelecimentos na região de Goiânia. *Ciênc. Anim. Bras.* **6**(2): 71-78.
- Leeson, S. 2006. Nutrition of the hen. In *Poultry Science Symposium Series*, Atlanta, Georgia. CABI Publishing. **27**: **39-46**.
- Li-Chan, E. C., Powrie, W. D. and Nakai, S. 1995. The chemistry of eggs and egg products. *Egg science and technology*, **4**: 105-75.
- Macnorth and Chime, 1990. Egg handling and egg breakage. *Commercial Chicken Meat and Egg Production*. 5th ed. Springer, Spring City, New York, USA. 1091-1105.
- Maynard L. Milks. 2002. Effect of cold storage of eggs on the response of cabbage looper (*Lepidoptera*: *Noctuidae*) larvae to a nucleopolyhedrovirus. **134**(6): 789-792. DOI: 10.4039/Ent134789-6
- Mensah, E. B. R. O.-K. H. C. K. S. 2021. An assessment of postharvest losses to support innovation in the egg value chain in Ghana. *Afr. J. Sci. Technol. Innov. Dev.* **14**: 947–959.
- Mine, Y., and S. Oberle. 2002. Egg yolk antibodies and their applications in research, diagnostics and therapeutics. *Anim. Health Res. Rev.* **3**(1): 3-17.

- MOFPI. 2022. Annual Report 2022. Ministry of Food Processing Industries, Government of India.
- Mohiti-Asli, M., Shariatmadar, F and Lotfollahian, H. 2010. The influence of dietary vitamin E and selenium on egg production parameters, serum and yolk cholesterol and antibody response of laying hens exposed to high environmental temperature. *Arch. Geflügelk.* **74**: 43-50.
- Monge, P., 1999. Introduction to the special issue: Communication processes for virtual organizations. *Organization science*, **10**(6): 693-703.
- Monira, K.N., M. Sahahuddin, G. Miah. 2003. Effect of Breed and holding period on egg quality characteristics of chicken. *Int. J. Poult. Sci.* **2**: 261-263.
- Morais, C. F. A., Campos, E. J. and Silva, T. J. P. 1997. Qualidade interna de ovos comercializados em diferentes supermercados na cidade de Uberlândia. *Arq. Bras. Med. Vet. Zootec.* **49**: 365-373.
- Moula, N., Antoine-Moussiaux, N., Famir, F. and Leroy, P. 2009. Comparison of egg composition and conservation ability in two Belgian local breeds and one commercial strain. *Int. J. Poult. Sci.* **8**(8):768-774.
- Mueller WJ. 1958. Shell porosity of chicken eggs. *Poult. Sci.* **37**:437-44.
- Mueller WJ. 1959. Factors affecting the quality loss in egg albumen during storage. *Poult. Sci.* **38**:843-6.
- Murray MW and Rutherford PP. 1963. The relationship between the loss of water and carbon dioxide from eggs and the effect upon albumen quality. *Poult. Sci.* **42**:505-8.
- Murshed, M. and Qaid, M.M., 2024. A Comparative Study of the Internal and External Quality Characteristics of Table Eggs and the Effect of Storage Periods and Layer Strain on them under Summer Conditions. *Indian J. Anim. Res.* **58**(4).
- Mutanyagwa, A. P., A. Isinika, and A. R. Kaliba. 2018. The Factors Influencing Farmers' Choice of Improved Maize Seed Varieties in Tanzania. *Int. J. Sci. Res. Manag.* **6** (4): 55-63.
- NABCONS. 2023. Annual Report 2023. National Bank for Agriculture and Rural Development, India.
- NABCOS. 2022. Annual Report 2022. National Bank for Agriculture and Rural Development, India.

- Nanda, SK, RK Vichwakarma. HVL Bathia, A Rai and P Chandra. 2012. Harvest and Post Harvest Losses of Major Crops and Livestock Produce in India. All India Coordinated Research Project on Post Harvest Technology, ICAR-CIPHET Ludhiana.
- Narushin VG, Orszulik ST, Romanov MN, Griffin DK 2023. A novel approach to egg and math: Improved geometrical standardization of any avian egg profile. *Ann N Y Acad Sci.* **1529**(1):61-71.
- Narushine V.G., 2005. Egg geometry calculation using the measurements of length and breadth. *Poul. Sci.*, **84**(3) 482-484.
- Nethercote, C. H., C. N. Boisvenu, and D. A. Fletcher. 1974. Egg carton tests. *Poult. Sci.* **53**: 311–325.
- No, H. K., Prinyawiwatkul, W., and Meyers, S. P. 2005. Comparison of Shelf Life of Eggs Coated with Chitosans Prepared under Various Deproteinization and Demineralization Times. *J. Food Sci.* **70**(6).
- Nongtaodum, S., Jangchud, A., Jangchud, K., Dhamvithee, P., No, H. K., and Prinyawiwatkul, W. 2013. Oil coating affects internal quality and sensory acceptance of selected attributes of raw eggs during storage. *J. Food Sci.* **78**(2): S329–S335.
- Nys, Y., Gautron, J. 2007. Structure and Formation of the Eggshell. In: Huopalahti, R., López-Fandiño, R., Anton, M., Schade, R. (eds) *Bioactive Egg Compounds*. Springer, Berlin, Heidelberg.: 99-102
- O’ Brien M., and Guillou R. 1969. An in-transit vibration simulator for fruit-handling studies. *Transactions of the ASAE.* **12**(1): 94–97
- O’ Brien M., Gentry J P., and Gibson R C. 1965. Vibration characteristics of fruit as related to in-transit injury. *Transactions of the ASAE.* **8**(2): 241–243
- Obanu ZA and Mpieri AA. 1984. Efficiency of dietary vegetable oils in preserving the quality of shell eggs under ambient tropical conditions. *J. Sci. Food. Agric.* **35**:1311–17.
- Onwude, D., Bahrami, F., Shrivastava, C., Berry, T., Cronje, P., North, J. and Defraeye, T. 2022. Physics-driven digital twins to quantify the impact of pre-and postharvest variability on the end quality evolution of orange fruit. *Resour. Conserv. Recycl.* **186**: 106585.

- Onwude, D.I., Chen, G., Eke-Emezio, N., Kabutey, A., Khaled, A.Y. and Sturm, B., 2020. Recent advances in reducing food losses in the supply chain of fresh agricultural produce. *Proc.*, **8**(11): 1431.
- Ortmann, G. F., and R. P. King. 2010. Research on Agri-Food Supply Chains in Southern Africa Involving Small-Scale Farmers: Current Status and Future Possibilities. *Agrekon*. **49** (4): 397–417.
- P.V.Sreenivasaiah. 2006. Scientific Poultry Production: A Unique Encyclopedia. International Book Distributing Co.01. **1**(3).
- Panda P C., Venkatasubbiah G, and Parthasarathy L. 1973. Effect of packaging and journey hazard tests on the internal quality of shell eggs. *Indian Food Packer*. **27**(4): 10–12
- Panda, B. 1989. Microbiological Quality of Poultry Meat. *Poult. Sci.* **68**(12): 1576-1579.
- Panda, S.C. and Natarajan, R., 1979. Effect of transportation on egg quality. *Int. J. Poul. Sci.*, **14**(1): 69-79.
- Parsons, A. J. P. S. 1982. Structure of the eggshell. *Poult. Sci.* **61**(10): 2013-2021.
- Paula, D. A. J., Orso, R., Barreta, M., Fernandes, L. C., Vieira, L. M., Caron, L. F., and Boiago, M. M. 2021. The effect of storage period on egg quality: A review. *J. Anim. Sci. Biotechnol.* **12**(1): 1-11.
- Peter Feng., Stephen D., Weagant., Michael A. Grant and William Burkhardt. 2020. Bacteriological Analytical Manual (BAM), Enumeration of Escherichia coli and the Coliform Bacteria. United state Food and Drug Administration.
- Pierce C D., Singh S P., Burgess G 1992. A comparison of leaf-spring with air-cushion trailer suspension in the transport environment. *Packaging Technology and Science*. **5**: 11–15
- Pires, C. A., A. R. S. Assis, P. J. C. Biscola, L. F. T. Albino, A. A. Mendonça, and J. S. P. Silva. 2018. Egg coating for the preservation of the internal quality of eggs at different temperatures and storage times. *Rev. Bras. Zootec.* **47**: e20170261.
- Pradhan, S., Barik, N., and Panda, S. K. 2018. Assessment of post-harvest loss in broiler meat production system. *Int. J. Livest. Res.* **8**(3): 285-290.
- Prakash, D., and Prabakaran, R. 2020. Effect of transportation and holding period on broiler meat quality. *J. Entomol. Zool. Stud.*, **8**(6): 1549-1552.

- R. G. Board, C. C. J. L. And J. D. 1994. The egg: a compartmentalized, aseptically packaged food. In *Microbiology of the Avian Egg* **1994**: 46–61.
- Rao, A.V. and Rao, L.G., 2007. Carotenoids and human health. *Pharma. Res.*, **55**(3): 207-216.
- Rathgeber and sharma, 2014. The natural history and clinical predictors of egg allergy in the first 2 years of life: a prospective, population-based cohort study. *Journal of allergy and clinical immunology*, **133**(2): 485-491.
- Réhault-Godbert S, Guyot N, Nys Y. The Golden Egg: Nutritional Value, Bioactivities, and Emerging Benefits for Human Health. *Nutrients*. 2019 Mar 22;**11**(3):684. Doi: 10.3390/nu11030684. PMID: 30909449; PMCID: PMC6470839.
- Reijrink, D., Berghmans, R., Kemp Meijerof, B. and van den Brand, H. 2010. Influence of egg storage time and pre-incubation warming profile on embryonic development, hatchability, and chick quality. *Poult. Sci.* **89**(6):1225-1238.
- Rhim, J. W., Weller, C. L., and Gennadios, A. 2004. Effects of soy protein coating on shell strength and quality of shell eggs. *Food Sci. Biotechnol.* **13**(4): 455–459.
- Roberts, J. R., and W. R. Willenberg. 2016. Egg shape index values. *World's Poult. Sci. J.* **72**(3), 507-513.
- Robinson, E.J. and Kolavalli, S.L., 2010. *The case of tomato in Ghana: Productivity* (No. 19). International Food Policy Research Institute (IFPRI).
- Rodenburg, P., 2018, October. Rationalization and the “Engineer-Economists” in the Netherlands, 1920–1940. In *Including a Symposium on Mary Morgan: Curiosity, Imagination, and Surprise*, Emerald Publishing Limited : 41-57.
- Roland, D. A. 1988. Research note: Egg shell problems: Estimates of Incidence and Economic impact. *Poult Sci.* **67**:1801–1803.
- Romanoff A.L., Romanoff A.J. 1949. *The Avian Egg*. New York: John Wiley and Son. Quality indices of shell eggs. *Biosyst. Eng.* **86**(3): 347–353
- Sabrani M, and Payne GG. 1978. Effect of oiling on internal quality of eggs stored at 28 and 12 æ°C. *Br. Poult. Sci.* **19**:567–71.
- Samiullah, S., Roberts, J., and Chousalkar, K. 2016. Oviposition time, flock age, and egg position in clutch in relation to brown eggshell color in laying hens. *Poult. Sci.*, **95**(9): 2052-2057.

- Samli, H.E., Agma, A. dan Senkoylu, N. 2005: Effects of Storage Time and Temperature on Egg Quality in Old Laying Hens. *J. Appl. Poult. Res.* **14**(3):548–553.
- Samli, Harms, R.H., Rossi, A.F., Sloan, D.R., Miles, R.D. and Christmas, R.B., 2004. A method for estimating shell weight and correcting specific gravity for egg weight in eggshell quality studies. *Poultry Science*, **69**(1): 48-52.
- Santos, M.D.S.V.D., Espíndola, G.B., Lôbo, R.N.B., Freitas, E.R., Guerra, J.L.L. and Santos, A.B.E. 2009. Efeito da temperatura e estocagem em ovos. *J. Food Sci. Technol.* **29**: 513-517.
- Sauter, E. A. And Peterson, C. F. 1974. The effect of eggshell quality on penetration by various Salmonella. *Poult. Sci.* **53**: 2159-2164.
- Sauter, E., Stadelman, W., Harns, Vivian., McLaren, B. 1951. Methods for Measuring Yolk Index. *Poult. Sci.* **30**: 629-632. 10.3382/ps.0300629.
- Sauveur, B. 1988. *Reproduction des volailles et production d'oeufs*. Editions Quae.
- Sauveur, B. E. 1993. *1 huevo para consumo: Bases productivas*. Tradução por Carlos Buxadé Carbó. Aedos Editorial, Barcelona. **1993**: 377.
- Scholtyssek, S. 1981. The influence of the age of chicken eggs and of pasteurisation on the quality and shelf life of liquid whole eggs. *Quality of Egg, Proc. 1st Eur. Symp., Spelderholt. Beekbergen. Inst. Poult. Res.* **1981**: 48–51
- Schulte Pason N L., Timm E., Brown G K., Marshall D E., Burton. C L. 1990. Apple damage assessment during intrastate transportation. *Appl. Eng. Agric.* **6**(6): 753–758
- Schultz, C. D. 1953. Comparison of Methods for Measuring the Shape of Eggs. *Poult. Sci.* **32**(3): 609-611.
- Schwall DV, Gardner FA and Parnell ED. 1961. Effects of oil treating on shell egg quality during short term refrigerated storage. *Poult. Sci.* **40**: 583–8.
- Scott TA, Silversides FG. 2000. The effect of storage and strain of hen on egg quality. *Poult. Sci.* **79**:1725–9.
- seydeim and dawson, 1999. Effect of Different Packaging Materials on Quality Characteristics of Chicken Eggs during Storage at Room Temperature in Sri Lanka. *Int. J. Poul. Sci.*, **12**(2): 169-181.
- Sezai, A., Ufuk, C., Onur, G., and Nazým, S. 2020. Effects of eggshell calcium application on the physical and chemical properties of eggs and eggshell quality. *Indian J. Anim. Res.* **54**(9): 1095-1101.

- Shafey, T.M. 2002. Eggshell conductance, embryonic growth, hatchability and embryonic mortality of broiler breeder eggs dipped into ascorbic acid solution. *Br. Poult. Sci.* **43**(1): 135-140.
- Shanawa, M. M. 1994. Quail Production Systems. A review. Food and Agriculture Organization of the United Nations. Rome. **145**.
- Sharp, P.F. and Powell, C.K., 1931. Increase in the pH of the white and yolk of hens' eggs. *Industrial & Engineering Chemistry*, **23**(2): 196-199.
- Sheng, X., Shu, D., Li, Y., Zhan, Z., Yuan, X., Liu, S., Wu, H., Bing, S. and Zang, Y. 2021. Combined approach consisting of slightly acidic electrolyzed water and chitosan coating to improve the internal quality of eggs during storage. *J. Sci. Food Agric.* **101**(6): .2355-2361.
- Shulte Pason., Timm, E.J., Brown, G.K., Marshall, D.E. and Burton, C.L., 1990. Apple damage assessment during intrastate transportation. *App. eng. Agri.*, **6**(6): .753-758.
- Silversides, F. G. and Budgell, K. 2004. The relationships among measures of egg albumen height, pH and whipping volume. *Poult. Sci.* **83**(10):1619-1623.
- Silversides, F. G., and T. A. Scott. 2001. Effect of storage and layer age on quality of eggs from two lines of hens. *Poult. Sci.* **80**(9): 1240-1245.
- Silversides, F.G., 1994. The Haugh unit correction for egg weight is not adequate for comparing eggs from chickens of different lines and ages. *J. App. Poul. Res.*, **3**(2): 120-126.
- Sim, J. S., A. E. Mustafa, Y. Ismail, A. R. Alimon, and A. R. Sazili. 2019. Effect of storage duration and temperatures on the quality of eggs from three breeds of laying hens. *J. Appl. Poult. Res.* **28**(3): 630-634.
- Singh S P. 1991. Vibration levels in commercial truck shipments. *ASAE.* **20**(06): .91–6016
- Singh, S. M. J. A. 1992. Vibration levels in commercial truck shipments as a function of suspension and payload. *J. Test. Eval.* **20**: 466–469.
- Siyar, H. S. A., Aliarabi, H., Ahmadi, A. and Ashori, N. 2007. Effect of different storage conditions and hen age on egg quality parameters. *Australia Poultry Science Symposium.* **19**:106-109.
- Smith, J., and Brown, A. 2023. The impact of storage conditions on egg quality and nutritional content. *J. Poult. Sci.* **45**(2): 123-135.

- Song, K. T., Choi, S. H. and Oh, H. R. 2000. A comparism of egg quality of pheasant, chukar, quail and guinea fowl. *Asian-Australas. J. Anim. Sci.* **7**:986-990.
- Spada, F. P., França, L. C., Canniatti-Brazaca, S. G., Rosario, M. F., Savino, V. J. M. and Coelho, A. A. D. 2008. Avaliação da intensidade da pigmentação vermelha das gemas de ovos crus utilizando a variável a no sistema Hunter La leque colorimétrico. *Simpósio Internacional de Iniciação Científica da USP*, 16.
- Spang, E. S., Moreno, L. C., Pace, S. A., Achmon, Y., Donis-Gonzalez, I., Gosliner, W. A., and Tomich, T. P. 2019. Food loss and waste: measurement, drivers, and solutions. *Annu. Rev. Environ. Resour.* **44**: 117-156.
- Sparks, N. H. C. and Board, R. G. 1985. Bacterial penetration of the recently oviposited shell of hen's eggs. *Aust. Vet. J.* **6**: 169-175.
- SPSS 20.0. 2012. *Statistical Package for Social Sciences*. United States, IBM.
- Sreenivasaiiah P.V. 2006. *Scientific Poultry Production: A Unique Encyclopedia*. International Book Distributing Co.01. **1**(3).
- Stadelman WJ and Wilson ML. 1958. An oil dispensing aerosol for quality preservation of shell eggs. *Poult. Sci.* **37**: 731-3.
- Stadelman, W. J. 1995. Quality identification shell egg. In Stadelman, W.J. and Cotterill, O.J. (eds). *Egg Science and Technology*. 4th edn. The Haworth Press, Inc., New York, London, 39-66.
- Stadelman, W. J., and Wilson, M. L. 1958. An Oil Dispensing Aerosol for Quality Preservation of Shell Eggs. *Poult. Sci.* **37**(3): 731-733.
- Stadelman, W.J. 1995. The preservation of quality in shell eggs. In: *Egg Science and Technology*, (edited by W.J. Stadelman & O.J. Cotterill). 4th edn New York: Food Products Press. 67-79.
- Stadelman, William J. 1986. *Egg Science and Technology*, Publisher: Avi Pub Co, ISBN: 0870555162
- Tabidi, M. H. 2011. Impact of storage period and quality on composition of table egg. *Adv. Environ. Biol.* **5**(5): 856-861.
- Techer, C., Baron, F., and Jan, S. 2014. Spoilage of animal products. *Microbial Milk Spoilage*. In *Encyclopedia of Food Microbiology*. Elsevier.: 446-452.

- Techer, F. B. and S. J. 2013. Microbial spoilage of eggs and egg products. *World's Poult. Sci. J.* **69**: 1–6.
- Thompson, G., 2003. *Between Hierarchies and Markets: The Logic and Limits of Network Forms of Organization*. Oxford University Press.
- Tilki, M. and Inal, S. 2004. Quality traits of goose eggs. 1. Effects of goose age and storage time of eggs. *Arch. Für. Geflügelk.* **68**:82-186.
- Tilki, M. and Saatci, M. 2004. Effects of storage time on external and internal characteristics in partridge (*Alectoris graeca*) eggs. *Vet. Med. Rev.* **155**(11):561-56.
- Tona, K., Bruggeman, V., Onagbesan, O. and Decuypere, E., 2009. Hatching egg and chick quality. Wallingford UK: CABI. In *Biology of breeding poultry*: 224-239.
- Tona, K., Onagbesan, O., De Ketelaere, B. and Decuypere, E. and Bruggeman, V. 2004. Effects of age of broiler breeders and egg storage on egg quality, hatchability chick quality, chick weight and chick post hatch growth to 42 days. *J. Appl. Poult. Res.* **13**(1):10-18.
- Torrico, D. D., W. Wardya, K. M. Carabantea, K. D. Pujolsa, Z. Xua, H. K. Nob, and W. Prinyawiwatkula. 2011. Quality of eggs coated with oilechitosan emulsion: combined effects of emulsifier types, initial albumen quality and storage. *Food Sci. Technol.* **57**:35– 1.
- Tyagi, Sachin. 2017. Pre-harvest Factors Influencing the Postharvest Quality of Fruits: A Review. *Curr. J. Appl. Sci. Technol.* **23**: 1-12.
- USDA, N., 2000. United States department of agriculture. Natural Resources Conservation Service. Plants Database. <http://plants.usda.gov>.
- USDA. 1938. Yearbook of Agriculture, Washington
- USDA. 2000. Egg Grading Manual. USDA, AMS, Agriculture Handbook **75**.
- V G Narushin. 2005. Egg geometry calculation using the measurements of length and breadth. *Poult. Sci.* 2005. **84**(3):482-4. Doi: 10.1093/ps/84.3.482. PMID: 15782919 DOI: 10.1093/ps/84.3.482
- Valeriy G. Narushin., Michael N Romanov., Attila Salamon. and John P Kent. 2023. An Innovative Non-destructive Technology for Controlling the Storage Period of Chicken Eggs Using Egg Parameters: 2025-2039

- Vilario, M. 2012. Calcium and phosphorus deposition in eggshell: A comparative study. *Br. Poult. Sci.*, **53**(4): 469-477.
- Waimaleongora Ek, P., Garcia, K. M., No, H. K., Prinyawiwatkul, W., and Ingram, D. R. 2009. Selected Quality and Shelf Life of Eggs Coated with Mineral Oil with Different Viscosities. *J. Food Sci.* **74**(9).
- Walsh, T. J., Rizk, R. E. and Brake, J. 1995. Effects of temperature and carbon dioxide on albumen characteristics, weight loss, and early embryonic mortality of long stored hatching eggs. *Poult. Sci.* **74**(9): 1403-1410.
- Wardy, W., Martínez, K.D.P., Xu, Z., No, H.K. and Prinyawiwatkul, W. 2014. Viscosity changes of chitosan solution affect physico-functional properties and consumer perception of coated eggs during storage. *LWT – Food. Sci. Technol.* **55**(1): 67-73.
- Watson, Jonathan. 2016. *Postharvest Storage, Packaging and Handling of Specialty Crops: A Guide for Florida Small Farm Producers.*
- Weir, S. and Knight, John. 2000. *Adoption and Diffusion of Agricultural Innovations in Ethiopia: The Role of Education.*
- Wong DW, Gastineau FA, Gregorski KS, Tillin SJ and Pavlath AE. 1992. Chitosan-lipid films: microstructure and surface energy. *J Agric. Food. Chem.* **40**: 540–544.
- Wong YC, Herald TJ and Hachmeister KA. 1996. Evaluation of mechanical and barrier properties of protein coatings on shell eggs. *Poult. Sci.* **75**:417–22.
- Woodard, A. E. 1982. *Raising Chukar Partridge.* Department of Avian Sciences, University of California, Davis, CA 95616. Available: <http://animalscience.ucdavis.edu/avian/chukar.pdf>. Accessed on 20 July, 2013.
- World Bank Group - <https://www.worldbank.org/en/news/feature/2012/05/17/india-agriculture-issues-priorities>
- Xie, L., Hettiarachchy, N. S., Ju, Z. Y., Meullenet, J., Wang, H., Slavik, M. F., and Janes, M. E. 2002. Edible film coating to minimize eggshell breakage and reduce post-wash bacterial Contamination measured by dye penetration in eggs. *J. Food Sci.* **67**(1): 280–284.
- Yeasmin Akter, Y., Kasim, A., Omar, H. and Sazili, A.Q., 2014. Effect of storage time and temperature on the quality characteristics of chicken eggs. *Journal of Food, Agriculture & Environment*, **12**(3-4): 87-92.

- Yüceer, M., and Caner, C. 2014. Antimicrobial lysozyme–chitosan coatings affect functional properties and shelf life of chicken eggs during storage. *J. Sci. Food Agric.* **94**(1): 153–162.
- Zang, Y.T., Bing, S., Li, Y.J. and Shu, D.Q. 2019. Application of slightly acidic electrolyzed water and ultraviolet light for *Salmonella enteritidis* decontamination of cell suspensions and surfaces of artificially inoculated plastic poultry transport coops and other facility surfaces. *Poult. Sci.* **98**(12): 6445-6451.
- Zeidler, G. 2002. Processing and packaging shell eggs. Commercial chicken meat and egg production. Springer: **99**: 1129-1161.





Dr. PRASAD WADAJKAR

Home : AMRUTULYA NIWAS, NILESHWARY COLONY, SHIV ROAD, BHAWASAR
CHOWK, NANDED, 431602, NANDED, India

Email: Prasadwadajkar@gmail.com **Phone:** (+91) 9552299490

Date of birth: 19 Mar 1999 **Nationality:** Indian

EDUCATION AND TRAINING

[17 Oct 2017 – 28 Dec 2022]

BVSc & AH

MAFSU-COLLEGE OF VETERINARY AND ANIMAL SCIENCES <https://covaspbn.co.in/>

City: PARBHANI | **Country:** India | **Final grade:** 7.23

[31 Jan 2023 – Current]

MVSc

ICAR- INDIAN VETERINARY RESEARCH INSTITUTE <https://www.ivri.nic.in/>

City: IZATNAGAR, BAREILLY | **Country:** India |

PATENTS

EGG Based Sweet product and a method of preparation thereof

Application Number : 202411030499

PUBLICATIONS

[2024] **Mitigation of Heat Stress in Broiler Chickens during Hot Summer Seasons through Betaine Hydrochloride Osmoprotectant Intervention**

Reference: Jaydip Rokade, M MONIKA, M Gopi, M Vispute, Nagesh Sonale, Prasad Wadajkar

DOI: <https://doi.org/10.21203/rs.3.rs-3994204/v1>

[2024] **Cage free farming a pathway to sustainable egg production and enhanced animal welfare**

Reference: Rokade JJ, Prasad wadajkar, Nagbhushan K., Nahesh sonale, Monika M., A.K. Tiwari

Book title Poultry Production and Management

ISBN: 978-93-58874-09-9

[2024] **Organic Poultry farming Navigating Opportunities, Challenges, and certification in India**

Reference: Monika M., Rokade JJ, Sonale N.S., Prasad wadajkar, S.Kerketta

Book title- Poultry Production and Management

ISBN: 978-93-58874-09-9

[2024] **Profit Optimization through value addition in poultry meat and egg production**

Reference: Monika M., Prasad wadajkar, sonale N., Rokade JJ., Shalini G.

Book title - Poultry in India

ISBN : 9788195214020

CONFERENCES & SEMINARS

- [13 Sep 2023 - 15 Sep 2023] **Assessing the impact of storage duration and temperature on the table egg quality**
Indian Poultry Science Association Conference 2023, SKUAST, Jammu
- [13 Sep 2023 - 15 Sep 2023] **Assessment of Welfare and meat Quality parameters of desi birds reared under deep litter verses cage rearing system**
Indian Poultry Science Association Conference 2023, SKUAST, Jammu
- [7 Feb 2024 - 8 Feb 2024] **Understanding the post-harvest loses in poultry and its amelioration strategies**
Annual Conference of IAAVR & National Symposium

NETWORKS & MEMBERSHIPS

- [30 Dec 2022 - 10 Jan 2028] **Maharashtra State Veterinary Council** Nagpur, India
Reg. no. MSVC-11124
- [1 Jan 2024 - Current] **Indian Poultry Science Association** Izatnagar, Bareilly, INDIA
Life Member of IPSA
- [22 Mar 2023 - Current] **Veterinary Council OF India** Delhi, India
Reg. no. 13090
- World's Poultry Science Association** Netherland



This document was created with the Win2PDF "print to PDF" printer available at <http://www.win2pdf.com>

This version of Win2PDF 10 is for evaluation and non-commercial use only.

This page will not be added after purchasing Win2PDF.

<http://www.win2pdf.com/purchase/>