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STORAGE STABILITY OF CABINET DRIED EGG WHITE, EGG YOLK, AND WHOLE EGG POWDERS UNDER ACCELERATED STORAGE CONDITIONS

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Abstract: *Egg powders are versatile food ingredients valued for their extended shelf life, functional, and nutritional attributes. However, the influence of environmental factors such as relative humidity on their storage stability remains underexplored. This study evaluated the storage stability of three types of egg powders: whole egg powder (WEP), egg white powder (EWP), and egg yolk powder (EYP) under accelerated storage conditions. Egg powders were produced by breaking, homogenizing, drying, milling, and sieving fresh eggs. Samples were stored at ambient temperature (30 ± 2 °C) under 75% and 100% relative humidity for four weeks and analysed weekly for flowability, foaming properties, and colour. The results showed that all powders experienced a decline in quality over time, particularly under 100% RH. EWP consistently exhibited the best flowability and foam performance, while EYP was the most vulnerable to moisture-induced degradation. Colour changes were observed across all samples, with lightness decreasing and redness increasing under prolonged humid storage. In conclusion, relative humidity significantly affects the physical and functional stability of egg powders during storage, and storing under lower humidity is essential to preserving quality. It is therefore recommended that egg powders be stored in cool, dry conditions (ideally 40–60% RH) using high-barrier packaging materials such as aluminium foil laminates or metallized PET to reduce quality loss and extend shelf life.*

Keywords: *relative humidity, accelerated storage, shelf life*

1. Introduction

Eggs are a staple food product consumed worldwide, providing a rich source of protein, vitamins, and minerals. They are an essential part of a balanced diet, offering numerous health benefits, including improved eye health, brain function, and heart health [1]. The global egg production has increased significantly over the years, with a 31% increase between 2009 and 2019 [2]. The importance of eggs cannot be overstated. They are a nutrient-dense food product, providing high-quality protein, vitamins, and minerals. Eggs are effective animal proteins with the potential to contribute to food and nutrition security and generate household livelihood. Eggs have been identified to represent the lowest-cost animal source of proteins, vitamin A, iron, vitamin B12, riboflavin, and choline, and the second-lowest-cost source of zinc and calcium [3]. Eggs are a main ingredient in various food products due to their unique functional properties, such as emulsification, gelation, moisture retention, foaming, and texture modification [4]. Despite the numerous benefits of eggs, fresh eggs have some drawbacks. They are delicate and bulky, thereby having an increased risk of breakage during transportation. To overcome these challenges, fresh eggs are often converted into powdered form, which provides a convenient alternative to fresh eggs. Egg

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powder is a widely used ingredient in various food products, including baked goods, pasta, confectionery, and beverages [1]. It can be stored for up to a year or longer under proper storage conditions, reducing the risk of bacterial contamination and spoilage. Egg powder is a versatile ingredient that can be used in a variety of applications, including food formulation and development. The unique characteristics of egg yolk and egg white make them essential ingredients in many food products. Egg yolk is an emulsion and also acts as an emulsifying agent, making it an essential ingredient in mayonnaise and salad dressings [5]. Egg white, on the other hand, is a natural antioxidant added to ground meat to decrease oxidation during cooking [6]. However, despite the advantages of egg powder, its storage remains a significant challenge. Egg powder is sensitive to temperature, humidity, and light, which can affect its quality and stability [7]. Compared with fresh eggs, egg powder can significantly reduce the weight of eggs, has higher biological safety and a shelf life of 1–2 years, and has been widely used in bakery products, mayonnaise, pasta, biscuits, and other food production domains [8, 9]. Various drying processes for dehydrating sensitive products like egg powder have been developed and employed. Spray drying, freeze drying, microwave drying, and osmotic dehydration are the most common procedures used to dry egg products and vegetal products [10] Spray drying and sometimes freeze-drying technologies are often specifically used in the developed economies for making dried egg products [11] but it is very expensive to procure, operate and maintain by the average poultry farmers or small-scale food processors that dominate the Nigerian economy. Therefore, the development of an alternative technology affordable to the farmers and processors is of practical interest; hence, the choice of cabinet drying technology in this study. Cabinet dryers are enclosed chambers where products are placed on trays, typically using convection to circulate hot air, allowing for precise temperature, humidity, and airflow control. Studies show that a cabinet dryer performs optimally at 70 °C and a relative humidity of 60%, with 3.0 m/s air speed for agricultural products. The storage conditions of egg powder can impact its colour, flowability, and foaming capacity, making it essential to study the effects of storage conditions on egg powder quality. Accelerated shelf-life study (ASLT) is a widely used method to evaluate the storage stability of food products, including egg powder. ASLT involves subjecting food products to an environment where one or more external factors are elevated beyond normal levels, thereby hastening the rate of degradation and condensing the product's deterioration cycle [7]. This study aims to investigate the effects of relative humidity on the storage ability of egg powder using an accelerated shelf-life study.

2. Materials and methods

Fresh eggs, not more than three days old, were obtained from the Directorate of University Farms (DUFARM), Federal University of Agriculture (FUNAAB), Abeokuta, Ogun State, Nigeria. All chemicals (sodium chloride and hydrogen peroxide) and distilled water used in the study were of food processing grade and purchased from a reputable certified chemical store in Abeokuta. A hot air dryer with the capacity of ≈1.5 kg of liquid egg per batch, developed by the Diversification of Egg Marketing and Pilot Scale Assessment of a Novel Egg Drying Technology in Nigeria (DEMEP project), Department of Food Science and Technology, Federal University of Agriculture (FUNAAB), Abeokuta, Ogun State, Nigeria. The dryer's design features allow adjustment of drying variables and optimize the operational conditions for specific product requirements. The drying temperature selected for the drying of the egg yolk, egg white, and whole egg was 60 °C. This temperature was selected to preserve the functional properties of the egg powder while ensuring microbial safety. Trays were inserted manually into runners within the chamber, and high-speed centrifugal blowers were installed to move air at velocities of 2 to 5 m/s. A variety of laboratory equipment was employed to ensure precise measurements and controlled experimental conditions. Equipment used for the experiment was obtained from the Food Chemistry Laboratory, Department of Food Science and Technology, Federal University of Agriculture (FUNAAB), Abeokuta, Ogun State, Nigeria. All laboratory equipment used was calibrated before every use to ensure accuracy.

2.1. Preparation of dried whole egg powder

Whole egg powder was produced using a modified method based on Ndife et al. [12]. Fresh eggs were washed and sanitised in 3% hydrogen peroxide solution, drained, and air-dried to remove surface moisture. The eggs were then broken, and the contents were mixed thoroughly using a Kenwood mixer to obtain a homogeneous liquid whole egg. The homogenised liquid was spread uniformly on drying trays and dried in a custom-built cabinet dryer at 60± 2 °C for 30 h. The dried product was milled and sieved to obtain powder particles smaller than 250 µm. The resulting powder was packaged in airtight containers and stored at 4 °C prior to accelerated storage analysis, as shown in Plate 1.

2.2. Accelerated storage studies of dried egg powder

For the accelerated shelf-life study, samples with a particle size of <250µm were used. 20 g of each of the three samples was packed inside high-density polyethylene containers and sealed, avoiding any air space. The containers were then placed in desiccators maintained at controlled relative humidity conditions of 75% and 100% using saturated salt solutions. Relative humidity (RH) plays a critical role in accelerated storage systems (or accelerated stability studies) by acting as a major accelerator of chemical and physical degradation in materials, particularly pharmaceuticals, foods, and electronics. Elevated RH levels increase the amount of moisture available to react with products, enabling faster degradation rates to be observed in a shorter timeframe [13].

The desiccators were stored in an enclosed, dry, clean, and well-ventilated environment with a temperature of 25 to 30 ± 2 °C and a relative humidity of 75 ± 2 %. The samples were analyzed for moisture content, colour, and foaming capacity every week during the four-week storage period. This setup was designed to intentionally expose the samples to stress conditions (controlled humidity and temperature) to speed up potential degradation reactions and assess the product's stability over a shorter period, as shown in Plate 1.

2.3. Flowability index, foaming properties, and colour of samples

The flowability index for dried egg powder was determined using a method documented by Singh et al. [14]. The foam capacity (FC) and foam stability (FS) were determined as described by Adebayo and Oladipo [10] with slight modification.

A 1 g sample of each type of egg powder (egg yolk powder, egg white powder, and whole egg powder) was gently blended with 50 mL of distilled water at a pH of 7.0 for 30 seconds using an electric blender. The mixture was then whipped at full speed. Once the blender was stopped, the whole content was transferred into a measuring cylinder, after which the initial foam volume was recorded immediately in millilitres, while the foam volumes were assessed at two intervals: after 30 seconds


A


B


C


D


E


F

Fig.1. Images showing the production process of egg powders
A: Washing of Eggs in the Egg washer, B: Pouring and spreading of Egg mixture in a tray
C: Positioning the trays for drying, D: Packaged egg samples, E: Laboratory analysis
F: Storage set-up

-to determine foam capacity and, after 30 minutes, to evaluate foam stability. The experiment was conducted in duplicate at a temperature of 28 ± 2 °C. The volume of foam 30 seconds after whipping was expressed as foam capacity using the formula in Equation 1:

$$FC = \frac{(AW - BW)}{BW} \times 100 \qquad (1)$$

where AW = after whipping, BW = before whipping.
The foam stability was calculated as shown below in Equation 2:

$$FS = \left(\frac{Foam\ volume\ after\ 30\ mins}{Inital\ foam\ volume}\right) \times 1 \qquad (2)$$

The colour of the various egg powders was determined using a Lab colourimeter. The $L*$, a∗, and b∗ values of the powder were determined with a colourimeter (Chroma meter CR-41D, Konica Minolta INC. B.8408286). Where, $L*$, a∗ and b∗, represent lightness (+) or darkness (−), redness (+) or greenness (−), and yellowness (+) or blueness (−), respectively.

3. Results and Discussion

3.1. Flowability of egg powder

Table 1 shows the flowability of whole egg powder (WEP), egg white powder (EWP), and egg yolk powder (EYP) stored for four weeks at 75% and 100% relative humidity. Before storage, whole egg powder demonstrated an impressive flowability value of 30.25±0.35. During the four weeks of storage, the flowability values increased steadily. Carr's compressibility index relationship between powder flowability and zero per cent compressibility: Excellent (5-15), Good (16-18), Fair (19-21), Poor (22-35), Very Poor (36-40), and Extremely Poor (>40) [15]. Week 4, WEP at 100% RH

Table 1.

Flowability of egg powder samples stored at 75 and 100% relative humidity

Samples	Storage Time (Week)	Flowability (RH=100%)	Flowability (RH=75%)	Flow Property
Whole Egg Powder	Control	30.25±0.35	30.25±0.35	Poor
	1	31.50±0.71	30.75±0.35	Poor
	2	33.00±0.00	32.00±0.00	Very poor
	3	36.75±0.35	33.50±0.71	Very poor
	4	37.75±0.35	36.50±0.71	Awful
Egg White Powder	Control	22.50±0.71	22.50±0.71	Passable
	1	23.50±0.71	22.50±0.71	Passable
	2	25.50±0.71	24.25±0.35	Poor
	3	30.25±0.35	28.00±0.00	Poor
	4	34.25±1.06	33.50±0.71	Very poor
Egg Yolk Powder	Control	34.50±0.71	34.50±0.71	Very poor
	1	37.50±0.71	36.00±0.00	Very poor
	2	40.50±0.71	38.75±1.06	Very poor
	3	43.50±0.71	40.75±0.35	Awful
	4	44.75±0.35	41.75±0.35	Awful

reached 37.75±0.35, while the sample at 75% RH rose to 36.50±0.71, resulting in a transition from "Poor" to "Fair" flow according to Carr's Classification System. This decline in flowability can be attributed to moisture uptake under high humidity conditions. As RH increases, powder particles absorb water, foaming liquid bridges between granules that enhance interparticle cohesion and hinder flow [16]. At 100% RH, WEP absorbed more ambient moisture than at 75% RH, which explains why the flow deteriorated slightly more in the 100% RH sample by week 4. In contrast, the 75% RH environment, although still high, slowed water uptake to some extent, resulting in marginally better flow stability. Similar findings have been reported in other studies on protein powders.

For example, the storage of soy protein isolates under humid conditions also led to a decrease in flowability over time, with higher RH accelerating caking and cohesion [17]. Consequently, WEP's behaviour aligns with established observations that moderate to high humidity during storage gradually compromises powder flow due to moisture-induced cohesion. Egg white powder (EWP) exhibited the best flow profile among all samples, as shown in Table 1, with an initial value of 22.50±0.71, categorizing it as having "Passable" flowability.

However, by week 4, its flowability had decreased, measuring 34.25 ± 1.06 at 100% RH and 33.50 ± 0.71 at 75% RH, which placed EWP in the "Very poor" flow category. This can be due to the highly soluble and hygroscopic proteins found in the egg whites. As the RH increases, these proteins absorb moisture and form semi-solid or liquid bridges that enhance the cohesion of the powder. This phenomenon explains the gradual increase in flowability values observed over the storage period [18]. Despite the decline in flowability, EWP consistently outperformed the other egg powders at each time point.

This can be attributed to EWP having lower fat content and a higher concentration of albumen proteins, which, when dried, form discrete particles that are less prone to agglomeration. Whereas other egg powders (egg yolk and whole egg powder) have significantly higher fat content, which contributes to increased cohesion and reduced flowability. [19] confirmed that high-protein powders generally have better initial flow characteristics than fat-containing powders, but they are also susceptible to cohesion-related flow issues over time under humid storage conditions. Thus, the behaviour of EWP aligns with documented trends: it starts with superior flow but gradually degrades due to moisture-induced cohesion. Egg yolk powder exhibited the lowest initial flowability among the three samples, with a value of 34.50±0.71, which was classified as "Very poor." Over four weeks, the Carr index increased substantially, indicating a marked deterioration in flowability. By week 4, the flowability value of EYP at 100% RH reached 44.75±0.35, and at 75% RH, it was 41.75±0.35, resulting in a classification of "Passable" range, as shown in Table 1. This change indicates a notable deterioration in flow characteristics. The decline in EYP's flowability is closely linked to its high lipid and phospholipid content. Under humid conditions, these lipids can form viscous or semi-solid bridges, leading to strong interparticle cohesion. As the relative humidity increases, yolk solids absorb moisture differently than protein-rich powders, making them more prone to sticky spots and caking due to fat absorption and complex protein-lipid interactions. These mechanisms are consistent with the findings of Martins & Netto [18], who observed that lipid-rich food powders typically display poor flow characteristics when exposed to elevated humidity. Furthermore, Martins & Netto [18] demonstrated that increasing relative humidity significantly decreases the flowability of food powders. Their study supports the current findings, reinforcing the conclusion that lipid-rich powders like EYP are particularly vulnerable to caking and flow issues during humid storage.

3.2 Colour stability of egg powder

Colour stability is a crucial indicator of quality in powdered food products, particularly during storage. Changes in the L^* (lightness), a* (red-green), and b* (yellow-blue) values, as shown in Table 2-4, provide insight into the potential chemical and physical transformations that egg powders may undergo under varying humidity conditions.

3.2.1. Colour stability of whole egg powder

In Table 2, the WEP samples exhibited a gradual decrease in lightness (L^*) from 48.07 at baseline to 44.88 by week 4, regardless of the relative humidity (RH) level, indicating a progressive darkening of the powder.

This trend aligns with the report by Hazlett et al. [20], who observed a consistent decline in L^* values of Whole Egg Powder during storage, reflecting a shift from lighter to darker shades. A temporary rise in L^* observed at week 3 under 75% RH may suggest short-term colour stabilization or variability caused by surface reflection or powder redistribution, similar to findings on colour stability in food products reported by Zang et al. [21]. Overall, the steady reduction in brightness suggests slow oxidative browning or protein-lipid interactions contributing to visual degradation.

The a* (redness) values increased during the early storage period and declined slightly by week 4, possibly due to transient pigment shifts or oxidative changes. Similarly, b* (yellowness) values rose modestly until week 3 before sharply declining, likely resulting from the degradation of yellow pigments or chemical modifications affecting colour tone. These changes further reflect the colour transition patterns described by Hazlett et al. [20], who noted a decrease in b* and an increase in a* values as egg powder shifted from light yellow to dark brown during storage.

Table 2.

Colour stability of whole egg powder

Sample	Parameter	ST (Week)	Storage Relative Humidity	
			100%	75%
WEP	*L**	Control	48.07 ± 0.01	48.07±0.01
		1	47.75 ± 0.02	47.76±0.01
		2	47.32 ± 0.31	47.23±0.16
		3	47.28 ±0.01	49.33±0.01
		4	44.88 ±0.01	44.88±0.01
	a*	Control	8.72 ±0.02	8.72±0.02
		1	9.33 ±0.01	9.14±0.01
		2	9.45 ±0.10	9.26±0.01
		3	9.51 ±0.01	9.47±0.01
		4	9.89 ±0.01	9.58±0.00
	b*	Control	32.13 ±0.01	32.13±0.01
		1	32.01 ±0.04	32.11±0.02
		2	31.69 ±0.19	31.75±0.11
		3	31.43 ±0.01	31.53±0.01
		4	30.12 ±0.00	30.02±0.00

3.2.2 Colour stability of whole egg powder

In Table 3, the egg white powder displayed the lightest colour profile at baseline, with L^* values starting around 59.89. By week 4, these values decreased to 54.27 (100% RH) and 55.74 (75% RH), indicating a noticeable reduction in brightness. A temporary increase in L^* at week 3, particularly under 75% RH, may reflect transient changes in particle alignment or moisture distribution, though the overall trend still indicates browning reactions or protein aggregation during storage. The redness (a*) values steadily increased from 0.46 to 2.92 at 100% RH and to 2.18 at 75% RH, while yellowness (b*) also increased over time. These changes are likely the result of chemical reactions involving proteins and residual pigments, in addition to moisture-driven changes that enhance visual colour intensity. This finding aligns with research by Fitzpatrick [19], which indicated that protein-rich powders often experience significant colour shifts and altered handling characteristics under varying humidity conditions. Hazlett et al. [20] also observed that protein-based powders frequently undergo visual and physical deterioration in ambient conditions due to oxidation and structural instability.

3.2.3 Colour stability of egg yolk powder (EYP)

In Table 4, it is observed that egg yolk powder initially showed a moderate lightness ($L^* \approx 56.63$), with subtle fluctuations observed throughout the storage period. After a slight decrease by week 2, the L^* values briefly increased at week 3, followed by a final decline to 52.04 at 100% relative humidity (RH) and 53.95 at 75% RH by week 4. These variations may indicate natural pigment transformations, particularly involving carotenoids and lipids, as well as moisture interactions within the powder matrix. The redness (a*) values increased until week 3 before plateauing, suggesting an exposure to or concentration of the red-orange pigments naturally present in the yolk. Yellowness (b*) values rose during mid-storage, peaking at 37.64 under 75% RH before declining by week 4. This behaviour indicates the dynamic nature of yellow

Table 3.

Colour stability of egg white powder

Parameter	ST	Storage Relative Humidity	
		100%	**75%**
L*	Control	59.89±0.00	59.89±0.00
	1	58.58±0.11	58.63±0.02
	2	57.82±0.04	58.73±0.00
	3	60.4±20.01	60.82±0.11
	4	54.27±0.01	55.74±0.02
a*	Control	0.46±0.04	0.46±0.04
	1	1.60±0.06	1.96±0.00
	2	1.27±0.03	1.49±0.02
	3	2.11±0.01	2.24±0.06
	4	2.92±0.03	2.18±0.02
b*	Control	19.95±0.07	19.95±0.07
	1	23.80±0.00	23.00±0.00
	2	22.30±0.00	22.30±0.00
	3	22.25±0.07	24.45±0.07
	4	22.60±0.00	22.80±0.00

Table 4.

Colour stability of egg yolk powder

Parameter		Storage Relative Humidity	
	ST	**100%**	**75%**
L*	Control	56.63±0.34	56.63±0.34
	1	55.75±0.00	55.76±0.00
	2	53.78±0.13	55.83±0.06
	3	57.58±0.01	58.86±0.14
	4	52.04±0.03	53.95±0.01
a*	Control	3.87±0.04	3.87±0.04
	1	4.12±0.06	4.12±0.01
	2	3.28±0.00	4.04±0.10
	3	4.35±0.00	4.97±0.06
	4	4.43±0.01	4.02±0.02
b*	Control	34.22±0.02	34.22±0.02
	1	36.00±0.10	36.62±0.11
	2	33.54±0.11	35.36±0.06
	3	35.87±0.01	37.64±0.04
	4	33.83±0.01	34.09±0.00

pigments, likely influenced by oxidation or instability over time. These findings are consistent with the research conducted by Katekhong & Charoenrein [23], which demonstrated that storage temperature and humidity can significantly affect the colour stability of egg-based powders due to chemical transformations and pigment reactivity. The colour changes observed across all egg powder types during storage reflect a complex interaction between relative humidity, storage duration, and the specific composition of each powder. Egg white powder exhibited the most pronounced shifts in lightness, redness, and yellowness, highlighting the sensitivity of protein-rich powders to even moderate humidity levels. In contrast, egg yolk powder demonstrated dynamic colour changes that are likely driven by lipid-soluble pigments and oxidative processes. Whole egg powder, on the other hand, displayed more gradual but continuous darkening and pigment transitions due to its combined protein and fat composition.

These observations align with previous studies of Fitzpatrick [19] and Katekhong & Charoenrein [23], emphasising how ambient storage conditions can trigger measurable and noticeable changes in colour. Across the three powder types, storage under elevated humidity resulted in measurable colour changes, although the pattern and extent of change differed among samples. These differences likely reflect variations in composition, particularly the relative proportions of protein, lipid, and natural pigments. Overall, the results suggest that both storage humidity and powder composition are important determinants of colour stability in dried egg products.

3.3 Foaming capacity and stability of the egg powder

Whole egg powder (WEP), Egg white powder (EWP), and Egg yolk powder (EYP) all exhibited a decline in foaming capacity and stability over the four-week storage period, as shown in Figure 1 below. The extent of this deterioration was influenced by relative humidity. The results are as shown in the figures below, indicating that high humidity significantly compromises the functional properties of egg powders during storage. The Foaming capacity of the whole egg powder (WEP) demonstrated a foaming capacity of 39%. However, after four weeks at 100% relative humidity (RH), this value sharply dropped to 11%. In contrast, a milder decline to 15% was observed at 75% RH. It is understood that moisture uptake in protein-rich powders can lead to structural collapse and denaturation, reducing the powder's ability to trap and retain air. The accelerated degradation at higher RH may be attributed to increased water activity, which promotes protein unfolding and aggregation. This observation aligns with the findings of Rao et al. [25], who emphasised that increased humidity negatively affects the structural and functional stability of dry food powders. The Foaming capacity result of egg white powder initially exhibited the highest foaming capacity (48%) among the samples, due to the strong surface activity and excellent foaming properties of egg white proteins, particularly ovalbumin. However, at 100% RH, this capacity fell to 21% by Week 4, compared to 27% at 75% RH. These results indicate that prolonged exposure to high humidity impairs the surface-active proteins in egg white, reducing their ability to stabilize air bubbles. This is consistent with the report by Fitzpatrick [19], which found that moisture absorption in food powders compromises flowability and functionality, especially in protein-dense matrices. The egg yolk powder began with the lowest foaming capacity (31%) and showed the steepest decline under high humidity conditions, dropping to just 7% at 100% RH by Week 3. This decline can be attributed to the high amounts of lipids and phospholipids in yolk, which do not support foam formation and can destabilize existing foams by disrupting protein films [19]. Even at 75% RH, the foaming capacity of yolk dropped to 11% by Week 4, indicating a general sensitivity to moisture. This finding is consistent with reports that lipid-rich powders are more prone to functional degradation during storage in humid environments, due to fat-induced caking and moisture-mediated structural breakdown.

The foaming stability results of the whole egg powder, egg yolk powder, and egg white powder are shown in Fig. 2.

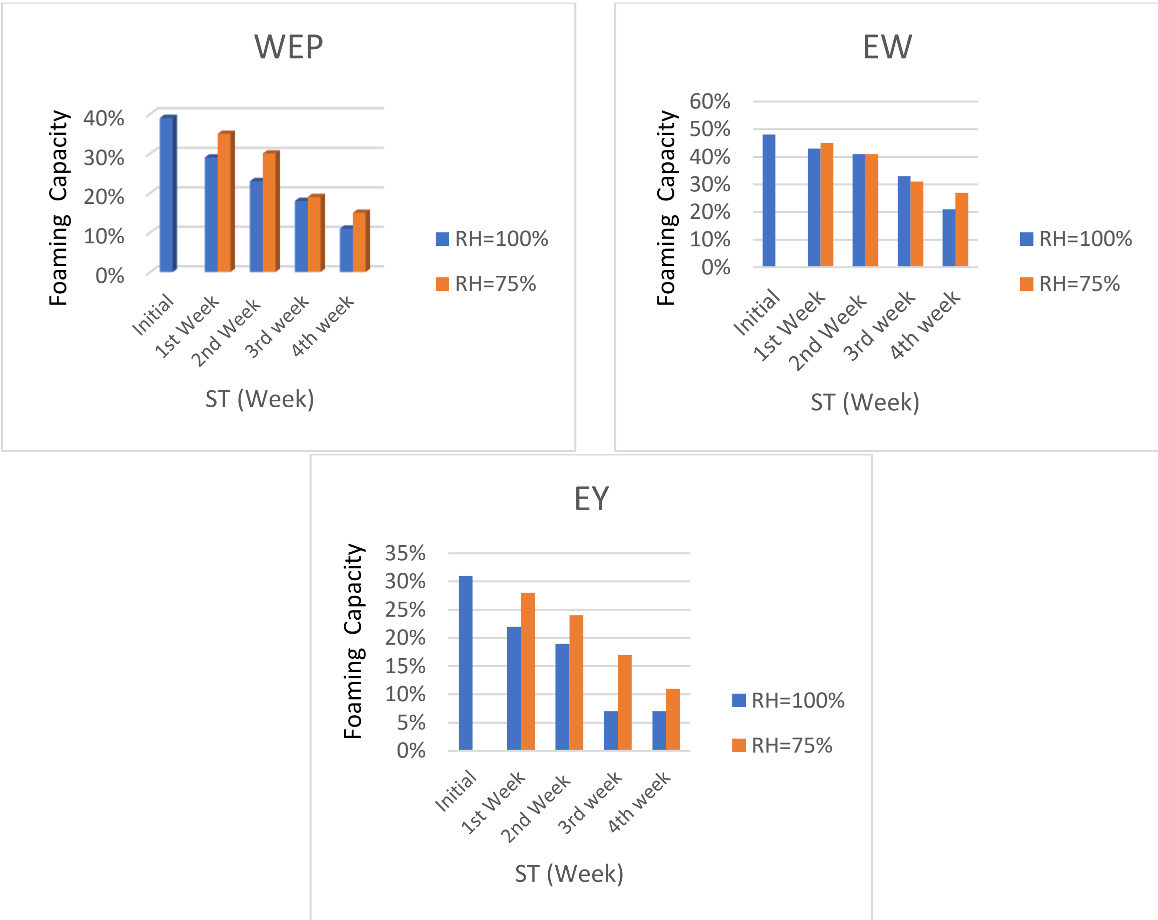

Fig. 2. Changes in the foaming capacities of the whole egg (WEP), egg white (EW), and egg yolk (EY) powder samples at 75 and 100% relative humidity

A trend similar to that of the foaming capacity result was observed. Egg white foam had the highest initial stability (41%) but dropped to 3% at 100% RH and 7% at 75% RH by the end of the storage period. The sharp decline in stability at high RH may be attributed to the weakening of the protein film surrounding air bubbles, which results in rapid drainage and collapse. It is in line with the report of Zhou et al. [24], which indicated that increased moisture facilitates protein hydrolysis and aggregation, reducing foam stability. Egg yolk exhibited the most dramatic reduction in foam stability at high RH, dropping from 26% to 3% over four weeks. It is because of the lipid content that inhibits protein-protein interactions required to stabilize foams. At 75% RH, the decline was less severe but still substantial (to 7%), suggesting that yolk is intrinsically less stable as a foaming agent and is highly susceptible to environmental humidity.

WEP showed moderate foam stability throughout but still suffered significant degradation, especially at 100% RH. By Week 4, stability declined from 36% to 7% at high RH and to 10% at 75% RH. This trend supports the assertion that composite egg powders (containing both yolk and white components) may experience dual mechanisms of destabilization, lipid interference, and protein denaturation under humid storage. These findings reinforce that storage at 75% RH better preserves the foaming capacity and stability of egg powders, aligning with the objectives of this study. It is in line with the report of [19] and [24], who both emphasised the importance of humidity control in maintaining the functional qualities of food powders.

4. Conclusion

The results indicate that the flowability and the foaming capacities of all egg powders reduced over the storage time due to moisture-induced cohesion. Whole egg powder demonstrated intermediate performance, while egg yolk powder showed the poorest results. As expected, product stability was observed to be better at 75% relative humidity compared to 100%. In conclusion, egg white powder exhibited the most favourable flow characteristics and was the most stable throughout the storage period. Both 75% and 100% Relative Humidity (RH) are considered highly unsuitable for the long-term storage of egg powder. In order to maintain product integrity, egg powders should be stored in a cool, dry environment with relative humidity levels between 40% and 60%. The different types of egg powders have unique characteristics: egg white powder is ideal for applications requiring stable foaming and colour integrity, whole egg powder is suitable for general use with moderate moisture protection, and egg yolk powder needs improved moisture-resistant solutions due to its sensitivity.

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