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Mechanism of Estimating Shelf Life of Eggs Using Optical Sensors

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***Abstract*— Eggs are food items that can be easily damaged. Damage to eggs can occur due to age and the handling process during storage. To avoid this damage, proper storage methods are needed. In this study, there are several storage methods, namely outside storage methods, inside storage boxes, and refrigerator storage. To estimate the shelf life of eggs, this study used RGB cameras, NIR cameras, NIR cameras + filters, smartphone cameras, and spectrometers. The data retrieval process is carried out by taking an image of the age of the eggs in each storage method. The image results are then extracted using ImageJ software from the extraction results, and the data is used as a graph to see the egg's shelf-life phase. Data analysis was done by calculating the RGB values in 4 egg images and then normalization. A statistical correlation test was used to determine the coefficient of determination (R2) and the degree of suitability of the independent and dependent variables. From the coefficient of determination, a good index for estimating the shelf life of eggs is good for each egg.**

Keywords—egg, image processing, optical sensor

I. INTRODUCTION

Eggs are perishable dietary products. In general, an egg's outer shell and inner structure can sustain injury. To address the issue of deterioration, a method of egg storage that preserves their freshness is required. The time an egg is stored can affect the integrity of the eggshell's structure. This alteration occurs during storage and depends on the duration of storage, relative humidity, temperature, and age of the chicken eggs. [1].

The technology for storing eggs continues to advance rapidly. This development in storage technology can facilitate food quality control by comparing visual changes from good to bad conditions. One technology that can be applied is an optical sensor that utilizes a visible object and then converts it into a digital image. This optical sensor can be used for food items such as eggs that undergo changes during storage.

Egg freshness can be estimated by utilizing image capture and spectroscopy techniques that measure the light absorption of the eggshell. Laser beams can pass through fresh eggs more quickly than through rotten eggs. The obtained images are then processed into RGB index data, where the RGB index is used to estimate the age of the eggs. The data processing in this study used a determination equation to determine the effect of egg age during storage using the indices obtained from digital images and spectrometer.

II. METHODOLOGY

A. Tools and Materials

The tools used in this study include the following: Canon IXUS 160 digital RGB camera, Canon IXUS 160 digital NIR camera, Xiaomi Note 4x smartphone, portable spectrometer, 50-watt LED and halogen lamp, cardboard box and refrigerator, computer set, ImageJ software, Microsoft Excel software, plastic tube, and Zomei 850Nm optical filter.

The materials used in this study consist of 30 eggs each duck eggs, chicken eggs for egg production, free-range chicken eggs, and quail eggs.

B. Research Procedures

The research was conducted in several stages. The first stage involved preparing the necessary tools and materials. In this stage, the researcher designed the location for egg collection and drafted the eggs and storage containers. The next step is seen in Figure 1 below.

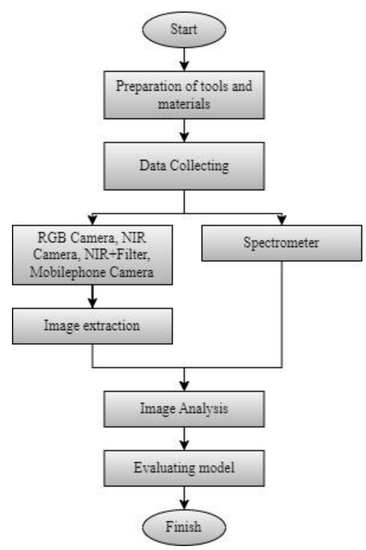

Figure 1. Flowchart Research

C. RGB Normalization Index

Normalizing RGB color is necessary to calculate the normalized R, G, and B indices when collecting data using digital cameras and smartphones. A specific calculation method for RGB color normalization [3]. RGB color normalization can be achieved through the following calculation.

$$Normalized\ r = \frac{r}{R+G+B} \quad (1)$$

$$Normalized\ g = \frac{G}{R+G+B} \quad (2)$$

$$Normalized\ b = \frac{B}{R+G+B} \quad (3)$$

III. Results and Discussion

A. Change in Eggs shelf-life

The phase changes of eggs can be observed from the results of image capture of the eggs using an RGB camera, smartphone camera, NIR camera, and NIR+filter camera, which are then extracted using ImageJ software to obtain the RGB data values. The obtained RGB data is then converted into a graph, and Figure 2 represents the graph data of egg age phase changes.

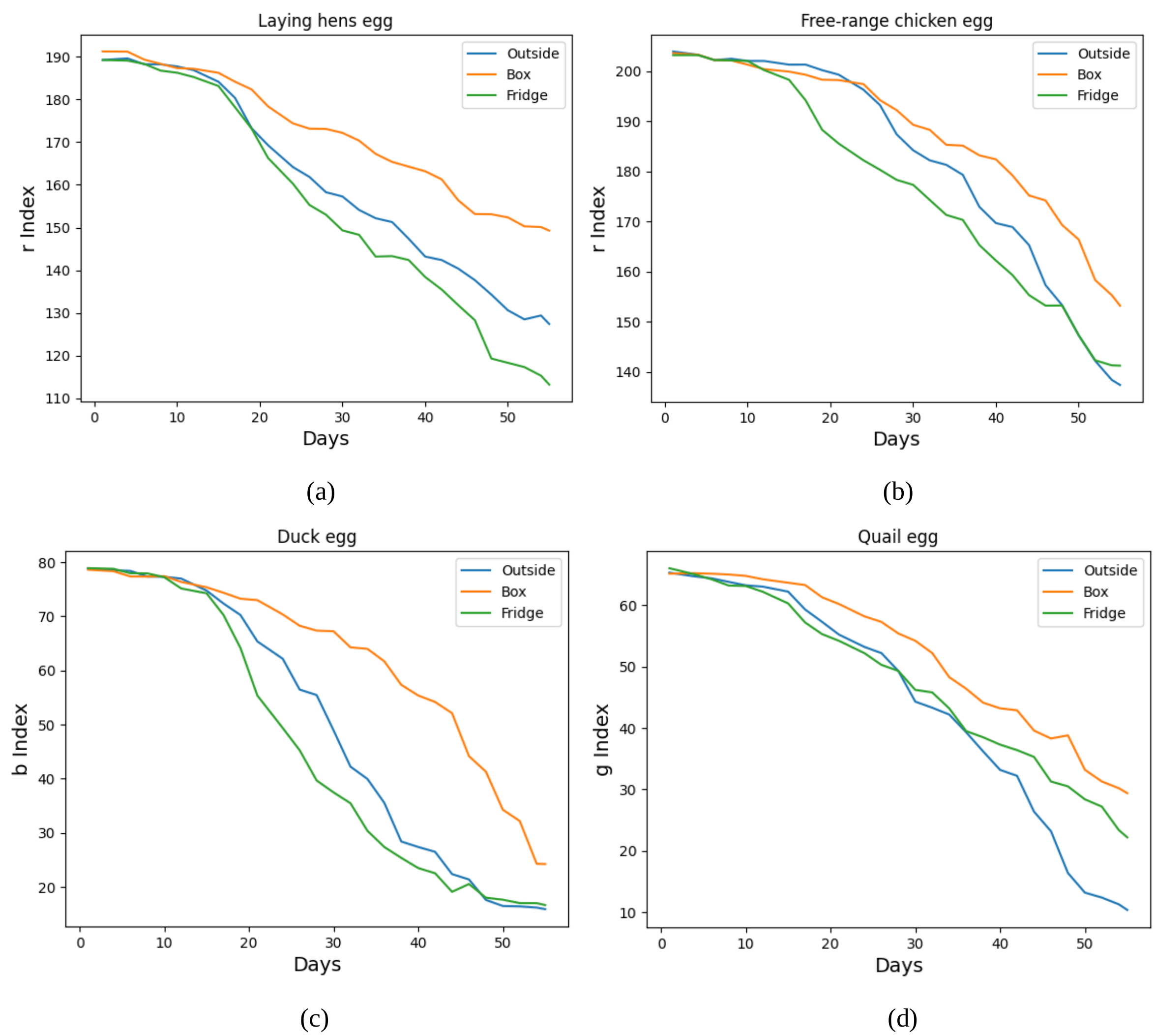

Figure 2. Change in eggs shelf-life, (a) Laying hens egg; (b) Free-range chicken egg; (c) Deuck egg; (d) Quail egg.

Figure 2 shows a graph of changes in the egg shelf-life period, where changes occur significantly from 16 to 55 days. For example, the RGB index value for laying hens at the first age is 189.27 in external storage, 191.27 in storage in a box, and 189.28 in the refrigerator until the age of 15, when it becomes 184.17 in outdoor storage, 186.27 in an internal storage box, and 183.17 on hold in the fridge. The decreased value of the RGB index that occurred $\leqslant$ 1. After the age of the eggs exceeded 15 days, the eggs experienced a significant decrease in an index where the decreased value was greater than 1. At the age of 17, the RGB index value of eggs was 180.17 in external storage, 184.18 in an internal storage box, and 178.19 in refrigerator storage. Storage of eggs in the refrigerator can last up to 4-5 weeks, and this method is very effective for keeping eggs reasonable. A good RGB index is found in storing eggs in the refrigerator, which can be seen clearly on the duck egg chart.

B. *Effective Index for Estimating the Shelf Life of Eggs*

Determining the most effective index makes it easier to understand a problem by providing an overview of the research being conducted. This study uses correlation analysis to find the best coefficient of determination (R^2).

1. Comparison of laying hens egg shelf life each camera index

The camera index used in this study is the RGB color index, which was normalized beforehand. After normalizing the data, the best one is selected using determination analysis to find the best coefficient of determination. The results of the analysis of the coefficient of determination between the age of the egg and the camera index normalized to the RGB index can be seen in Table 1

The R index show that the longer the eggs are stored, the lower value shown on the index will decrease. The smaller the value of the r index, the lower the quality of the eggs. The decrease in the value of the r index occurs when the image is taken using a NIR camera, where the dominant color is accepted when the image is taken. The longer the eggs are stored, the lower the r index value. This is caused by the imperfect absorption of light by the egg. Inadequate light absorption occurs because the egg's interior already shows indications of decay [4].

TABLE 1. COEFFICIENT OF DETERMINATION BETWEEN THE SHELF-LIFE OF LAYING HENS CHICKEN EGG EACH CAMERA INDEX.

No	Treatment	Camera Index	Camera Type			
			RGB	*Smartphone*	NIR	NIR+Filter
1	Outside	r	0.8154	0.0026	0.1360	0.2710
2		g	0.6810	0.3213	0.3147	0.6313
3		b	0.4185	0.0008	0.9209	0.8762
4		b-g	0.8877	0.0235	0.3438	0.7810
1	Fridge	r	0.4313	0.2204	**0.9365**	0.8855
2		g	0.1702	0.0579	0.7139	0.0029
3		b	0.6048	0.1173	0.5847	0.5486
4		b-g	0.8557	0.4004	0.5508	0.2233
1	Box	r	0.8797	0.0352	0.7106	0.9272
2		g	0.1780	0.2487	0.0291	0.2928
3		b	0.4249	0.1479	0.4072	0.5444
4		b-g	0.5359	0.0002	0.5700	0.8230

TABLE 2. COEFFICIENT OF DETERMINATION BETWEEN THE SHELF-LIFE OF FREE-RANGE CHICKEN EGG EACH CAMERA INDEX.

No	Treatment	Camera Index	Camera Type			
			RGB	*Smartphone*	NIR	NIR+Filter
1	Outside	r	0.6668	0.0523	0.5899	0.3531
2		g	0.7582	0.2751	0.1062	0.4904
3		b	0.0916	0.1818	0.5718	0.3684
4		b-g	0.8427	0.2263	0.5272	0.3808
1	Fridge	r	0.7618	0.75	0.4323	0.3584
2		g	0.8419	0.2716	0.3835	0.4769
3		b	0.2326	0.4881	0.4274	0.4009
4		b-g	0.5475	0.4309	0.4234	0.4086
1	Box	r	**0.8961**	0.585	0.5519	0.3912
2		g	0.8206	0.5194	0.4873	0.4522
3		b	0.0019	0.7154	0.5461	0.3693
4		b-g	0.7537	0.6401	0.5413	0.378

2. Comparison of free-range chicken egg shelf life each camera index

The normalized RGB color index is then chosen with the highest normalized value based on the coefficient of determination. The index data taken presented in Table 2.

Based on Table 2, the highest normalization of the r index shows a coefficient of determination of 0.8961, which means that the longer the eggs are stored, the higher the value of the r index. The increase occurred because the color characteristics of the dominant eggshell were brownish-red and quite thick. Dark and dense egg color has a high content of red pigment, so the r index is more prevalent [2]. The eggshells of laying hens are brownish-red, so the r-index data is more dominant than the other indices.

3. Comparison of duck egg shelf life each camera index

Based on the collected data, the duck egg age indicator analysis with the camera index presented in Table 3. The determination analysis graph with the closest value to 1 is found on the green index (g) on external storage.

TABLE 3. COEFFICIENT OF DETERMINATION BETWEEN THE SHELF-LIFE OF DUCK EGG EACH CAMERA INDEX.

No	Treatment	Camera Index	Camera Type			
			RGB	*Smartphone*	NIR	NIR+Filter
1	Outside	r	0.7282	0.8392	0.386	0.5487
2		g	0.0168	0.0065	0.354	0.392
3		b	0.7626	0.0051	0.1746	0.2252
4		b-g	0.2798	0.4639	0.1235	0.3843
1	Fridge	r	0.7676	0.1496	0.3027	0.3809
2		g	0.425	0.6471	0.0173	0.367
3		b	0.7474	0.276	0.0977	0.3895
4		b-g	0.7664	0.0622	0.0122	0.4037
1	Box	r	0.6132	0.4467	0.2578	0.356
2		g	0.6428	0.5526	0.3295	0.2916
3		b	0.8201	**0.9064**	0.3749	0.5409
4		b-g	0.6345	0.2982	0.2328	0.0261

TABLE 4. COEFFICIENT OF DETERMINATION BETWEEN THE SHELF-LIFE QUAIL EGG EACH CAMERA INDEX.

No	Treatment	Camera Index	Camera Type			
			RGB	*Smartphone*	NIR	NIR+Filter
1	Outside	r	0.0126	0.0342	0.0006	0.4382
2		g	**0.9276**	0.2182	0.0406	0.4231
3		b	0.0079	0.1361	0.0101	0.0277
4		b-g	0.4522	0.1736	0.0228	0.4274
1	Fridge	r	0.0473	0.5726	0.238	0.4509
2		g	0.4917	0.6285	0.4491	0.4478
3		b	0.6999	0.4548	0.2996	0.032
4		b-g	0.824	0.3908	0.4437	0.3954
1	Box	r	0.3602	0.7970	0.3129	0.067
2		g	0.869	0.4759	0.3462	0.0837
3		b	0.3935	0.692	0.3733	0.3377
4		b-g	0.7065	0.6063	0.346	0.4488

TABLE 5. COEFFICIENT OF DETERMINATION BETWEEN THE SHELF-LIFE OF SEVERAL EGG VARIETY USING SPECTROMETER INDEX.

No	Treatment	Camera Index	Egg Variety			
			Laying Hens Egg	*Free-range Egg*	Duck Egg	Quail Egg
1	Luar	r 670	0.6647	0.2377	0.6504	0.5095
2		g 560	**0.8873**	0.028	0.8579	0.1406
3		b 480	0.7886	0.3374	0.7621	0.6332
4		Red Nir 720	0.5848	0.6605	0.6425	0.0015
5		NIR 840	0.6225	0.3278	0.6225	0.0768
1	Kulkas	r 670	0.1476	0.2911	0.0094	**0.7877**
2		g 560	0.1009	0.1342	**0.8724**	0.4821
3		b 480	0.0634	0.1777	0.0694	0.0003
4		Red Nir 720	0.5684	0.0084	0.6101	0.3097
5		NIR 840	0.2661	0.1668	0.2661	0.1455
1	Box	r 670	0.3384	0.6392	0.29	0.0039
2		g 560	0.6735	**0.7476**	0.6241	0.0587
3		b 480	0.6209	0.2903	0.5516	0.0881
4		Red Nir 720	0.0844	0.122	0.0504	0.029
5		NIR 840	0.0029	0.4327	0.0029	0.3519

TABLE 6. COMPARISON OF CAMERA AND SPECTROMETER INDEX IN EACH EGG VARIETY

No	Egg Variety	Index	(R^2)	Tools	Storage
1	Laying Hens Egg	r	0.9365	NIR Camera	Fridge
		g	0.8406	Spectrometer	Outside
2	Free-range Egg	r	0.8961	RGB Camera	Box
		g	0.7476	Spectrometer	Box
3	Duck Egg	b	0.9064	Mobilephone Camera	Box
		g	0.8724	Spectrometer	Fridge
4	Quail Egg	g	0.9276	RGB Camera	Outside
		r	0.7877	Spectrometer	Fridge

Table 3 shows that suitable storage for duck eggs is in a box where the coefficient of determination is close to 1. Duck eggs generally last two weeks during storage. After two weeks, the eggs will experience genuine changes. This opinion can also be proven in this study.

4. Comparison of quail egg shelf life each camera index

Based on the data that has been collected, an analysis of the duck egg age indicator with the camera index presented in Table 4. The graph of the analysis of the coefficient of determination with the closest value to 1 is found in the green index (g) in external storage.

Based on Table 4, the highest coefficient of determination is found at index g with external storage where the image is taken using an RGB camera. The value contained in the g index is 0.9276, where this value is the best index value that can be used to estimate the age of eggs because it has a value that is almost close to 1. Quail egg shells have 2 different color patterns for each egg, namely white and black, however, when observed again the white color of the quail eggs is more of a greenish white color. This greenish-white color most likely makes the g index more dominant than the other indices in image capture. The color of the eggshell has a major influence in determining the index to be observed, as well as the RGB index which greatly influences the dominant color of the material to be observed [5].

5. Comparison of quail egg shelf life measured by spectrometer

Based on the data that has been collected, an analysis of duck egg age indicators with spectrometer index presented in Table 5.

Based on Table 5, the best coefficient of determination values were obtained for four types of eggs with each treatment, ranked from the first to the last as follows: the highest coefficient of determination value was obtained for commercial layer chicken eggs stored outside with the g (green) index, with a value of 0.8873; the second was obtained for village chicken eggs stored in a box with the g (green) index, with a value of 0.7476; the third was obtained for duck eggs stored in a refrigerator with the g (green) index, with a value of 0.8724; and the last one was obtained for quail eggs stored in a refrigerator with the r (red) index, with a coefficient of determination value of 0.8724.

C. *The Comparison of Each Index*

Following the data analysis for each index, a comparison was made to determine the most effective determination coefficient among the RGB color index, NIR index, NIR+filter index, smartphone index, and spectrometer index in the comparison results.

Based on Table 6, the best determination coefficients for each egg to estimate age are as follows: for chicken eggs, the best index is the NIR camera index (r) for refrigerated storage and the spectrometer index (g) for outdoor storage. For free-range chicken eggs, the best index is the RGB camera index (r) for storage in a box and the spectrometer index (g) for storage in a box. For duck eggs, the best index is the smartphone camera index (b) for storage in a box and the spectrometer index (g) for refrigerated storage. For quail eggs, the best index is the RGB camera index (g) for outdoor storage and the spectrometer index (r) for refrigerated storage. The results in Table 6 align with the study [5], which states that the dominant colors influence the RGB index in the observed material.

IV. CONCLUSSION

The camera index effectively predicted the shelf life of eggs in each of the four egg samples, namely the index r for chicken eggs, the index r for free-range chicken eggs, the index b for duck eggs, and the index g for quail eggs. The effective spectrometer index was the index g for chicken eggs, the index g for free-range chicken eggs, the index g for duck eggs, and the index r for quail eggs. Good egg storage practices varied for each of the four egg samples, with chicken eggs stored in the refrigerator, free-range chicken eggs stored in a box, duck eggs stored in a box, and quail eggs stored outside.

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