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Research Article

Computer-Assisted Automatic Egg Fertility Control

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Abstract

This research aimed to determine the fertilization control of the eggs in an incubator between 0th and 5th days by image processing techniques via low-priced tools. Three different datasets that were composed of eggs whose images taken at different times in the incubator were prepared. Several filtering and morphology methods, gray level conversion and dynamic thresholding were utilized to process the 15 egg images. Moreover, the original processing codes based on the problem were given. White and Black percentages of binary images were utilized to determine the egg control. According to the test results, for the first dataset; 73.34% of fertility accuracy was achieved on the third day; 100% of fertility accuracy was achieved on the fourth day, for the second dataset; 93.34% of fertility accuracy was achieved on the third day; 93.34% of fertility accuracy was achieved again on the fourth day; for the third dataset, 93.34% of fertility accuracy was achieved on the third day; 100% of fertility accuracy again was achieved on the fourth day. When the results were evaluated, it was seen that egg fertility has been determined successfully automated with low cost tools.

Keywords: *Egg incubator, Poultry production, Egg fertility control, Image processing, Dynamic thresholding*

Bilgisayar Destekli Otomatik Yumurta Döllülük Kontrolü

Öz

Çalışmada kuluçka makinesinde yumurtaların 0-5 gün aralığında döllülük kontrolünün kolay elde edilebilen ve az maliyetli araçlar kullanılarak görüntü işleme teknikleri ile tespit edilmesi amaçlanmıştır. Denemede, ev tipi standart kuluçka makinesi içine farklı zamanlarda görüntüleri alınan 15 yumurtadan oluşan üç farklı veri seti hazırlanmıştır. Yumurta görüntülerinin işlenmesinde çeşitli filtreleme ve morfoloji yöntemleri, gri seviye dönüşümü ve dinamik eşikleme yöntemi kullanılmıştır. Ayrıca probleme dayalı özgün görüntü işleme kodları yazılmıştır. Elde edilen binary görüntülerin beyaz/siyah oranları döllülük kontrolünü belirlemede kullanılmıştır. Deneysel sonuçlara göre ilk veri setinde 3. gün %73.34, 4. gün %100, ikinci veri setinde 3. gün %93.34, 4. gün %93.34 ve üçüncü veri setinde 3. gün %93.34, 4. gün %100 doğrulukla döllülük durumları tespit edilmiştir. Elde edilen sonuçlar değerlendirildiğinde, yumurta döllülük kontrolünün az maliyetli ve edinilebilir araçlar ile başarılı bir şekilde otomatikleştirilebileceği görülmüştür.

Anahtar sözcükler: *Kuluçka makinesi, Kanatlı hayvan üretimi, Döllülük kontrolü, Görüntü işleme, Dinamik eşikleme*

INTRODUCTION

The egg industry is one of the main industries in the food chain as well as it plays a significant role in meeting the protein need of the world. Hatchability is essential in the egg industry. Even though the hatchability is affected from various factors such as the quality of eggs, breeding ratio, survival rate, and poultry quality; the most important factor is being sure about the eggs in the incubator are the fertile ones [1,2]. Durmuş pointed out that using quality hatching eggs is pretty significant besides providing optimum incubation conditions to keep hatching at high levels. However, Kamalı and Durmuş pointed out that there are a lot of factors that affect the chick quality as well as the chick quality will increase based on these factors to reach the optimum level [3]. Generally, the qualified personnel manually control the eggs which have fertility before putting them into the egg incubator. However, the fertility control is performed during the preliminary development phase and the final phase (18th day for chicken egg) to

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keep the temperature and humidity values of the egg incubator. Performing the fertility control by manual and being based on the expert control increase the error rate. The control process is effort consumption; the qualified employees who control thousands of eggs per day are not productive because of tiredness and optical aberrations. Therefore, only some of the eggs are randomized to determine the fertilized eggs; this means that many of the unfertilized eggs will remain in the incubator [4]. Moreover, the unfertilized egg that remains in the incubator will spoil and there will be gas emission that negatively affects other healthy embryos. This is because; performing control and pulling out the unfertilized eggs from the incubator will increase the hatchability [1]. Developing an error-free, rapid and low priced computer-aided system to identify the unfertilized eggs at the right time will provide an advantage for the incubation system by purifying the system from the man-made errors.

Many of the investigators tried to determine the fertility control, embryo development, and fracture-crack control by using image processing methods with the help of the computer. Das and Evans [5,6] obtained egg images by using backlighting and high intensity candling lamp and get 100% classification result on 4th day. Lawrence et al.[7], Smith et al.[8], Smith et al.[9] Liu and Ngadi [4] and Islam et al.[10] used hyperspectral NIR imaging method and get success rates 100% (4th day), 91%-83% (3rd days), 100% (1st day) and 100% (4th day) respectively. Zhu and Ma [11] use halogen lamp for taking the egg images and achieved 92.5% success rates on 6th day. Lin et al.[12] used thermal imaging and 96% success rates are obtianed. Hashemzadeh and Farajzadeh [1] preferred light emitting diode based imaging method and get 98.25% classification rates on 5th day. Önler et al.[13] used ultrasound based imaging technique and get 86% success rates.

We can see screening method and enlightening have a significant effect on success rates of fertilization control. However, many of those methods are expensive and do not contain easy-to-use systems. Our research offered a cheap and easy-to-use approximation. Therefore, our research aimed to determine the fertilization control of eggs between zero and fifth days in the egg incubator by using derivable and low priced tools with the help of the image processing techniques.

MATERIAL and METHODS

The system is composed of three main elements. The first of them is the incubator system; the second of them is the screening system and the third one is the computer software that provides to be processed the images obtained. Since the goal of the study was to actualize the eggs fertilization control by the cheap and derivable methods, the materials to be used was selected in accordance with the method. A professional household type incubator with 48 egg capacity was used in the system actualized. 10 Watt 24 Volt 350mA Power LED lightened the egg incubator. A mechanism was designed in which an egg can be put on in and the lightning remains in the lower part. Color camera with 16 mm lens at 2048x1536 pixels resolution recorded the images. Moreover, for constituting a dark environment, there was designed a box with a hole for the camera to monitor inside. Box designing is absolutely optional for the dark environment. It is enough to take the pictures in a dark environment even if a box is not available. The first two stages of the system designed are shown in *Fig. 1*.

The images of the eggs put in the incubator were recorded by putting in the imaging system at the appointed times. Those images recorded were transferred into computer-aided fertilization control software. The control success of the software is based on operating these two systems successfully. As the accuracy and noiselessness of the images increase, the possibility of obtaining a result with an easy algorithm increases at the same time. Afterward, the development in the environment with 37.8°C temperature and 50-55% humidity was let for 18 days; the eggs were transferred into the exit machines with 37.5°C temperature, 65-70% relative humidity. The assembly process was automatically actualized so as to be once every h. The incubation machine was settled within the boundaries that are determined by Kamanlı and Durmuş [3]. Since 10W Power LED dissipated a great deal heat, egg shooting time was taken short (1 s) to avoid eggs from the heat. Moreover, the boxes that were designed for a dark environment was used so as not to affect the backgrounds of the images.

There is computer-aided fertilization control software in the third stage. *Fig. 2* shows the block diagram of the software created.

The first stage in computer-aided fertilization control software is to take pictures. The images are transferred into the software after the imaging process is actualized. Those pictures are turned into a binary image by a

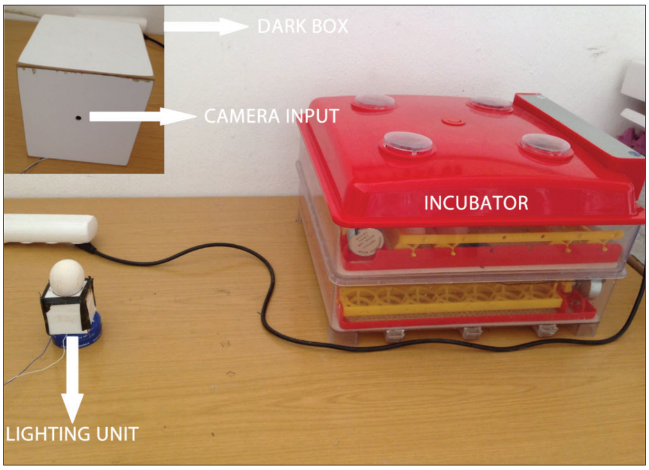

Fig 1. Designed system

specific threshold value to specify the boundaries of the eggs. Since the different eggs have a different color, size and blood vessels in the embryo and also these values change in different days; the attributes of the image was considered to determine the threshold value. In other words, the threshold values of the images each of the eggs in different days are distinct. This transaction is named as dynamic thresholding in the literature [1]. The errors that emerge by a constant threshold value will be avoided by the dynamic thresholding. The noise images arising from the enlightening may occur after the thresholding. Dilation and erosion methods from the morphological processes were used to eliminate the noise. *Fig. 3* shows the turning process of the image of the camera to the binary image by applying dynamic thresholding.

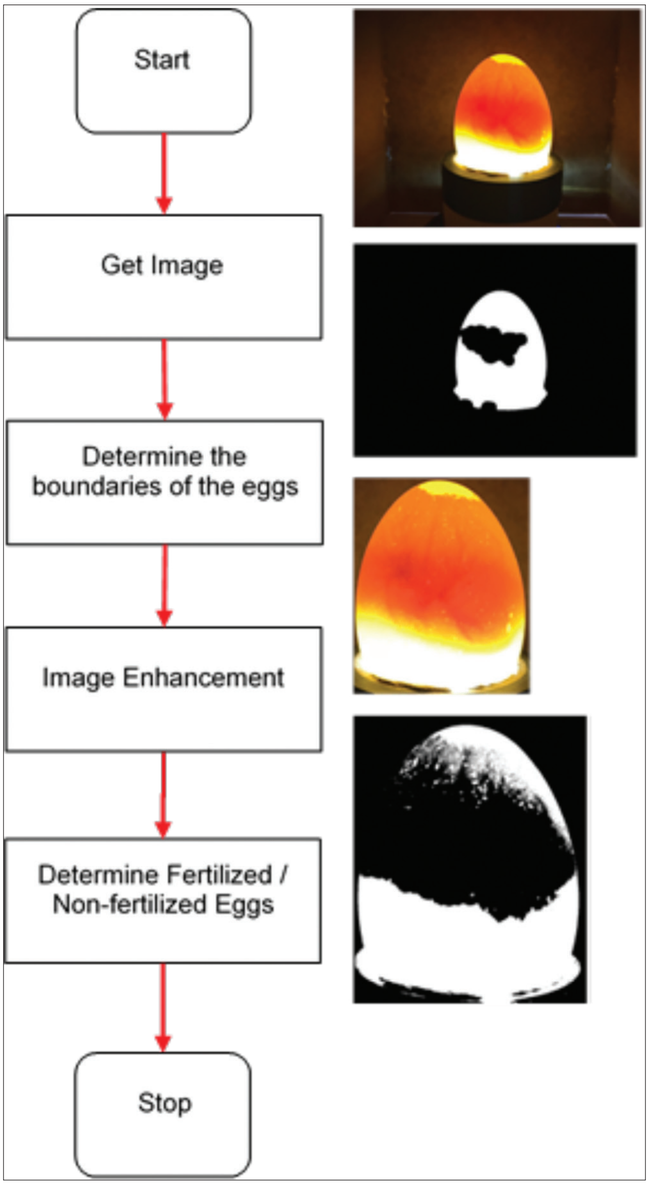

Fig 2. Flow diagram of the software designed

In the next step, the boundaries of the egg were determined by applying dynamic thresholding and morphological processes. The boundaries of the white area in the binary image were determined (top-left/right, bottom-left/right). The boundaries of the eggs were determined by taking the values of the points. The egg image was separated from the background at the end of this process.

There is a need for applying image enhancement methods to actualize the fertilization control on the egg image separated from the background. This circumstance may occur because of the camera, shooting method or the person that takes the picture. Median filter (5x5) was used in our research to enhance the egg images and also purify the images from the probable noises.

The area of the embryo was computed for the fertilization control after the filtering application. As is mentioned in literature, this area shows an alteration from starting the zero day to 21st day. This change was observed in the images obtained. It is enough to use proper incubation, lightning, and imaging for this observation. Our research used the images obtained by actualizing the conditions. *Fig. 4-a* shows the change of fertilized eggs between zero and fourth days; *Fig 4-b* shows the change of unfertilized eggs between zero and fourth days.

As is seen in *Fig. 4-a,b*, the embryo that develops in fertilized eggs grows in the egg and its area increases at the same time. This condition for the fertilized eggs is consistent when all the images are analyzed. Since an embryo development does not form in the unfertilized eggs, any area increase cannot be seen as well. However, some eggs spoil in incubation environment over time, the yellow area in them becomes darker. This situation may reveal the errors in the test results. Starting from this point, the binary images that can be obtained by a threshold

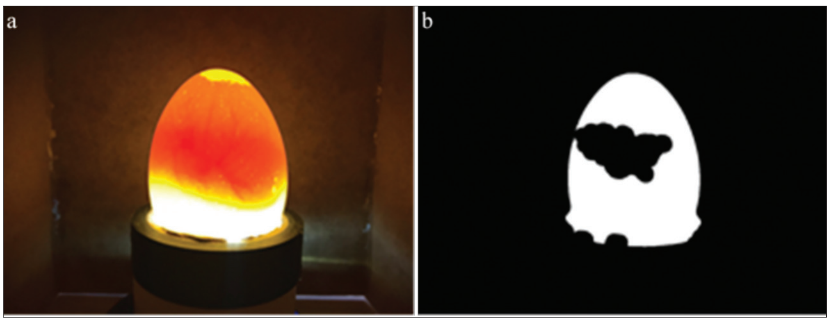

Fig 3. Obtaining binary image by dynamic thresholding **a)** raw image **b)** binary image

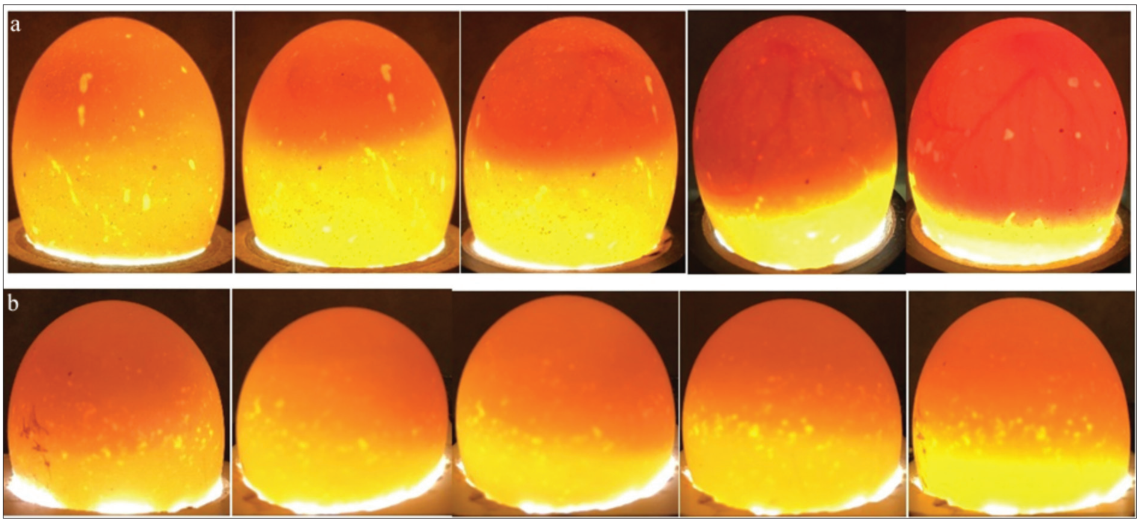

Fig 4. Changes of an eggs **a)** change of a fertilized egg between 0 and 4 days, **b)** change of an unfertilized egg between 0 and 4 days

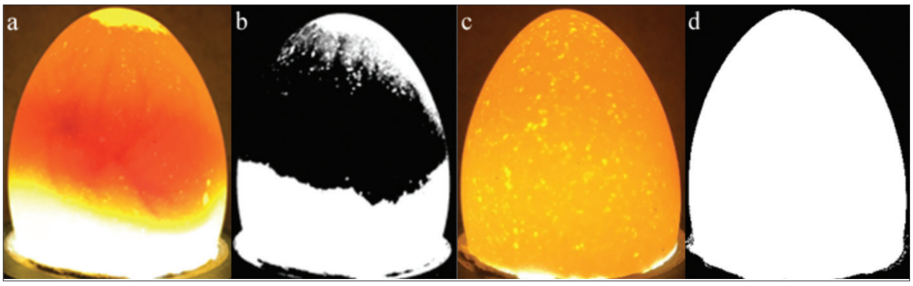

Fig 5. Fertilized and unfertilized eggs' binary images obtained by the dynamic threshold **a)** the Third day fertilized egg, **b)** Binary image of A **c)** the Third-day unfertilized egg, **d)** Binary image of C

value (dynamic threshold) was applied to the enhanced egg pictures in the fertilization control. It is observed at the end of this process that the white areas of fertilized eggs are narrowest; the white areas of unfertilized eggs are large. Furthermore, it is seen when the change between the images taken between zero and fourth days are reviewed that the fertilization control can be easily actualized. *Fig. 5* shows the image of the picture by the dynamic thresholding by separating from the noises.

Matlab R2014a version was used at the stage of actualizing image processing software. Image processing codes peculiar to the egg fertilization control problem were utilized besides the standard function of Matlab.

Dataset Preparation: Our research used three different datasets that were composed of eggs whose pictures were taken at different times. There were 45 eggs so as to be 15 eggs in each of the datasets that were decided by the qualified personnel. The eggs whose effects (broken, cracked, porous, etc.) are less for affecting the fertility were selected. Fifteen Light brown shelled eggs (10 fertilized, 5 unfertilized) from ATAK-S race were used in the first dataset. Again, 15 Light brown shelled eggs (10 fertilized, 5 unfertilized) from ATAK-S race were used in the second dataset. Fifteen Light brown shelled eggs (14 fertilized, 1 unfertilized) from ATAK-S race were used in the third dataset. When the quality characteristics of ATAK-S eggs are examined, it is seen that egg weight is 65.21 g, shape index is 75.59%, shell thickness is 0.33 mm and shell weight is 7 g [14]. The images of the eggs were recorded so as to be taken an image in every 24 h from the moment (zero hour, zero day) that is placed in incubation to 120th h. The recorded images are in JPEG format. Entirely, 75x3=225 images (15x5=75 for each of the dataset) were recorded. The eggs were kept in incubation for 21 days to be completed during the incubation process. The eggs which did not incubate at the end of the 21st day were analyzed by the expert and it is pointed out that there was not a problem about the fertilization control; the problem resulted from the incubator and environmental conditions.

When the materials and methods used in this study are listed, a professional household type incubator with 48 egg capacity, 10 Watt 24 Volt 350mA Power LED, Color camera with 16 mm lens at 2048x1536 pixels resolution, ATAK-S race eggs and dynamic thresholding method with Matlab R2014a Image Processing ToolBox.

RESULTS

The images of 15 eggs (10 fertilized, 5 unfertilized) between zero and fourth days were given as an entrance to the system designed. The images in software separated from the background by processing; the percentage ratio of white and black areas was found in the egg image. The higher the white pixel rate, the less the fertility rate. In the same way, the less the white pixel rate, the greater the fertility rate. *Table 1* shows the white pixel ratios of 15 eggs between zero and fourth days.

As is seen them of pixel changes values, the eggs which do not change throughout the period (0-4 days) or change at a low ratio are unfertilized ones. The eggs whose value at the end of the period is far lower than the value at the start of the period are fertilized ones. For example, egg 13; initial value: 80, end value: 14, result: egg 13 fertile. Egg 3; initial value: 79, end value: 73, result: egg 3 infertile.

Sum difference between two days was considered to evaluate these ratios (the difference between zero and first day; the difference between zero and second, the difference between zero and third day, the difference between zero and fourth day). *Table 2* shows the values.

As is seen in *Table 2*, if the difference of white pixel ratios of the eggs changes in an instant at a high rate, the egg is likely to be fertilized. This change ratio is accepted as 2% for 0-1; 4% for 0-2; 8% for 0-3; 20% for 0-4. This change does not exceed 20% between 0 and 4 days, the result is selected as unfertilized. The information on the growth ratio of the chick in the egg was used. The success rates obtained according to this data are given under each column.

The success rate at the end of the first day was 53.34%; 66.67% for the end of the second day; 73.34% for at the end of the third day; 100% for the end of the fourth day. As is seen in *Table 3*, the effect of the white pixel ratio change to the fertility value is quite a little between zero and the first day. This is because using data of 1st and 5th day's leads to the correct conclusion rather using the data belong to zero and fifth days.

The images of 15 eggs (10 fertilized, 5 unfertilized) between the first and fifth days were given as an entrance to the system designed. The *Table 3* shows the white pixel ratios of 15 eggs between first and fifth days.

As is seen them of pixel changes values, the eggs which do not change throughout the period (1-5 days) or change at a low ratio are unfertilized ones. The eggs whose value at the end of the period is far lower than the value at the start of the period are fertilized ones. For example, egg 28; initial value: 75, end value: 22, result: egg 28 fertile. Egg 24; initial value: 72, end value: 66, result: egg 24 infertile.

Sum difference between two days was considered to evaluate these ratios (the difference between the first and the second day; the difference between the first and the third day, the difference between the first and the fourth day, the difference between the first and the fifth day). *Table 4* shows the values.

As is seen in *Table 4*, if the difference of white pixel ratios of the eggs changes in an instant at a high rate, the egg is likely to be fertilized. This change ratio is accepted as 4% for 1-2; 8% for 1-3; 20% for 1-4; 30% for 1-5. If this change does not exceed 20% between zero and fourth days, or the change takes a negative value, the result is selected as unfertilized. The information on the growth ratio of the chick in the egg was used

The success rate for the second dataset was 73.34% at the end of the second day; 93.34% at the end of the third day; 93.34% at the end of the fourth day; 93.34% at the end of the fifth day.

The images of 15 eggs (14 fertilized, 1 unfertilized) between the first and fifth days were given as an entrance to the system designed in the third dataset. *Table 5* shows the

Table 1. *Number of white pixel ratio for dataset 1 for 0th and 4th days (%)*

Egg Number	Day					Expert Assessment
	0th day	1st day	2nd day	3rd day	4th day	
1	70.05218	74.7298	74.19153	65.37102	17.75795	Fertile
2	73.0347	72.62266	71.44976	35.76302	25.62944	Fertile
3	79.73458	78.43909	75.59067	69.04541	73.83005	Infertile
4	72.60527	71.53416	58.64252	37.23622	29.57277	Fertile
5	70.90953	65.08063	70.98815	53.69586	51.42568	Infertile
6	75.98155	70.81526	63.63636	30.83919	29.09275	Fertile
7	73.25327	70.70671	61.06334	42.71911	28.00998	Fertile
8	74.77697	72.29558	60.86581	38.3648	23.08489	Fertile
9	77.3723	70.24388	78.0647	64.69531	60.64912	Infertile
10	80.20004	74.46872	79.76624	60.4134	60.7817	Infertile
11	68.97427	66.83322	54.21348	33.66571	32.0993	Fertile
12	79.0481	75.03264	75.27244	58.69613	59.58343	Infertile
13	80.02702	67.60631	56.60874	28.253	14.84707	Fertile
14	60.56951	58.25204	58.78945	46.65361	30.3672	Fertile
15	71.86004	65.10965	64.02399	48.62033	34.39325	Fertile

Table 2. *White area changing table between the days (%)*

Egg Number	Differences by Days				Software Assessment	Expert Assessment
	0-1 Difference ≥2% (fertile)	0-2 Difference ≥4% (fertile)	0-3 Difference ≥8% (fertile)	0-4 Difference ≥20% (fertile)		
1	-4.67	-4.13	4.68	52.29	Fertile	Fertile
2	0.41	1.58	37.27	47.40	Fertile	Fertile
3	1.29	4.14	10.68	5.90	Infertile	Infertile
4	1.07	13.96	35.36	43.03	Fertile	Fertile
5	5.82	-0.07	17.21	19.48	Infertile	Infertile
6	5.16	12.34	45.14	46.88	Fertile	Fertile
7	2.54	12.18	30.53	45.24	Fertile	Fertile
8	2.48	13.91	36.41	51.69	Fertile	Fertile
9	7.12	-0.69	12.67	16.72	Infertile	Infertile
10	5.73	0.43	19.78	19.41	Infertile	Infertile
11	2.14	14.76	35.30	36.87	Fertile	Fertile
12	4.01	3.77	20.35	19.46	Infertile	Infertile
13	12.42	23.41	51.77	65.17	Fertile	Fertile
14	2.31	1.78	13.91	30.20	Fertile	Fertile
15	6.75	7.83	23.23	37.46	Fertile	Fertile
Success rate	53.34%	66.67%	73.34%	100%		

Table 3. *Number of white pixel ratio for dataset 2 for 1st and 5th days (%)*

Egg Number	Day					Expert Assessment
	1st day	2nd day	3rd day	4th day	5th day	
16	62.89813	71.27311	78.88054	76.23356	77.21532	Infertile
17	62.48269	51.5847	30.56968	19.40743	14.91582	Fertile
18	56.85506	52.23822	34.70326	50.5552	42.58216	Fertile
19	54.96044	49.9108	36.8949	25.05271	15.01342	Fertile
20	72.31574	82.1813	78.18832	68.6549	63.36109	Infertile
21	63.21411	56.53763	40.92532	19.11876	11.55453	Fertile
22	59.17022	52.65631	39.00066	22.67896	11.30802	Fertile
23	55.64947	43.04546	33.24711	18.53764	11.29753	Fertile
24	72.22282	51.68187	62.22455	67.82684	66.80628	Infertile
25	57.04524	61.20489	39.50373	29.52043	26.61711	Fertile
26	49.0064	40.1006	28.68986	17.23708	10.34289	Fertile
27	48.58799	45.78101	27.86972	17.70482	22.59436	Fertile
28	75.29982	62.32376	40.22897	19.06477	19.06477	Fertile
29	41.12498	53.78965	47.32667	52.08565	50.06751	Infertile
30	43.65557	55.23351	47.89443	46.40716	43.31085	Infertile

white pixel ratios of 15 eggs between first and fifth days.

As is seen them of pixel changes values, the eggs which do not change throughout the period (1-5 days) or change at a low ratio are unfertilized ones. The eggs whose value at the end of the period is far lower than the value at the start of the period are fertilized ones. For example, egg 36; initial value: 76, end value: 14, result: egg 36 fertile. Egg 32; initial value: 71, end value: 75, result: egg 32 infertile.

Sum difference between two days was considered to evaluate these ratios (the difference between the first and the second day; the difference between the first and the third day, the difference between the first and the fourth day, the difference between the first and the fifth day). *Table 6* shows the values.

As is seen *Table 6*, the success rate for the third dataset was 60% at the end of the second day; 86.67% at the end of the third day; 93.34% at the end of the fourth day; 100% at the end of the fifth day.

DISCUSSION

In this paper, there was performed a situation assessment as fertilized/unfertilized of the eggs by making an image-

Table 4. *White area changing table between the days (%)*

Egg Number	Differences by Days				Software Assessment	Expert Assessment
	1-2 Difference ≥4% (fertile)	1-3 Difference ≥8% (fertile)	1-4 Difference ≥20% (fertile)	1-5 Difference ≥30% (fertile)		
16	-8.37	-15.98	-13.34	-14.32	Infertile	Infertile
17	10.90	31.91	43.08	47.57	Fertile	Fertile
18	4.62	22.15	6.30	14.27	Infertile	Fertile
19	5.05	18.07	29.91	39.95	Fertile	Fertile
20	-9.87	-5.87	3.66	8.95	Infertile	Infertile
21	6.68	22.29	44.10	51.66	Fertile	Fertile
22	6.51	20.17	36.49	47.86	Fertile	Fertile
23	12.60	22.40	37.11	44.35	Fertile	Fertile
24	20.54	10.00	4.40	5.42	Infertile	Infertile
25	-4.16	17.54	27.52	30.43	Fertile	Fertile
26	8.91	20.32	31.77	38.66	Fertile	Fertile
27	2.81	20.72	30.88	35.99	Fertile	Fertile
28	12.98	35.07	56.24	56.24	Fertile	Fertile
29	-12.66	-6.20	-10.96	-8.94	Infertile	Infertile
30	-11.58	-4.24	-2.75	0.34	Infertile	Infertile
Success rate	73.34%	93.34%	93.34%	93.34%		

Table 5. *Number of white pixel ratio for dataset 2 for 1st and 5th days (%)*

Egg Number	Day					Expert Assessment
	1st day	2nd day	3rd day	4th day	5th day	
31	61.48384	65.76606	54.1254	29.72434	30.62046	Fertile
32	71.24564	68.02674	70.05505	75.39222	75.40167	Infertile
33	62.16644	65.04775	56.84631	32.06525	29.84828	Fertile
34	73.97004	55.07065	52.86121	41.95793	36.86408	Fertile
35	49.74073	46.3681	40.28495	20.06469	10.3954	Fertile
36	76.629	66.53882	52.30564	17.72862	14.06614	Fertile
37	64.16081	47.61415	40.44904	26.43988	19.40788	Fertile
38	67.84067	62.05111	39.7178	30.64041	22.47425	Fertile
39	74.53868	64.07787	48.70116	21.99707	20.60232	Fertile
40	56.10094	49.67823	33.35632	28.53916	19.93295	Fertile
41	71.26095	57.1348	45.10106	36.09442	31.20518	Fertile
42	75.32446	73.28786	67.29159	47.35383	38.64619	Fertile
43	65.79996	54.47365	56.1797	41.19385	32.47017	Fertile
44	75.30359	71.54523	48.6836	26.07057	20.89791	Fertile
45	58.17535	57.69725	48.3054	40.76475	20.89839	Fertile

based analysis between the zero and the fifth days. Pictures of the eggs were taken on a daily basis by using a power led camera. The fertility status was controlled by the image processing software. There was guessed right at 100% at the end of the study conducted on three datasets that were composed of 15 eggs.

Outer shell boundaries of the eggs were determined first. After, the region of interest (ROI) was separated from the image obtained by various filtering and morphological processes. The color-gray level conversion was actualized and the black-white image was received by using an adaptive thresholding method. The white pixels in the black-white image were counted; the number was proportioned to the whole of the egg. The dark areas which are marked as white are the areas that are constituted by the chick which grows in the egg.

Daily changes of the percentage values were computed by taking the arithmetic difference. These proportional differences were compared with the threshold values determined (≥2% between zero and first day, ≥4% for the zero and second day, ≥8% for the zero and the third day, ≥20% for the zero and the fourth; ≥30% for zero and fifth). The results with fertilized and unfertilized were obtained. Experts' information on the growth rate of the chick in the egg was effective in determining these threshold values.

Table 6. *White area changing table between the days (%)*

Egg Number	Differences by Days				Software Assessment	Expert Assessment
	1-2 Difference ≥4% (fertile)	1-3 Difference ≥8% (fertile)	1-4 Difference ≥20% (fertile)	1-5 Difference ≥30% (fertile)		
31	-4.28	7.36	31.76	30.86	Fertile	Fertile
32	3.22	1.19	-4.15	-4.16	Infertile	Infertile
33	-2.88	5.32	30.10	32.32	Fertile	Fertile
34	18.90	21.11	32.01	37.11	Fertile	Fertile
35	3.37	9.46	29.68	39.35	Fertile	Fertile
36	10.09	24.32	58.90	62.56	Fertile	Fertile
37	16.55	23.71	37.72	44.75	Fertile	Fertile
38	5.79	28.12	37.20	45.37	Fertile	Fertile
39	10.46	25.84	52.54	53.94	Fertile	Fertile
40	6.42	22.74	27.56	36.17	Fertile	Fertile
41	14.13	26.16	35.17	40.06	Fertile	Fertile
42	2.04	8.03	27.97	36.68	Fertile	Fertile
43	11.33	9.62	24.61	33.33	Fertile	Fertile
44	3.76	26.62	49.23	54.41	Fertile	Fertile
45	0.48	9.87	17.41	37.28	Fertile	Fertile
Success rate	60%	86.67%	93.34%	100%		

With reference to the experimental results, the fertilization was found as 73.34% for third day and 100% for the fourth day in the first dataset; as 93.34% for the third day and 93.34% for the fourth day in the second dataset; 93.34% for the third day and 100% for the fourth day in the third day in the third dataset. Taking the pictures via nonprofessional apparatus is one of the significant reasons that negatively affect the success. Success rate can be increased by improving the imaging mechanism. Moreover, the circumstances like shell color, shell thickness affect the success of the system because of the types of eggs. It is thought that there can occur success difference in different egg types.

When we compare the proposed method with the previous works, it can be seen that many of the previous works achieved 100% success rates [4,7,8,10] in determination of the fertilization of the eggs. However, many of those methods are expensive (halogen lighting and NIR sensing system, Near-Infrared Hyperspectral Imaging system and visible transmission spectroscopy screening technique) and do not contain easy-to-use systems. Our research also achieved 100% success rate and offered a cheap (LED illumination), easy-to-use and derivable method to ideally perform the fertilization control of the eggs.

The success of the system can be tested by controlling fertilization status of the eggs in different characteristics (white-brown-dirty-crack etc.) in the next part of the research.

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