Required Force for Penetrate the Duck Eggshell to Protect at Handling and Hatching

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ABSTRACT

The research aims to study the force required to break the shell of duck eggs, which helps to provide the conditions for the process of hatching eggs and circulation. The physical and mechanical properties had been measured. The most important results were as follows: The arithmetic mean of the length and the longest diameter 56.19, 42.94 mm, the coefficient of shape, surface area and volume were 0.77, 18.0711 mm2 2, 16.0 mm3, the thickness of the eggshell from the middle, top and bottom 0.23 mm, 0.23 mm 2, 0.21 mm, the minimum and maximum force required to break the egg and the occurrence of hatching, at top, middle, and bottom (0.05, 32.24 N), (0.11, 25.67 N), (0.05, 32.70 N), the standard deviation was 7.53, 6.52, and 8.02, respectively, the mean was 14.91, 12.23, and 14.73 N, respectively. The minimum and maximum distance that the surface advances was 0.015, and 9.0 mm to the center, and 13.8 mm to the bottom of the egg shell. The results of the ANOVA analysis showed that there were significant differences in the value of the compressive force depending on the area of breaking the egg. The least of them was in the middle, the area of fracture (collapse) when the egg hatched. It is preferable to use the largest pressure force (32.7 N) to break the egg to ensure the highest hatching rate inside the hatchery.

Keywords: Duck eggs, physical, mechanical, break.

INTRODUCTION

De Ketelaere et al. (2002) conducted research on the effects of several egg physical characteristics, including egg mass and volume, surface area, shell thickness, and mass, on the mechanical qualities of eggs. A popular method for determining the strength of an egg's shell is to compress it quasi-statically between two parallel steel plates.

Kemps et al. (2003) developed a different approach for determining the elastic modulus of eggshells is obtained by observing the laser vibrometer's vibration response to a clamped rectangular piece of eggshell. These authors' nondestructive loading approach has the benefit of enabling reproducible measurements to be taken on the same test specimen. However, it does not mention how resistant to breakage the eggshell is (fracture toughness).

Bain (2005) insisted on our understanding of eggshell architecture has been substantially improved by ultrastructural investigation of eggshells, which has also strengthened the idea that eggshell mechanical qualities cannot be determined by a straightforward thickness measurement. Rodriguez et al. (2002) implied that enhancement in eggshell quality would benefit the industry economically. Strength and colour of the shell are two factors that greatly influence how good an eggshell is. Eggs' mechanical characteristics are influenced by geometric factors including the shell's form and thickness as well as the material's basic characteristics. The shell's chemical composition and microstructure, both of which change as the shell strength increases, determine the material properties of the shell. Given that Ruiz and Lunam (2000) noted a direct correlation between shell thickness and strength, it stands to reason that altering the palisade layer's thickness without changing the structural arrangement of the palisade columns could have an impact on shell strength.

In his study of the impact of drinking water calcium levels on the integrity of laying hens' shells, Coetzee (2002) showed that birds given an additional 200 mg of calcium per litre of water produced eggs with a mean shell strength of 42.6 N as opposed to those receiving unsupplemented water, whose eggs had a mean shell strength of 38.9 N.

According to USDA (2000) and FAO (2003), a number of factors affect an egg's size. Heat, stress, congestion, and inadequate nutrition are among causes that are dependent on the bird itself, while others are environmental, such as reduced egg masses. The egg producer places a high value on
each of these factors. Egg size categorization, are divided into
groups based on the minimum net mass. Jumbo (above 70 g),
extra-large (65-70 g), giant (56-65 g), medium (49-56 g), small
(42-49 g), and peewee are the different egg sizes (35-42 g).
The most prevalent sizes are medium, big, and extra-large.

The influence of egg form on the mechanical behavior of
eggs under a compression stress was examined by Altuntas
and Sekeroglu in 2008. The physical characteristics and
mechanical behavior of eggs as they relate to egg mass are
not well understood on a technical level in the scientific
community.

Kul and Seker(2004) abstracted that it has been aimed
to determine the internal and external quality traits of the quail
eggs as well as the phenotypic correlation between these
traits. As a result, it has been considered that it was possible
to use the egg mass in determining the eggshell mass, shell
thickness and the shell ratio instead of using these traits that
are the determinants of the eggshell quality of the quail eggs.

The mechanical characteristics of the rupture force,
specific deformation, rupture energy, and hardness were
looked at by Altuntas and Ekerolu (2008).

Thus according Lin et al. (2009), an acoustic
resonance-based system was created to detect eggshell cracks.
It was done by analyzing the frequency response of eggshell
that had been activated using a light method. Three pattern
recognition algorithms—K-nearest neighbours, artificial
neural network, and support vector machine—were looked at
in order to create a reliable classification model. The
outcomes demonstrated that, in comparison to k-nearest
neighbours and artificial neural network models, the vector
machine model is the most effective. With recognition rates
of 95.1% in the calibration set and 97.1% in the prediction set,
the best support vector model was discovered.

Berrueta et al. (2007), attention was on the
optimization of the acoustic system's parameters and on an
analysis of the response signals' characteristic frequencies.
The term "supervised pattern recognition" refers to methods
where the category membership of samples used for
classification is known in advance.

For the purpose of determining egg freshness, Dutta
et al. (2003) developed an electronic nose (EN) system with
four tin-oxide aroma sensors. They claimed that, depending
on freshness, they could accurately divide the eggs into three
groups with a 95% accuracy.

According to Casasent and Chen (2003), spectrum
data can provide useful chemical, moisture, and other
descriptions of an item's constituent parts, making visible/Near-infrared spectroscopy (VIS/NIRS) one of the
most effective methods for quantitative and qualitative
examination of foods.

Kemps et al. (2007) noticed that the egg business is
experiencing difficulties due to intensive manufacturing with
less workers. The amount of laying has increased, and their
diets have improved. These elements have caused egg output
to rise at a reduced price. However, this business needs
accurate and trustworthy information about the egg in order
to grade it exactly and to offer consumers quality that
complies with their standards for egg quality.

According to Kemps et al. (2007), the egg industry is
having trouble because of labor-intensive manufacturing.
Laying populations have grown, and their diets have
improved. These factors have led to an increase in egg
production at a lower cost. However, in order to grade the egg
precisely and provide customers with quality that meets their
expectations for egg quality, this company needs reliable and
accurate information about the egg.

The influence of egg form on the mechanical behavior of
eggs under a compression stress was examined by Altuntas
and Sekeroglu in 2008. The physical characteristics and
mechanical behavior of eggs as they relate to egg mass are,
however, not well understood on a technical level in the
scientific community. Measures like rupture force, specific
deformation, and rupture energy can be used to describe the
physical characteristics of eggs as well as their resistance
to damage from mechanical shock.

According to Kirmizibayrak and Altinel (2001), the
egg size, egg mass, and shape index all have a significant
impact on the total hatchability. The mass of an egg is one of
the straightforward ways to gauge its physical features.

According to Anderson et al. (2004), the proportion of
damaged eggs that are handled and transported has an
impact on the egg shape index and shell thickness.

Our study had two main objectives. First, the test of
hardness of duck shell to select suitable environment through
hatching process and handling process by measuring required
force to broke eggshell. The second one was to data analysis
to improve eggshell quality goring handling process.

**MATERIALS AND METHODS**

In this work, 150 eggs with intact shells were collected
from a farm within 2 days after laying. All egg sizes were used
for the experiment.

**The physical measurements**

The physical measurements had been measured as
external measurements of eggs.

Dimensions of egg samples were measured by caliper
with accuracy of 0.01 mm.

External measurements of eggs were length, diameter,
large end, and small end, and also, shell mass, and shell
thickness wear measured.

Mass of samples was measured by sensitive digital
scale with accuracy of two decimal digits of gm.

**Egg volume measurement (V):** The volume of the duck egg
is measured by measuring the volume of the displaced water
using the graduated cylinder.

**Egg surface area measurement (S)**

Egg surface area was calculated from the equation (1)

\[
S = -7004.39 + 82.97 L + 216.05 W
\]

Where: (S): Egg surface area mm\(^2\), (L): Egg length in mm, (D): Egg
maximum diameter in mm, and (7004.39), (82.97) and
(216.05) are constants.

**Egg shape index measurement**

Shape Index (Sha-I) is estimated using the following
equation (2), according to Anderson et. al (2004).

**Shape Index = [Egg maximum diameter “D”/ Egg length
"L"] × 100.**

**Experimental system**

The impacting point was placed randomly in the intact
eggshell, for each egg, in three positions (top, mid and
bottom) breaking force and eggshell thickness were
measured. Duck eggshells and diagram of breaking test setup
of samples was used, it was illustrated in Figure (1).

Bench top testing setup (Figure 1d, 1e) (Tinus Olsen-
model HSks-USA) using to determine the mechanical
properties of the egg such as stress-strain behavior and egg firmness. The device has three main components, which are stable up and stationary bottom of the platform, a driving unit (AC electric motor and electronic variator) and the data acquisition (dynamometer, amplifier and display recorder) system. Technical specifications for bench top testing setup according to manufacturer catalogue are shown in Table (1).

<table>
<thead>
<tr>
<th>Model (hS5k)</th>
<th>Unit</th>
<th>Capacity</th>
<th>kg</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum sample diameter</td>
<td>mm</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum crosshead travel</td>
<td>mm</td>
<td>750</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Testing speed range</td>
<td>mm/min</td>
<td>0.001 to 500 up to 5kN</td>
<td></td>
</tr>
</tbody>
</table>

Eggs were placed horizontally between two flat parallel steel plates and compressed at a speed of 1.0 mm/min. The accuracy of the force sensor was ±0.001 N. A maximum force of 10 N was exerted. The setup was used single side penetration shaft in eggshell with height 9 mm and diameter 6.36 mm, while the penetration shaft with cone height and diameter were used of 9.95 and 3.69 mm, respectively. The measurement was repeated on three equidistant places at the equator of the egg. The average value of the three measurements was used in the statistical analysis.

**Table 1. Technical specifications for bench top testing setup.**

**Statistical analysis**

Descriptive analysis method had been used to describe and summarize the basic characteristics of the data to estimate how the data is distributed and develop some relationships between the variables {break force and Extension (pending distance of duck eggshell)} and know the values in which the data is concentrated.

Using ANOVA (analysis of variance) in one way to study the presence of significant differences between the average distance of the weapon advance to the sample in the first three cases are at top, middle and bottom of the egg - at the level of significance 5%.

**RESULTS AND DISCUSSION**

**Physical properties of Duck eggshell:**

Figures (2, 3 and 4) show that the frequency percentage distribution of physical properties of duck and eggshell, which important to specify quality of duck eggs and very important during handling process and hatching eggs during incubation process. Figure (2) shows the curves of the middle and top thickness distribution of the duck eggshell are the same, but it is not necessary the same value on the same egg.

The data presented in Table (2) indicate the results analysis of some physical properties measured for duck eggs, which were collected through 9 separate samples, and it was found that for the characteristics of the egg length and the maximum egg diameter, its minimum reached 53.36, 41.41 mm and the maximum 61.62, 44.25 mm and the values of the standard were 2.768, 0.963 mm for both the length attribute and the maximum egg diameter respectively, which indicates that there is no dispersion in the data and that most of the data falls around its arithmetic mean of 56.19 and 42.94 mm, respectively. Also, it was found that the minimum value of the adjective value is the longest distance from the diameter to the bottom which amounted to 17.59 mm, while the maximum reached 31.96 mm, and the values of standard deviation was 5.482. Relatively large value shows the existence of figures after anomalies of this character far removed from the middle of arithmetical 24.17 mm.

The data presented in Table (2) indicate the results of the analysis of some of the calculated physical properties of duck eggs, which were collected through 9 separate samples, and with regard to the shape index, surface area, and volume of the egg, it was found that the minimum limit for it was 0.71, 16714.662 mm², and 44 mm³ respectively, while the
maximum reached 0.79, 20408.00 mm², and 60.0 mm³ on the tip, and the standard deviation values were 0.030, 1335.763, and 4.690 respectively, and it indicates that the data is not widely dispersed in the data of this attribute and its occurrence around its arithmetic mean, 077, 18071.11 mm² and 16.0 mm³, respectively.

With regard to the characteristics of the duck egg shell, which was tested, the results shown in Table (2) also indicated that for the egg shell thickness attribute in the middle, top and bottom of the egg, it was found that their minimum value was of 0.10, 0.10, and 0.10 mm, while the maximum value reached to 0.30, 0.30, 0.30 mm respectively, and the standard deviation values were 0.061, 0.061, 0.058 respectively, and it indicates that the data is not dispersed and its presence is around its mean of 0.23, 0.23, and 0.21 mm, respectively, for these characteristics.

Relationship between break force and Extension (pending distance of duck eggshell) in different position of egg

The results shown in figure (2) indicate to the relationship step of progress blade towards egg and required break force in top, mid and low positions of egg.

From the results in figure (2), the large step progress towards the egg was during the press towards in bottom position of egg, which was ranged between 0.02 to 13.80 mm, with average 6.90 mm, this extension resulted in the largest required break force in towards bottom position of egg, which was ranged between 0.05 to 32.70 with average 14.73 mm. Meanwhile, the lowest step progress towards the egg was during the press towards in middle position of egg, which was ranged between 0.02 to 9.0 mm, with average 4.50 mm, this extension resulted in the lowest required break force in towards in middle position of egg, which was ranged between 0.11 to 25.76 with average 12.23. But, the values of step progress towards the egg during the press towards in top position of egg were intermediate the step progress values of towards bottom and middle of egg, which was ranged between 0.02 to 12.80 mm, with average 6.40 mm, this extension resulted in the required break force in towards in top position of egg, that also, intermediate the break force values of towards bottom and middle positions of egg, which was ranged between 0.05 to 32.24 with average 14.91 N. That is mean; it shall be to design the incubator of duck eggs incubation under environment conditions of temperature degree and relative humidity, which allow by the pressing on egg by high break force (32.70), which was towards bottom position of egg. The average change of break force over time is depicted in Figure (5).
Relation between the break force and extension on the top of duck eggshell

Table (3) shows all break forces which were affected on tops of duck eggshell samples, it showed significant differences in terms of break forces, with extension tops of duck eggshell having the minimum value 0.05 N at extension distance of 0.02 mm and the maximum value 32.24 N at extension distance of 12.80 mm, therefore the average value 14.91 N at extension distance of 6.40 mm. According the previous data, the data analysis showed that the standard deviation of break force on top duck eggshell was 7.53 at 3.70 of extension distance, and the variation of break force on top duck eggshell was 57.64 at 13.69 of extension distance, the standard error of break force on top duck eggshell was 0.26 at 0.1266 of extension distance, coefficient of variance of break force on top duck eggshell was 1.74 at 0.9791 of extension distance. Nine samples of duck eggs have been tested and numbered from N1 to N9.

Relation between the break force and extension on the middle of duck eggshell:

Table (4) shows all break forces which were affected on middles of duck eggshell samples, it showed significant differences in terms of break forces, with middles of duck eggshell having the minimum value 0.11 N at extension distance of 0.01 mm and the maximum value 25.76 N at extension distance of 9.0 mm, therefore the average value 12.23 N at extension distance of 4.50 mm. According the this result, the data analysis showed that the standard deviation of break force on middle duck eggshell was 6.52 at 2.60 of extension distance, and the variation of break force on middle duck eggshell was 46.88 at 6.784 of extension distance, the standard error of break force on middle duck eggshell was 0.27 at 0.1062 of extension distance, coefficient of variance of break force on middle duck eggshell was 2.17 at 2.3609 of extension distance. Twelve samples of duck eggs have been tested and numbered from N1 to N12.
Relation between the break force and extension on the bottom of duck eggshell:

Table (5) shows all break forces which were affected on bottoms of duck eggshell samples, it showed significant differences in terms of break forces, with bottoms of duck eggshell having the minimum value 0.05 N at extension distance of 0.02 mm and the maximum value 32.70 N at extension distance of 13.80 mm, therefore the average value 14.73 N at extension distance of 6.90 mm. According to date in table 5, the data analysis showed that the standard deviation of break force on bottom duck eggshell was 8.02 at 3.99 of extension distance, and the variation of break force on bottom duck eggshell was 64.99 at 15.922 of extension distance, the standard error of break force on bottom duck eggshell was 0.26 at 0.1315 of extension distance, coefficient of variance of break force on bottom duck eggshell was 1.81 at 1.9055 of extension distance. Nine samples of duck eggs have been tested and numbered from N1 to N9.

The highest average value of break force was (14.91 N) at extension distance of 6.40 mm on top duck eggshell sample, while the lowest value was (12.23 N) at extension distance of 4.50 mm on middle duck eggshell sample. The average value of break force for bottom duck eggshell of (14.73 N) at extension distance of 6.90 mm was intermediate between top and middle duck eggshell samples.

Table 5. Statically analysis of extension and penetrate force in the bottom duck eggshell

<table>
<thead>
<tr>
<th>Extension mm</th>
<th>Force Mean</th>
<th>Force Min</th>
<th>Force Max</th>
<th>Force Range</th>
<th>Force Std</th>
<th>Force Variance(s2)</th>
<th>Force Mean of variation</th>
<th>Force S.E.</th>
<th>Force C.V.</th>
<th>General Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>0.02</td>
<td>0.10</td>
<td>0.05</td>
<td>0.04</td>
<td>0.04</td>
<td>0.08</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Max</td>
<td>13.80</td>
<td>39.75</td>
<td>36.85</td>
<td>25.00</td>
<td>30.84</td>
<td>32.00</td>
<td>33.52</td>
<td>30.24</td>
<td>30.00</td>
<td>36.08</td>
</tr>
<tr>
<td>Range</td>
<td>13.79</td>
<td>39.65</td>
<td>36.80</td>
<td>24.96</td>
<td>30.80</td>
<td>31.92</td>
<td>33.48</td>
<td>30.20</td>
<td>29.96</td>
<td>36.04</td>
</tr>
<tr>
<td>Std</td>
<td>3.99</td>
<td>9.12</td>
<td>8.69</td>
<td>6.61</td>
<td>7.07</td>
<td>8.47</td>
<td>7.75</td>
<td>7.46</td>
<td>8.44</td>
<td>8.59</td>
</tr>
</tbody>
</table>

The results shown in table (6) indicate that the minimum and maximum strength required to break the egg and the occurrence of hatching and measured in three places, namely the top of the egg shell and the middle of the shell, then the bottom of the egg shell shows that it reached (0.05 and 32.24), (0.11 and 25.67), (0.05 and 32.70), respectively.

Table 6. Average of stastically analysis of extension and penetrate force in the duck eggshell types.

<table>
<thead>
<tr>
<th>Eggshell types</th>
<th>Average</th>
<th>Min.</th>
<th>Max.</th>
<th>Range</th>
<th>Std</th>
<th>Variation(s2)</th>
<th>Mean of variation</th>
<th>S.E.</th>
<th>C.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of Eggshell</td>
<td>14.91</td>
<td>0.05</td>
<td>32.24</td>
<td>32.19</td>
<td>7.53</td>
<td>57.64</td>
<td>0.07</td>
<td>0.26</td>
<td>1.26</td>
</tr>
<tr>
<td>Mid of Eggshell</td>
<td>12.23</td>
<td>0.11</td>
<td>25.67</td>
<td>25.65</td>
<td>6.52</td>
<td>46.88</td>
<td>0.08</td>
<td>0.27</td>
<td>2.17</td>
</tr>
<tr>
<td>Bottom of Eggshell</td>
<td>14.73</td>
<td>0.05</td>
<td>32.70</td>
<td>32.65</td>
<td>8.02</td>
<td>64.99</td>
<td>0.07</td>
<td>0.26</td>
<td>1.81</td>
</tr>
</tbody>
</table>

The standard divisions values for each of them was 7.53, 6.52, and 8.02, respectively, and the average values were 14.91, 12.23, and 14.73, respectively, meaning that the amount of dispersion in the data in the case of the force needed to break the egg shell from the top is lower than the other two cases.

The results shown in Table (7) show that the minimum distance the blade advances from the egg shell is 0.015 mm, and the maximum value is about 9.0 mm in the case of approaching the middle of the egg shell and about 13.8 mm in the event of approaching the bottom of the egg shell. The results of ANOVA came to clarify the significance of the differences between the distance of progress of the blade towards the egg shell in the case of approaching the top, middle or bottom, where the value of p-value was significant at the level of 1%, 5%

And by doing LSD analysis, it was found that there were significant differences between the three cases of the distance of the breakage blade towards the egg. meaning that the force required to break the egg varies according to the breakage side.

Table 7. the results of ANOVA to show the differences between the distances of the blade's advance towards the egg shell in different positions.

<table>
<thead>
<tr>
<th>One-way ANOVA</th>
<th>Extension of Top</th>
<th>Extension of Middle</th>
<th>Extension of Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptive</td>
<td>0.15</td>
<td>12.795</td>
<td>0.15</td>
</tr>
<tr>
<td>Sig.</td>
<td>0.000</td>
<td>9.000</td>
<td>0.15</td>
</tr>
<tr>
<td>F</td>
<td>85.357</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results of ANOVA analysis showed that when comparing the force needed to break the egg at constant levels
of the pressure blade on the nine samples in three cases, which are pressure from the top of the egg and pressure from the middle and then pressure from the bottom of the egg. The results show that the average strength of the case of pressure from the egg top reached 39.698. While in the case of pressure at the center of the egg reached 33.402, and in the case of pressure from the bottom of the egg the average pressure strength reached 40.853, as the value of P-Value shows that there are significant differences between each case and this means that the pressure strength needed to break the egg varies according to the area of the egg breaking.

Therefore, it is preferable to use the greatest pressure force needed to break the egg to ensure the highest hatching rate inside the hatchery.

Table 8. ANOVA analysis to compare the force needed to break an egg at fixed levels of the pressure blade on different samples

<table>
<thead>
<tr>
<th>One-way ANOVA</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>3822.944</td>
<td>852</td>
<td>39.698</td>
<td>982.094</td>
<td>0.001</td>
</tr>
<tr>
<td>Top</td>
<td>0.000</td>
<td>1.0</td>
<td>0.000</td>
<td>0.000</td>
<td>1.00</td>
</tr>
<tr>
<td>Total</td>
<td>3822.944</td>
<td>853</td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Middle</td>
<td>20007.608</td>
<td>599</td>
<td>33.402</td>
<td>401438412</td>
<td>0.001</td>
</tr>
<tr>
<td>Within groups</td>
<td>0.000</td>
<td>1.0</td>
<td>0.000</td>
<td>0.000</td>
<td>1.00</td>
</tr>
<tr>
<td>Total</td>
<td>20007.608</td>
<td>600</td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Bottom</td>
<td>37543.849</td>
<td>919</td>
<td>40.853</td>
<td>22696076060001</td>
<td>0.001</td>
</tr>
<tr>
<td>Within groups</td>
<td>0.000</td>
<td>1.0</td>
<td>0.000</td>
<td>0.000</td>
<td>1.00</td>
</tr>
<tr>
<td>Total</td>
<td>37543.849</td>
<td>920</td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

CONCLUSION

- In general, there is great stability in the physical properties of duck eggs and shell characteristics such as, the egg length and the maximum egg diameter which followed also with the shape index, surface area, and volume of the egg.
- For thickness of eggshell, it indicates that the data is not dispersed and its presence is around its mean of 0.23, 0.23, and 0.21 mm, respectively.
- To design the incubator of duck eggs incubation under environment conditions of temperature degree and relative humidity, the high break force (32.70), which was towards bottom position of egg.
- The ordering of the strains from weakest to strongest in terms of break force stiffness, a strong correlation was found between break force and step progress of blade towards the eggs in different positions.
- The results clarify the significance differences between the distance of progress of the blade towards approaching the top, middle or bottom, the value of p-value was significant at the level of 1%, 5% meaning that the force required to break the egg varies according to the breakage side.
- Therefore, it is preferable to use the greatest pressure force needed to break the egg to ensure the highest hatching rate inside the hatchery.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Agricultural Engineering Department, Agricultural Faculty, Ain Shams University, Egypt; Agricultural Engineering Research Institute, Agricultural Research Center, Egypt; National Institute of Laser Enhanced Sciences (NILES), Cairo University, Egypt; and Agricultural Economic Research Institute, Agricultural Research Center, Egypt for their technical support.

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El Helew, W. K. et al.


