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Abstract: An unusually popular index reflecting the quality of the egg contents and known as the Haugh unit (HU) score is empirical in nature. Because of that, a number of studies appeared that contradict or try to improve this index. In this regard, we set a study that pursued several goals: (i) to trace the rationale for developing the HU index and give it a theoretical reassessment; and (ii) based on the assumptions of previous studies in this field, to revisit and refine the index by increasing such its components as the mathematical adequacy and information value. As a result, an alternative index was inferred that we called the Egg Quality Index (EQI) and described using the appropriate mathematical dependencies. This novel index, in addition to the egg weight (W), takes into account the physical properties of the thick albumen (by measuring its height, H) and yolk (by identifying its diameter, d, or height, h). We, then, compared the two indices, HU and EQI, using the simulation modelling approach. The results of comparison of the two indices as applied to a various set of parameters characteristic of chicken eggs suggested a wider potential for using EQI due to the inclusion of an additional parameter reflecting the yolk condition as well as a more accurate distribution of the studied eggs in quality grade groups with various gradations of consumer attractiveness.

1   **A Novel Egg Quality Index as an Alternative to Haugh Unit Score**

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10

Abstract

An unusually popular index reflecting the quality of the egg contents and known as the Haugh unit (*HU*) score is empirical in nature. Because of that, a number of studies appeared that contradict or try to improve this index. In this regard, we set a study that pursued several goals: (i) to trace the rationale for developing the *HU* index and give it a theoretical reassessment; and (ii) based on the assumptions of previous studies in this field, to revisit and refine the index by increasing such its components as the mathematical adequacy and information value. As a result, an alternative index was inferred that we called the Egg Quality Index (*EQI*) and described using the appropriate mathematical dependencies. This novel index, in addition to the egg weight (*W*), takes into account the physical properties of the thick albumen (by measuring its height, *H*) and yolk (by identifying its diameter, *d*, or height, *h*). We, then, compared the two indices, *HU* and *EQI*, using the simulation modelling approach. The results of comparison of the two indices as applied to a various set of parameters characteristic of chicken eggs suggested a wider potential for using *EQI* due to the inclusion of an additional parameter reflecting the yolk condition as well as a more accurate distribution of the studied eggs in quality grade groups with various gradations of consumer attractiveness.

1. Introduction

30

31   Since the publication of the original article by Haugh (1937), an index named by the

32   author as the Haugh unit (*HU*) has gained extraordinary popularity in assessing the quality of the

33   contents of poultry eggs. The essence of the method is to measure the height of the thick layer of

34   egg white (albumen) and the egg weight, followed by the *HU* computation according to the

35   formula:

36    $$HU = 100\log\left(H - \frac{\sqrt{G}(30W^{0.37} - 100)}{100} + 1.9\right),$$ (1)

37   where *H* is the height of the thick albumen in millimeters, *W* is the egg weight in grams, and *G* is

38   the gravitational constant equal to 32.2.

39   Later on, Eisen *et al*. (1962) simplified the above formula (1) by substituting the value of

40   the constant and recalculating the whole equation as follows:

41    $$HU = 100\log(H + 7.57 - 1.7W^{0.37}),$$ (2)

42   and, as a result, the formula (2) became the main computation tool for *HU* scoring.

43   Nevertheless, despite the high popularity of this index, criticisms of *HU* periodically

44   appear in scientific publications, which can be divided into the following three main subgroups.

45   *1. Correction of the index by the egg weight is impractical.*

46   At the time when Haugh deduced his universal formula, the poultry world used two

47   approaches to determining the quality of albumen. First, the albumen index (*AI*) proposed by

48   Heiman and Carver (1936) as the ratio of the height of thick albumen (*H*) to its average diameter

49   (*D*)

50    $$AI = \frac{H}{D},$$ (3)

51   which later was improved by Wilhelm and Heiman (1936) in the form of a calculation

52   nomogram that takes into account eggs of various weights. Second, measurement of the height of

53   thick albumen (*H*) adjusted for the egg weight (*W*) that is different from the weight of a standard

54 two-ounce egg (Wilgus and VanWagenen, 1936). The latter authors did not give any name to

55 their index, so we will call it here for convenience as the albumen quality (*AQ*):

56 $$AQ = H \cdot \frac{56.7}{W} \qquad\qquad (4)$$

57 Thus, the scholars of that time agreed that the egg weight directly affects the calculated

58 quality indicators of the chicken egg contents, and this was used by Haugh in developing his

59 formula. Yet, more recent studies (Eisen *et al*., 1962; Silversides *et al*., 1993; Silversides and

60 Villeneuve, 1994) noted that the value of *W* can be excluded from the formula (2).

61 *2. An adjustment for the egg weight is needed, but it does not change in a power-law*

62 *relationship.*

63 In his formula, Haugh introduced the egg weight correction using the exponent 0.37 and

64 following the nomogram of Wilhelm and Heiman (1936). Kidwell *et al*. (1964) suggested on the

65 basis of their own studies that the dependence on *W* should be linear, thereby confirming the data

66 of Eisen *et al.* (1962).

67 In his theoretical research, van Tijen (1968) explained this fact by examining a

68 "corrective" part of the formula (2):

69 $$y = 1.7W^{0.37} - 7.57 , \qquad\qquad (5)$$

70 and substituting the *W* data in the range between 0 and 70 g. The region of the obtained curve

71 within 40 and 70 g, i.e., the egg weight range characteristic of chicken eggs, can be conditionally

72 assumed to be linear.

73 *3. Modification of the Haugh formula and obtaining alternative indices.*

74 According to Stadelman *et al*. (1957), *HU* does not provide a complete description of

75 internal egg quality, and this, obviously, facilitated the search for new indices that would

76 improve, as suggested by their authors, the Haugh formula and be able to more adequately

77 calculate from a mathematical point of view an indicator of the quality of egg contents.

78 Kidwell *et al*. (1964), when exploring the linear nature of the variation in the height of

79 thick albumen vs egg weight, proposed modifying *HU* and used the new name for the index, *GE*:

80    $GE = 100 \log(H - b(W - 56.7))$ (6)

81   in which $b = 0.067$ is the combined linear regression coefficient.

82   According to the data of Robinson *et al*. (1994), the *HU* score is a weak and less

83   appropriate quality index when the albumen heights are below 5 mm. Instead of *HU*, these

84   authors proposed an alternative index with the correction of egg weight following a logistic

85   model.

86   Another alternative index for assessing the quality of egg contents was proposed by

87   Narushin (1997), who attempted to introduce a theoretical background for its derivation. As a

88   result, he suggested a rationale for developing a quality index called Egg Quality (Q_e) for eggs of

89   any poultry species, i.e., not just for chicken as suggested by Haugh for his index and mistakenly

90   extrapolated to all varieties of poultry.

91   Based on the above studies, one can conclude that deeper theoretical assumptions and a

92   more comprehensive analysis would be required to further serve as a basis for inferring an

93   adequate quality index, and this has become the main objective of the present study. In this

94   paper, we proposed a novel Egg Quality Index (*EQI*) and showed that, as compared with the *HU*

95   index, *EQI* could better and in the most suitable and informative way reflect the characteristics

96   of egg contents.

97

98

99   **2. Methodology**

100   *2.1. Effect of the egg weight*

101   Let us try to slightly modify the basic formula (3) for calculating *AI* using the theoretical

102   calculations performed by Narushin (1997).

103   If we consider the principle of measuring the thick albumen (Fig. 1), it is obvious that the

104   average diameter (*D*) can be expressed in terms of the surface area of the thick albumen (*A*),

105 which can be determined by the circle area formula minus the area, which the yolk occupies. If

106 we denote the average diameter of the yolk by d, then,

107 $$A = \frac{\pi}{4}(D^2 - d^2)$$ (7)

108 Given that the volume of thick albumen (V_{ta}) is the product of its surface area (A) and

109 height (H), the average diameter of thick albumen (D) can be expressed then by the following

110 formula:

111 $$D = \sqrt{\frac{4V_{ta}}{\pi H} + d^2}$$ (8)

112 In their classic book on the avian egg, Romanoff and Romanoff (1949), on the basis of numerous

113 experimental data, proposed a graphical dependence of the albumen weight (W_a) on the total

114 chicken egg weight (W), which we can approximate quite accurately ($R^2 = 0.998$) with the

115 following linear equation:

116 $$W_a = 0.76W - 7.2$$ (9)

117 Romanoff and Romanoff (1949) also stated that the thick albumen is approximately

118 57.3% of the total mass of the whole egg white, so the coefficients in the equation (9) were

119 correspondingly reduced, as a result of which the thick albumen weight (W_{ta}) can be written as

120 $$W_{ta} = 0.44W - 4.13$$ (10)

121 In order to transform the formula (10) into the volume equation (V_{ta}), the weight should

122 be divided by the density of the thick albumen (D_{ta}), the average value of which can be taken

123 equal to 1.04 g/cm^3 that is confirmed by several other studies (Romanoff and Romanoff, 1949;

124 Meuer and Egbers, 1990; Punidadas and McKellar, 1999; Cameron, 2010; Kumbár $et\ al.$, 2015).

125 Then,

126 $$V_{ta} = 0.42W - 3.97$$ (11)

127 and

128 $$D = \sqrt{\frac{0.5W - 5}{H} + d^2} \ ,$$ (12)

129   so, the final formula for determining *AI* can be rewritten in the following form:

130
$$AI_i = \frac{H\sqrt{H}}{\sqrt{0.5W - 5 + d^2 H}} \qquad (13)$$

131   where the values of H and d are given in centimeters, and that of W in grams. To avoid confusion

132   with the albumen index (*AI*) suggested by Heiman and Carver (1936), we introduced a different

133   parameter, the Improved Albumen Index (*AI$_i$*).

134   Thus, based on the formula (13), the egg weight has a direct effect on AI_i and, as a

135   consequence, on the *HU* score.

136

137   *2.2. Effect of yolk dimensions*

138   Judging from the formula (13), the yolk diameter (*d*) also affects the AI_i value. The step

139   of measuring the albumen index is carried out after the contents of the egg are poured on a flat

140   surface, as a result of which the yolk takes the form of a spherical cap (Fig. 1). The yolk volume

141   (*V$_y$*) can be determined by the appropriate formula as can be seen, for example, in Weisstein

142   (2020):

143
$$V_y = \frac{\pi h}{24}(3d^2 + 4h^2) \qquad (14)$$

144   in which h is the yolk height (Fig. 1).

145   Using the formula (14), we obtained an equation for calculating the yolk diameter (*d*):

146
$$d = \sqrt{\frac{8V_y}{\pi h} - \frac{4h^2}{3}} \qquad (15)$$

147   By analogy with the above mathematical calculations of the volume of thick albumen, we tried

148   to express the volume of the yolk (*V$_y$*) through the egg weight (*W*). At first, we also used the data

149   from Romanoff and Romanoff (1949), approximating the graphical dependence presented by the

150   authors for the change in the mass of the yolk (*W$_y$*) with an increasing egg weight ($R^2 = 0.999$):

151
$$W_y = 0.18W + 6.69 \qquad (16)$$

152   The density of the yolk (D_y) was taken to be 1.035 g/cm^3, which corresponded to our data

153   and, on average, is in good agreement with the other studies (Fromm and Gammon, 1968;

154   Lineweaver *et al*., 1969; Meuer and Egbers, 1990; Punidadas and McKellar, 1999; Kumbár *et*

155   *al*., 2015). Then,

156     $$V_y = 0.17W + 6.46 \tag{17}$$

157   Given (17), the formula (15) can be rewritten as follows:

158     $$d = \sqrt{\frac{0.4W + 16.5 - 1.3h^3}{h}} \tag{18}$$

159   Then, substituting (18) in (13), we can determine the value of AI_i using the yolk height

160   instead of its diameter:

161     $$AI_i = \frac{H\sqrt{Hh}}{\sqrt{(0.5W - 5)h + (0.4W + 16.5 - 1.3h^3)H}} \tag{19}$$

162   where the values of H and h are taken in centimeters, and W in grams.

163

164   *2.3. AI vs HU: mathematical view*

165   In his work, Haugh (1937) did not explain how he got his final formula, thereby only

166   referring to the article by Wilhelm and Heiman (1936), who continued research on improving the

167   albumen index (*AI*) and proposed a nomogram for its calculation based on the data of H and W.

168   Haugh (1937) approximated the nomogram by the following equation:

169     $$AI = \frac{H}{\sqrt{G}} - (30W^{0.37} - 100) \tag{20}$$

170   in which the value of G was called the gravitational constant equal to 32.2, while the values of H

171   were taken in millimeters and W in grams.

172   Nevertheless, substituting the specific values of H and W in (20) with those in the

173   Wilhelm and Heiman (1936) nomogram, we would obtain a stably negative result that is far from

174   the actual *AI* values provided in the nomogram.

175   To figure out exactly where the error occurred, we decided to repeat the approximation,

176   for which we used the data from the Wilhelm and Heiman (1936) nomogram, transferring them

177   to the Excel table, constructing similar graphical dependencies and approximating each of them

178   with the power function $H = f(W^{0.37})$ in order to get them as close as possible to the formula (20).

179   The results are presented in Fig. 2.

180   All the obtained equations have the following form:

181     $H = aW^{0.37} + b$ (21)

182   where a and b are coefficients.

183   The values of both coefficients a and b in the equation (21) were approximated by the

184   dependences $a,b = f(AI)$ that are presented in Fig. 3.

185   As can be seen from the diagram (Fig. 3), the function $a = f(AI)$ is a straight line parallel

186   to the abscissa axis and, therefore, in the calculation formula, it is purposeful to use the average

187   value of a equal to 1.632. The computation formula for determining the coefficient b is accurate

188   enough for its use in further calculations. Substituting these data in (21), we have:

189     $H = 1.632W^{0.37} + 0.0536AI - 5.0287$ (22)

190   wherefrom

191     $AI = 18.66H - 30.45W^{0.37} + 93.82$ (23)

192   Most likely, Haugh (1937) wanted to make his formula the most convenient for

193   calculations of that time, and due to this he slightly modified it, taking the coefficient value

194   30.45 equal to 30, and 93.82 to 100. We did the same in a similar way, recalculating the

195   coefficient 18.66 that turned out to be equal to 17.6 in this case. As a result, the equation (23)

196   was transformed into the following formula:

197     $AI = 17.6H - (30W^{0.37} - 100)$ (24)

198   or taking into account the constant $G = 32.2$ as proposed by Haugh (1937),

199     $AI = 100\dfrac{H}{\sqrt{G}} - (30W^{0.37} - 100)$ (25)

200   Thus, in the formula for *AI* (Haugh, 1937), the coefficient 100 was omitted that led to a

201   computation error. This was due to the fact that Wilhelm and Heiman (1936) suggested using

202   integers in the calculations: for example, instead of $AI = 0.099$, use $AI = 99$, and instead of $H =$

203   0.76 cm, assume $H = 76$.

204   The rationale of Haugh (1937) regarding the use of the gravitational constant *G* in his

205   formula (20) is not entirely clear, and that caused some confusion among the authors of later

206   works. For example, Wells (1968), introducing the Haugh formula, quite logically indicated the

207   value of the gravitational constant *G* equal to 981 cm/s^2 that corresponded to its value in the

208   measurement system given by him. However, most likely, Haugh (1937) simply tried to give his

209   empirically derived formula some physical meaning, in connection with which he used a mixture

210   of dimensions, proposing to determine the height of the albumen in millimeters, the egg weight

211   in grams, and the gravitational constant in feet/s^2.

212   The next question is how Haugh (1937) derived his formula (1). To address this question,

213   let us consider its sublogarithmic part and compare with the equation (25). Obviously, the Haugh

214   formula (1) is composed from the equation (25) by simple mathematical transformations:

$$H - \frac{\sqrt{G}(30W^{0.37} - 100)}{100} + 1.9 = AI \cdot \frac{\sqrt{G}}{100} + 1.9 \qquad (26)$$

216   Evidently, the purpose of introducing the coefficient $\sqrt{G}/100$ was to make the

217   calculation formula (1) more demonstrative and simpler, freeing it from the corresponding

218   coefficient. The parameter 1.9 was added by Haugh (1937) to comply with the notion of a

219   'standard egg' previously proposed by VanWagenen and Wilgus (1935) and Wilgus and

220   VanWagenen (1936) as an egg whose weight was 2 ounces (56.7 g), and that was entirely

221   supported by Haugh.

222   Thus, the *HU* score is a somewhat modernized formula for calculating the modified

223   albumen index based on the nomogram proposed by Wilhelm and Heiman (1936), which implies

224   that the alternative equations (13) and (19) we derived here can also be used for practical

225   purposes.

226

227

3. Results and Discussion

3.1. Introducing EQI

For convenience and by analogy with what proposed by Wilhelm and Heiman (1936), we
can multiply the equations (13) and (19) by 100. Also, fully agreeing with Haugh (1937) that the
logarithm of the resulting function would make its use more convenient, due to changes in the
data on linear dependence, and multiplying again the logarithm by 100 to get rid of the decimal
places after the logarithm operation, we will get the final expression for defining the quality of
the chicken egg contents that, in order not to cause confusion with the previous indices, we
called here Egg Quality Index (*EQI*):

$$EQI = 100\log\left(\frac{100H\sqrt{H}}{\sqrt{0.5W - 5 + d^2 H}}\right) \tag{27}$$

or

$$EQI = 100\log\left(\frac{100H\sqrt{Hh}}{\sqrt{(0.5W - 5)h + (0.4W + 16.5 - 1.3h^3)H}}\right) \tag{28}$$

240

3.2. HU vs EQI: simulation modelling

In view of the fact that in reality it is sometimes difficult to select a sample of chicken
eggs whose qualitative characteristics are widely variable, we undertook evaluation of the
obtained *EQI* values using simulation modelling methods. This made it possible to take into
account all possible combinations of various values of the three parameters, H, W, and h, as were
applicable to chicken eggs and used in the formula (28).

The simulation modelling included the following steps. Based on the data from Heiman
and Carver (1936), Wilgus and VanWagenen (1936), Wilhelm and Heiman (1936) and Haugh
(1937) that served as the basis for the creation of the *HU* score, plus more recent works on the

250   *HU* estimation (Eisen *et al*., 1962; van Tijen, 1968; Silversides *et al*., 1993; Silversides and

251   Villeneuve, 1994), the *H* values were taken in the range between 2 and 11 mm and divided into

252   classes with an increment of 1 mm, whereas the range of the *W* values was set between 42 and

253   70 g and split into classes with an increment of 2 g. Since the above authors, unlike us, did not

254   use the size of the yolk in their models, variation in the yolk height was derived from the data of

255   Keener *et al*. (2006), Sarica *et al*. (2012), Ogunwole *et al*. (2015), Rath *et al*. (2015) and Feddern

256   *et al*. (2017), with the range of the *h* values being taken between 6 and 20 mm and with a 2-mm

257   increment for dividing into classes. All possible simulation modelling combinations of the *H*, *W*

258   and *h* values were substituted into the formulae (28) and (1), thus obtaining a dataset of 1280

259   variants. The interrelation between *HU* and *EQI* values computed for each of the simulation

260   variants are presented in the form of a graphical dependence (Fig. 4).

261   The values of both *HU* and *EQI* indices vary widely: from 11 to 107 for *HU*, and from 12

262   to 133 for *EQI*, so we can suggest that the *EQI* quality index more fully reflects the nuances of

263   changes in the qualitative characteristics of chicken eggs.

264

265   *3.3. HU vs EQI: egg quality grading*

266   In order to carry out a deeper qualitative analysis of the *EQI* index in comparison with

267   *HU*, let us use the United States Standards, Grades, and Weight Classes for Shell Eggs (USDA,

268   2000) that include the following egg quality grades: AA, with *HU* values of 72 and higher; A,

269   with *HU* values of 60 to 71; and B, with *HU* values less than 60. This classification, however,

270   was recently amended with the grading data from the other sources, e.g., ORKA (2019) and Pius

271   and Olumide (2017) that suggested to define the B quality grade if the *HU* score ranges between

272   31 and 59, while eggs with *HU* values of 30 and less should be included in the C grade.

273   Schematically, the distribution of the *HU* and *EQI* indices according to the above four quality

274   grades is shown in Fig. 5.

275   A more detailed analysis of the results showed that based on the *HU* data, 816 simulation

276   modelling combinations (simulation variants) of egg parameters were included in the AA grade

277   group. However, if we analyze the simulation dataset using the *EQI* index, 3 eggs fell into this

278   group falsely, since their index calculated by the formula (28), which also takes into account the

279   yolk height, was lower than 72. A more pronounced discrepancy between the two simulation

280   datasets obtained with *HU* and *EQI* was observed for the A grade group: of the 144 simulation

281   combinations identified for this grade category using *HU*, 8 eggs should be placed into a lower

282   category B if they were evaluated using *EQI*, while 60 eggs of the lower A grade should be

283   transferred to a higher category AA. A similar mismatch was observed in the B grade group.

284   This category had 256 simulation combinations using *HU*, although, when calculated according

285   to *EQI*, 60 eggs should be put into a lower category C, and 36 eggs to a higher category A.

286   Simulation modelling combination of the lowest C grade included 64 conditional eggs that

287   coincided when using *HU* vs *EQI*. Thus, even if we use the above four grades that reflect quite a

288   rough consumer attractiveness scale for the qualitative assessment of eggs, we can conclude that,

289   despite the rather high correlation between the two studied indices (r = 0.981), *HU* cannot cope

290   properly with all possible combinations of qualitative egg characteristics and that the middle

291   grade groups A and B are especially affected because almost up to half of all eggs in them did

292   not correspond to their appropriate category based on *EQI*. Moreover, these inconsistencies can

293   be exacerbated when using *HU* for research purposes where variation of egg quality parameters

294   can be much greater, and the results of an entire experiment can depend on the exact assignment

295   of eggs to the correct grade categories.

296   Despite the wide usage of *HU*, many researchers still continue to additionally evaluate

297   the quality of egg contents using the albumen and yolk indices. Earlier studies aimed at revealing

298   the relationship of these indices did not identify clearly this relationship between them. For

299   example, Sauter *et al*. (1951) found a close relationship between the albumen and yolk indices at

300   a correlation level of 0.945 and suggested an empirical formula for their computation. On the

301   other hand, Wesley and Stadelman (1959) confirmed that the relationship between the yolk index

302   and the diameter of the thick albumen, which they used instead of the albumen index, only at the

303   level of 0.17, and that between the yolk index and *HU* 0.39, and concluded that it would be

304   advisable to use all three indicators for a more adequate assessment of the quality of the chicken

305   egg contents. However, there were previously no attempts to combine different egg quality

306   parameters into one index. In this connection, we developed here the novel index, *EQI*, and

307   suggest that this can be a good alternative to a comprehensive assessment of the egg quality.

308

309   *3.4. Conclusions*

310   Our theoretical and computational studies enabled to derive the novel index for assessing

311   the quality of the contents of chicken eggs, which is a function of the height of the thick

312   albumen, the average diameter or the height of the yolk, and the egg weight. Based on the

313   analysis performed by means of the simulation modelling, this novel indicator, the Egg Quality

314   Index (*EQI*), has a much higher potential for a qualitative assessment of the eggs in view of a

315   wider range of measurements, the inclusion of an additional parameter characterizing the

316   condition of the yolk, and a more accurate distribution of the studied eggs in quality groups with

317   a different gradation of consumer appeal. We suggest the novel index to be a promising and

318   useful tool for further application in food and poultry industries.

319

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396

397 **Figure captions**

398

399 **Fig. 1.** Scheme for measuring egg quality parameters of the thick albumen (NABEL, 2016).

400 **Fig. 2.** Graphical representation of Wilhelm and Heiman (1936) chart used to demonstrate the dependence of the

401 albumen heights on the egg weights.

402 **Fig. 3.** The results of approximating the values of the coefficients *a* and *b* by the functions *f(AI)*.

403 **Fig. 4.** Variations of *HU* and *EQI* values computed on the base of the simulation modelling data for the qualitative

404 characteristics of chicken eggs.

405 **Fig. 5.** Distribution of the *HU* and *EQI* values in accordance with the four egg quality grade groups, AA, A, B and
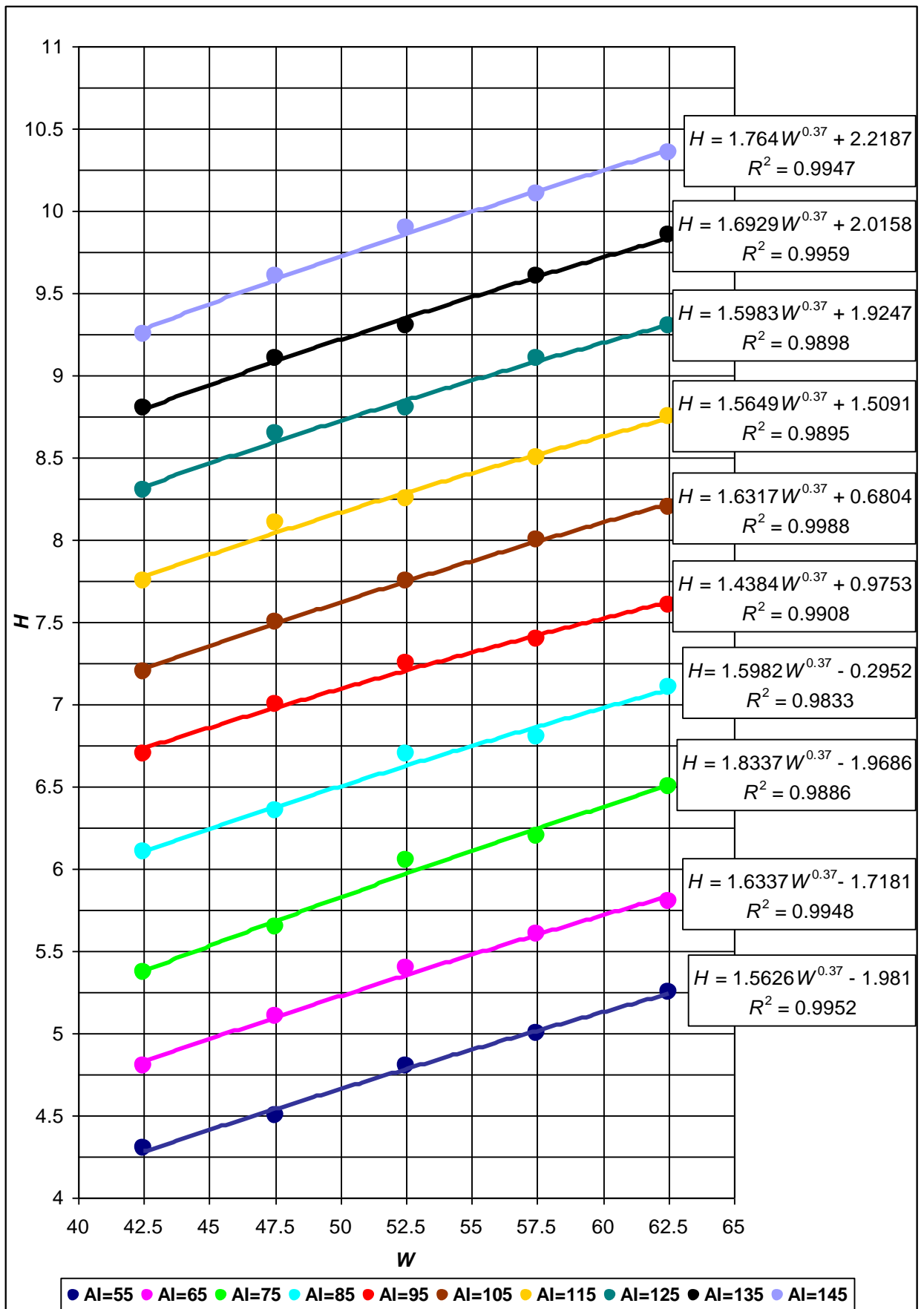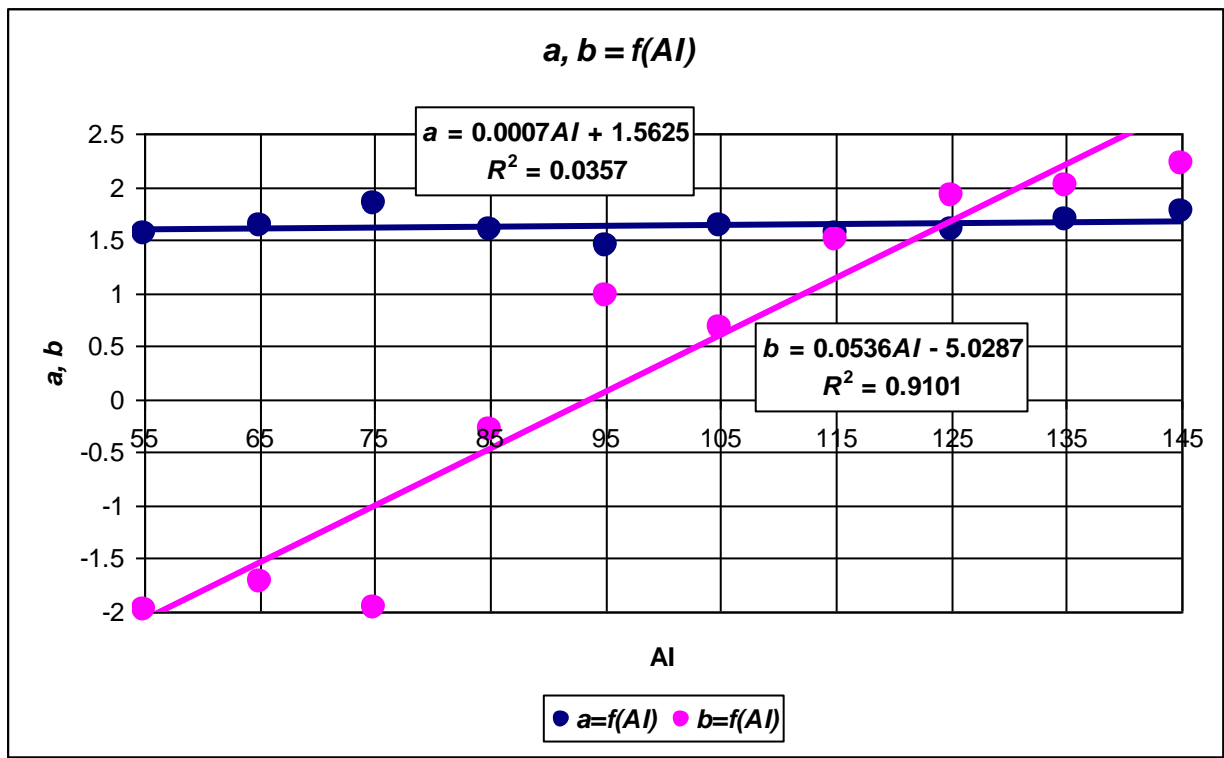
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Figure 1
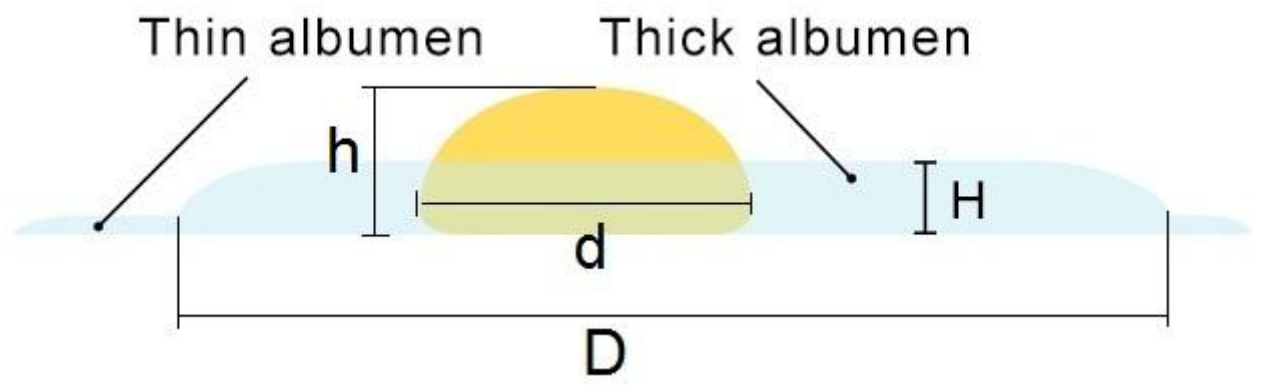
Figure 2

Figure 3
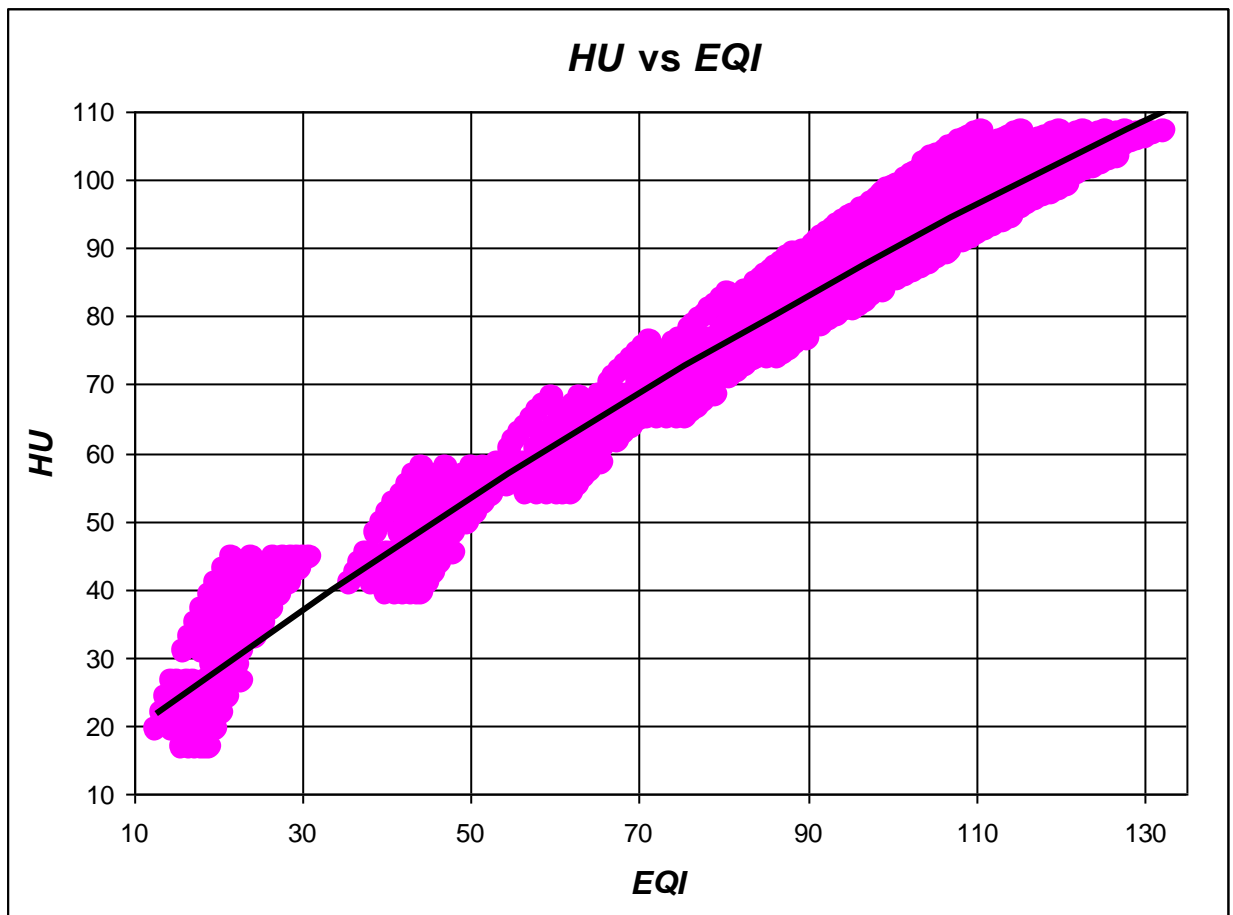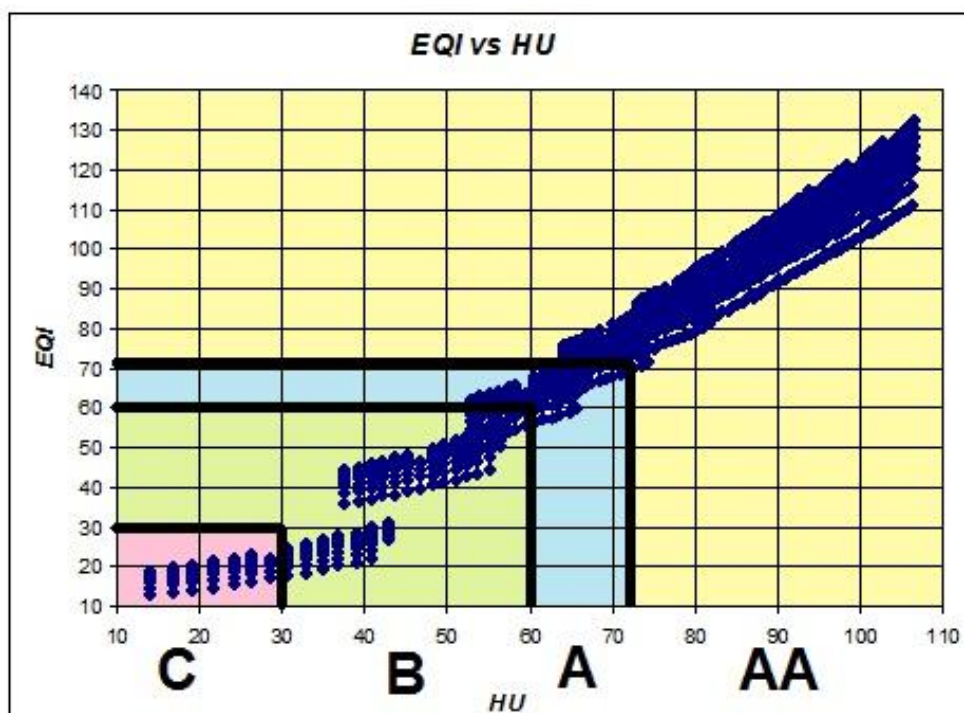
Figure 4 (corrected)

HU vs *EQI*

Figure 5

Highlights

- Haugh unit score (*HU*) is a conventional predictor of the quality of egg interior.

- We propose a new score, Egg Quality Index (*EQI*), using mathematical dependencies.

- Two indices, *HU* and *EQI*, were compared using the simulation modelling approach.

- *EQI* has a stronger potential due to an additional parameter for egg yolk condition.

Credit Author Statement

VGN: Conceptualization; Investigation; Methodology; Roles/Writing - original draft; Writing - review & editing.

MNR: Conceptualization; Investigation; Roles/Writing - original draft; Writing - review & editing.

DKG: Project administration; Resources; Supervision; Writing - review & editing.

1   **A Novel Egg Quality Index As an Alternative to Haugh Unit Score**

2

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11   **Conflicts of interest**

12   The authors have no conflict of interest to declare.