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The design, fabrication and evaluation of egg weighing device using capacitive sensor and neural networks

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Introduction: Grading agricultural products always has a particular important position for submission to domestic and overseas markets. The grading causes more profitable product ranges and customer satisfaction. Grading treatment is carried out based on various parameters such as color, ripeness level, dimensions and weight. Product weight is one of the most effective parameters in grading operation. Egg weight is directly related to the smallness and coarseness of eggs. In egg grading, the largeness value is very important in marketing. This research aimed to design, fabricate and evaluate the egg weighing system based on its dielectric properties.

Materials and Methods: To perform this research, the stages of work are divided into several sections including, design and construction of the hardware section, writing code for the software section to collect data, conducting nondestructive tests and data collection, analysis of obtained data using artificial intelligence, and giving the results of analysis for device calibration of the system as the software code. The large eggs as dielectric substances cause more increase in the capacity of the capacitive sensor. Furthermore, by derivation of a relation between capacity of capacitive sensor and egg weight, one can predict the weight of the sample. A prototype unit of weighing system was designed and fabricated. The designed unit was composed of a chassis, a voltage source, a sinusoidal signal generator, a voltage measurement unit, an AVR micro controller, a COM port, a capacitive sensor, and an LCD and a keyboard. Neural network technique was used for egg weight prediction. The designed net receives 16 voltage values at different frequencies as inputs and its output is the egg weight. In order to calibrate and evaluate the weighing unit, 150 fresh egg samples were provided on egg laying day from a local poultry farm. Experiments were divided into three groups. The experiments were carried out on egg-laying day, and the second and fourth day after laying.

Results and Discussion: In this study, two networks were built and evaluated. In the first series, two-layer networks and in the second series, three-layer networks were developed. In the two-layer neural networks, the number of neurons in the hidden layer was changed from 2 to 10.According to the given results for two-layer networks, two layer networks with 10 neurons offer the best results (the highest R-value and minimum RMSE) and it can be chosen as the most effective two-layer network. Three-layer neural networks have been composed of two hidden layers. The number of neurons in the first hidden layer was 10 and in the second layer it was changed from 1 to 20. Between three-layer networks, the network with 7 neurons with the highest R-value and the lowest error is the most appropriate network. It is even more efficient than the two-layer network with 10 neurons. So, the most appropriate structure is 1-7-10-16 and it has been selected for calibration of the weighing device. To evaluate and assess the accuracy of the weighing machine, weights of 24 samples of fresh eggs were predicted and compared with the actual values obtained using a digital scale with the accuracy of 0.01 gr. The paired t-test has been used to compare the measured and predicted values and the Bland-Altman method has been used for charting the accordance between the measured and predicted values. Based on the findings, the difference between the measured and predicted values was observed up to 5.4 gr that is related to a very large sample. The mean absolute error is equal to 2.21 gr and the mean absolute percentage error is equal to 3.75 %. According to the findings, 95% of the actual and approximate matching range to compare the two weighing methods is between -5.3 gr and 3.36 gr. Thus, the dielectric technique may underestimate the egg weight up to 5.3 gr or it may overestimate it up to 3.36 gr more than the actual prediction.

Conclusions: The best results were obtained with a 3 layers net having 10 and 7 neurons, respectively in the first and the second hidden layers with the highest R-value, 0.983 and the lowest error, 0.502. Therefore, this net was applied for egg weight prediction. To evaluate the device, the weights of 24 fresh eggs were estimated using the device and were compared with actual values and the maximum error was observed to be equal to 5.4 gr.

Keywords: Capacitive sensor, Eggs, Neural network, Weighing device

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