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Egg Candling Analysis Equipment Design: A Safety Solution

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Abstract

Egg candling analysis is a process that consists in applying light to an egg in order to detect abnormalities inside it. The light makes the eggshell transparent; hence it is possible to analyze the components inside the eggs in a non-destructive procedure. Manual egg candling is time consuming and pays a toll in workers' health. It is mainly prevalent in small and medium business in developing countries. The following work describes the design of an egg candling device for a poultry factory in Ecuador. The device consists of a conveyor belt with a chamber for classification. The conveyor belt was designed to allow a cold light to illuminate the eggs inside the analysis chamber. Defective eggs were separated using a mechanism which softly pushes the abnormal samples to the center of the conveyor belt. The analysis and decision making was done by a software developed in MatLAB using digital image processing. Additionally, the software enables the worker to operate the device and classify the eggs by himself in manual mode. As a result, 1000 samples were analyzed and classified with a process effectiveness of 95%.

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Keywords: Egg candling; occupational safety; ergonomics; digital image processing.

1. Introduction

Egg candling is a process that consists in applying a strong light against an egg in order to detect abnormalities such as fertilized eggs, blood stains, spots, cracks, dirt (Ragni, Cevoli, & Berardinelli, 2010). Moreover, this process classifies the eggs in different grades (FAO, 2002) (Liu, Ter Hsin Chen, & Tan, 2017). In this process, the egg's internal elements are examined. For this reason, it is necessary to consider an analysis beyond superficial vision

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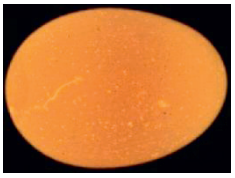
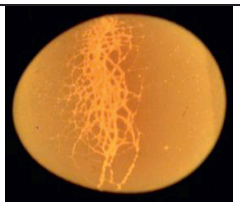
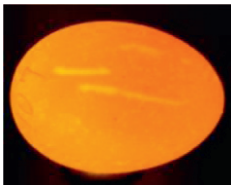
(Abdullah, Nashat, Anwar, & Abdullah, 2017). Thus, the usage of a bright light in a dark room penetrates the egg's shell which makes it transparent and possible to view the internal components of the eggs (Arivazhagan, Shebiah, Sudharsan, Kannan, & Ramesh, 2013). It is a non-destructive selection method and a quality control process for determining the grade of an egg and also for removing eggs with defects from the supply chain (United States Department of Agriculture (USDA), 2000). This process was performed before using candles as a source of light, therefore its name nowadays. Table 1 shows pictures of common defects detected in eggs by the candling analysis.

Generally this procedure is performed manually in small companies and developing countries. Its efficiency relies on the workers' skills. They possess the necessary knowledge to detect eggs' problems and remove them from the production line (Avicol, 2013). Therefore, it is a source for human mistakes. Automated systems have been developed for inspecting eggs in large quantities, especially at the poultry industry to recognize the fertile eggs (Hashemzadeh & Farajzadeh, 2016). Although, for quality control purposes there is still a sampling process where one egg is candled at a time. In this process 5% of the eggs classified by an industrialized system are downgraded. Due to this aspect, the candling process is still relevant in the food industry (Philip & Ashurst, 1996). It is necessary to develop a system where manual and automated processes come together in order to produce a high quality product.

Table 1. Pictures of egg's defects using the egg candling method presented in this study.

Type of Defect	Picture	Type of Defect	Picture
Linear Rupture		Body Check	
Cage Marks		No defect	

The fact that candling is performed by workers brings concerns over their occupational safety and health. This process is done in dark rooms in order to be able to detect the internal components of the eggs. Poor illumination at the workplace can deal into stress, burnout and accidents. It is related with health issues such as eye strain, headaches and musculoskeletal disorders. In addition, working for prolonged hours in artificial lighting can be the cause of an unbalance of the natural rhythms of the body that in long term can lead into depression (Ponting, 2009).

Moreover, egg candling analysis involves repetitive and specialized tasks. They are performed for long periods of time and on a daily basis, which have consequences in the employees' health. For this reason, it is important to apply ergonomics to the design of the devices. Therefore, the equipment is fitting the worker's body instead of physically forcing his body to perform the job (U.S Department of Labor Occupational Safety and Health Administration (OSHA), 2000).

The following work presents a solution in terms of operability, health and safety regarding a food quality control process. It describes the planning, design and building of an egg candling equipment that combines manual and automated nondestructive egg analysis.

2. Design

Before starting to plan the equipment design it is necessary to establish defined parameters in order to comply with the industry requirements. Eggs and egg-candling procedure involve a complex criterion of design that must be noted before developing the device layout. In this case, the requirements needed were: light should pass through the

egg-shell, the system should be capable to analyze and transport at the same time, and finally, the selection should not damage any sample. Table 2 shows the specific characteristics of the device

Table 2. Specification of the system.

Specification	Quantity/Description
Maximum transportation load	200 [Kg]
Maximum transportation speed	2 [m/s]
Material of fastener	Sponge
Material of belts	Polymer
Dimensioning of the structure	2m x 1m x 1,75m
Material of the structure	Steel A36

For a better understanding of the device, the design was divided into several steps described below.

2.1. Transporting Design

A conveyor chain was used for constructing the eggs' transportation system. This element is convenient because of various reasons: it allows the light to pass through the egg shells; the fasteners secure each egg, avoid them to hit each other during the process and prevent a possible egg breakage. Fig. 1 shows the upper view of the device. Table 3 shows the cavity dimensions: dimension b is a chain pitch standard value, whereas dimension a depends on the selection mechanism to be used that in this case is a lever- mechanism.

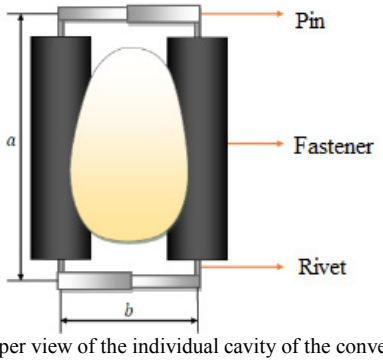


Fig. 1. Upper view of the individual cavity of the conveyor chain.

Table 3. Dimensions of the cavity.

Legend	Dimension
a	0.0800 [m]
b	0.0127 [m]

2.2. Mechanical design of the analysis chamber and selection mechanism

The analysis chamber is conveniently located in the middle of the conveyor belt, because eggs have to be arranged first along the side conveyor chains (number 1 – Fig. 2). Later, two conveyor chains carry the eggs to the analysis chamber where the selection mechanism softly pushes the egg into the conveyor belt (number 2 – Fig. 2), separating eggs with abnormalities from healthy ones. The selection mechanism (Figure 3) consists of six levers propelled by servo-motors. The shape of the lever has been designed in a way that fits the egg curvature. The servo motors' speed is electronically tuned to prevent sudden movements that can crash the eggs.

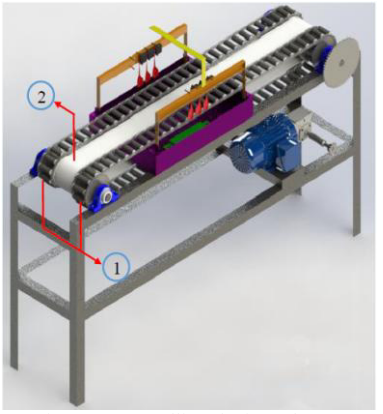


Fig. 2. Egg candling device scheme:
1) Conveyor Chain; 2) Conveyor. Layout made with software Solid Works 3D Design.

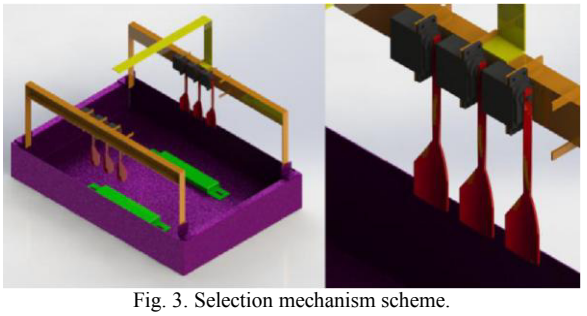


Fig. 3. Selection mechanism scheme.

2.3. Artificial Intelligence Classification Design

Digital Image Processing (DIP) was utilized for egg selection. A friendly Graphic User Interface (GUI) developed in MATLab was used to analyze the images of the samples. MATLab software requires a steady picture with high resolution in order to perform an optimal image processing. Therefore, after three consecutive movements the conveyor chain stops for taking the picture to be processed. The algorithm used for failure detection consists on an image binarization. This is a process where only abnormalities on the egg-shell remain as white pixels. White pixels are counted, and through a given threshold the algorithm finally rejects or accepts the sample. The GUI in Fig. 4 shows how the operator can visualize the result of the final algorithm.

Fig. 4. Graphic User Interface (GUI) of the system.
Text in Spanish due to the Ecuadorian company design.

3. Discussion

The egg candling analysis device was designed exclusively for an egg producing factory located in the center area of Ecuador. This area produces around 48% of the poultry consumption of the country (LA HORA, 2015). Poultry industry in Ecuador is not as stringent as in other South American countries. This company is one of the rare cases where eggs are inspected for quality by egg-candling analysis. The development of a smart device like the one presented above gives the company the opportunity to locally grow, provide a quality product to consumers and potential to export to neighboring countries.

Previously at the poultry factory mentioned above, the egg-candling analysis was performed manually. The identified eggs were used for the incubation process. However, after this selection process, the final result can be seen only 21 days later, which is the regular incubation time in poultry. As a result, the company's loss was between 20 and 40 percent of the incubated eggs. The company invest energy in the incubation chamber and at the same time the non-fertile eggs become waste. Implementing a more effective inspection method, those non-fertile eggs can be sold (because a non-fertile egg can be used for human consumption), the chicken production rises and there is an improvement in terms of energy usage. The effectiveness of the egg-candling method described above using 1000 samples can reach up to 95%.

The introduction of this kind of device in a small and medium enterprises, gives a competitive advantage in terms of productivity. This company analyzed 50000 eggs per month by manual candling. With the automation of the process, the device is capable of analyzing one sample per second, which is 48000 eggs within 8 hours of work. This fact opens the option of expanding the business or even renting the device to other small companies and overall providing a healthy and cheap protein source that is needed in developing countries.

Economically, the device construction itself is near 3000 USD (materials and manufacturing). But, as it was described before, the improvement leads to a reduction of losses and a better energy usage. Furthermore, the operator in charge of the egg-candling analysis becomes an inspector of the device. His/her empiric knowledge contributes to constantly improve the software.

Safety design is a vital factor considered during the whole constructing process of the equipment. Yield strength was taken into account in order to build a device resistant to time and able to function numerous work cycles. Fig. 5 is a simulation of the stress produced by the multiple loads over the main structure using SolidWorks software. Static analysis performed in this software clearly shows the distribution of the safety factor where the minimum is 2.23 in the upper side part. Therefore, it fulfills standard parameters, and also assures the company an efficient service for at least 10 years.

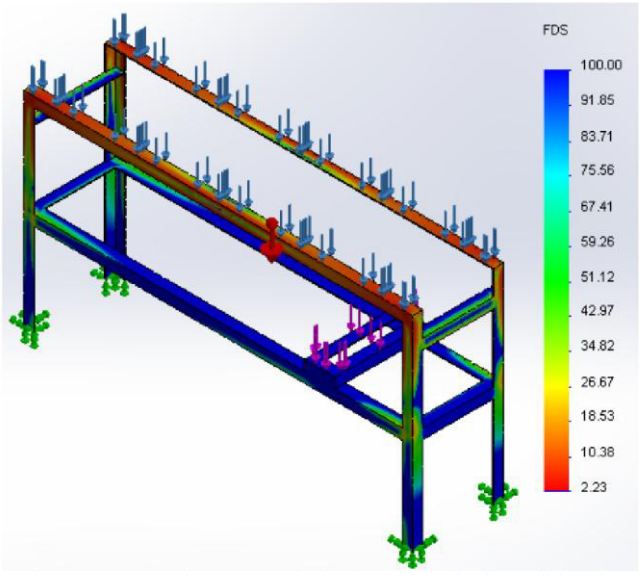


Fig. 5. Device structure's Safety Factor Distribution obtained using SolidWorks software

Due to the fact that the Digital Image Processing and Graphic User Interface were developed in MATLab, the channel to communicate hardware and software should have multiple coordination capabilities. For this reason, ARDUINO UNO board was used for the electric and electronic instrumentation of this device. The usage of ARDUINO is favorable for new developers because of its simplicity and prices.

4. Conclusions

The innovative characteristic of this equipment relies on the combination of the manual and automated egg candling process that lets the company process great quantities of eggs but also sample manually by a skilled worker in order to perform a total quality control of the product. Additionally, the design of a friendly graphic user interface that merges the manual and automated egg candling process gives a solution in terms of ergonomics preventing worker's burnout and human mistakes.

Furthermore, this equipment provides a valid solution regarding occupational safety and health. The necessity of an employee to be in a dark room sorting eggs is eliminated by the addition of the analysis chamber and the software operated selection method. The automated system prevents the worker of spending the workday doing repetitive tasks and let employees to focus on more rewarding activities which have a positive impact in their health, lifestyle and professional goals.

This device has the potential to be used in other industries such as pharmaceutical or chemistry where it is needed to evaluate the elements that are inside a product using nondestructive procedures such as egg candling. Nevertheless, it is needed to redesign the device to fit the new purpose.

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