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Development and Evaluation of Egg Processing Machine for Poached Eggs Production

Adepoju, A.L., Sanusi, M.S., Ayoade, A.A., Babajide, C.O., Raji, R. and Akpenpuun, T.D.

Abstract: This study was carried out to develop and evaluate an egg processing machine for poached eggs. The parts of the machine include the hopper, conveyor screw, the main housing, shell outlet, liquid egg outlet, motor, belt, pulley and cooking section. Materials for construction of the machine were carefully selected by balancing availability, durability, resistance to corrosion, suitability for food contact application with cost. The machine was evaluated in terms of throughput and material capacities and the values obtained were 301.14 kg/h and 548.4 kg/h respectively. Proximate compositions of the raw and poached eggs were 0.655%, 10.751%, 6.722% and 0.569%, 9.849%, 6.344% for ash, protein and fat contents respectively. It can be deduced that there was no reduction in the quality of the poached eggs as compared to the raw eggs.

Keywords: Egg processing machine, Proximate compositions, Poached eggs, Raw eggs, Material capacity.

I. Introduction

Egg, especially poultry egg, is among the most nutritious foods on the earth with a little of almost every nutrient needed by humans. It has been reported to be the cheapest source of animal protein and is rich in amino acids, vitamins like A, B, D, E and minerals that can sometimes be difficult to obtain from other foods [1]. Eggs generally consist of three main components which are the eggshell, the egg white (also known as albumen) and the egg yolk. The shell, which protects the egg white and yolk against physical and microbial damage as well as against small predators is composed of mineral salts such as calcium and magnesium carbonates while the remaining matter is rich in protein [2]. Eggs can be consumed in various forms to provide well-balanced nutrients for both infants and adults. They can also be processed into different liquid, frozen and dried products which are widely used by the food industry to make various dishes such as scrambled eggs and omelettes or as ingredients in foods such as ice cream, mayonnaise, salad dressings, frozen desserts, cream puff and cakes. Eggs also contain a myriad of biologically active components and are a great source of potential nutraceuticals [3-4].

A major way of processing eggs for variety and shelf-life extension is the production of poached eggs. Poached eggs, also referred to as soft-boiled eggs, is an egg product in which the egg white is cooked while the egg yolk remains essentially raw. The cooking of the egg white helps to render potential pathogenic bacteria inactive and inhibits antinutritional factors while preserving most vitamins, lipids, micronutrients, and some bioactive compounds in the raw egg yolk [3]. The processing of fresh eggs by cooking them into poached eggs provides a convenient alternative to fresh eggs wastages. Just like powdered eggs, poached eggs possess notable advantages over their fresh counterparts such

Adepoju, A.L. and Sanusi, M.S. (Department of Food Engineering, University of Ilorin, Kwara State, Nigeria)
Ayoade, A.A., Babajide, C.O., Raji, R. and Akpenpuun, T.D. (Department of Agricultural & Biosystems Engineering, University of Ilorin, Kwara State, Nigeria)
Corresponding author: adepoju.al@unilorin.adu.ng
Phone Number: +2347065139079
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as reduced weight per volume of whole egg equivalent, longer shelf life, firmer texture, lesser storage space and better functionality, for instance, it can be served on butter toast, or breakfast dishes [1].

Notwithstanding the usefulness of eggs, they are quite perishable and prone to contamination during processing without the use of appropriate machine(s). These, therefore, necessitate the adoption of unique methods for processing eggs and the development of a suitable machine to extend the shelf life in order to reduce losses incurred due to perishability. The processing of eggs includes breaking of eggs, filtering, pasteurizing, cooling, freezing or drying, and packaging. This is achieved by the use of egg processing machines. The important feature of these machines is the egg breaking mechanism and existing machines can crack the eggshells and separate the yolk (yellow) from the albumen (white) through a separation process that works exactly like a household egg strainer [5]. However, these existing machines do not have the feature of steaming which is a major requirement in the production of a poached egg. This study was therefore undertaken to develop and evaluate an egg processing machine for poached egg. This machine will help to solve pertinent issues in egg processing such as manual breaking of eggs, spills and wastages, prevention of food contamination and extension of shelf life which will invariably increase the availability of eggs all year round.

II. Materials and Methods

A. Material Selection

Several criteria were considered in selecting materials for the construction and fabrication of the poached eggs processing machine. The functional attainment, reliability of the equipment, the economy of production, assembling and durability were all put into consideration. Stainless steel was used for the construction of the separating chamber and its components, considering its resistance to

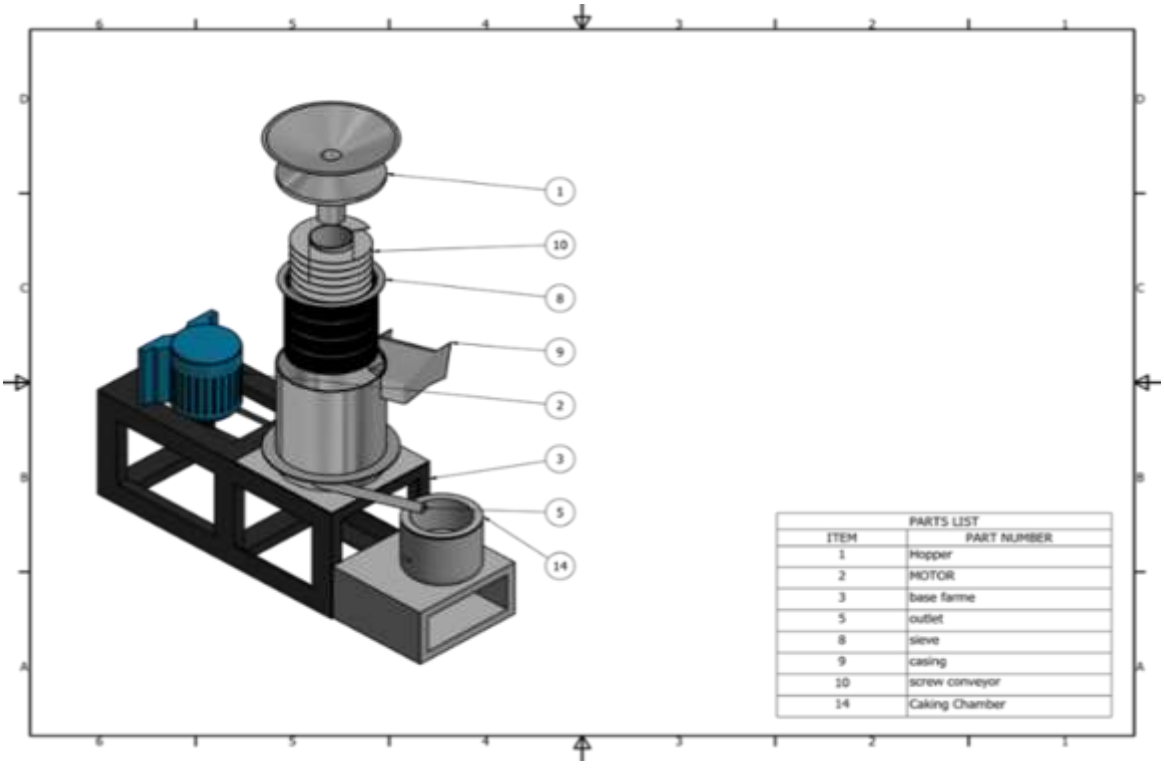

Figure 1: Detailed view of the conceptual design

corrosion, suitability for food contact application, light-weight, availability and cost. The materials used for the construction of the machine were obtained locally from Ilorin, Kwara state. Eggs were obtained from a poultry farm at Tanke, Ilorin, Kwara state, and were sorted into various sizes which are medium, large, extra-large and jumbo for testing the machine.

B. Description of the Egg Processing Machine

The egg processing machine consists of the hopper, screw, housing, base, chaff outlet, liquid egg outlet, the motor, belt and pulley, and cooking section as part of its components, as shown in the conceptual design in Figure 1. The hopper (Figure 2) is the compartment where the egg was fed into the screw conveyor for the cracking and separating operation. This hopper consists of two sections, which are the conical sections (one inverted over the other) where the eggs were being fed into the machine and the extruded hollow pipe which enters the screw conveyor. The screw conveyor (Figure 3) is a helical screw wound around a hollow circular pipe for the conveyance of the eggs dropped in it. There is an opening towards the end of the hopper through which the egg dropped was passed to the screw conveyor. Using the geometric mean diameter of the jumbo egg size, a screw pitch of 60 mm was used. The screen (Figure 4) is a stainless-steel hollow pipe of diameter 1mm and screen openings of diameter 0.2mm. This is the component that separates the eggshell from the liquid egg (yolk and albumen). The main housing of the machine (Figure 5) houses the screw conveyor and the screen, while the eggshell outlet is at the upper end of the main housing. The electric motor will convert electrical energy to rotary motion (mechanical energy) and the power was then transmitted to the screw via the belt and pulley. The cooking section

Figure 2: The Hopper

Figure 3: The Screw Conveyor

Figure 4: The Screen

Figure 5: The main housing with attached egg shell outlet

Figure 6: The cooking section

(Figure 6) is made of an electric heater, a steaming pot (which sits on the heater and hereby converts water to steam), and a liquid egg collector.

C. Working Principle

The eggs were fed into the hopper and passed through the hollow pipe to the screw (there is an opening at the lower end of the screw through which the egg will get to the screw conveyor). Electric power is transmitted from the motor through the belt and pulley, which rotates the screw conveyor. As the conveyor rotates, cracking, and separation of the eggshell takes place with the use of the screen. The separated egg will then be collected via the liquid egg outlet and the retained eggshell will be conveyed to the eggshell outlet. The cooking of the egg takes place in the liquid egg collector for a period of 3-4 minutes [6]. Figures 7 and 8 show the fabricated machine and the sample of poached egg produced.

D. Design Calculations

i. Determination of the Volume of the Separating Chamber Housing

$$\text{Volume, V} = \pi \frac{d^2 h}{4} \quad (1)$$

Where d = diameter of the chamber, h = height of the chamber

ii. Screw Conveyor Helix Angle

The helix of the screw conveyor is determined from the equation given by [7]:

$$A_e = \left\{\left(\frac{p}{\pi D}\right)\left(\frac{R_o}{R_e}\right)\right\} \quad (2)$$

$$R_e = \frac{2}{3}\left\{\frac{R_0^3 - R_1^3}{R_0^2 - R_1^2}\right\} \quad (3)$$

where, Ae is the helix angle, R_o is the outer radius of the screw, R_i is the inner radius of the screw, R_e is the effective radius of the screw, C_r is radial clearance, P is the screw pitch, D is the screw diameter.

iii. Power Requirement for the Screw Based on Capacity

The power required to drive the screw conveyor based on the throughput capacity was determined as specified by [8]:

$$P_r = Ql\rho gF \quad (4)$$

The power of the electric motor to drive the system was determined as:

$$P_m = \frac{P_r}{\mu_d} \quad (5)$$

iv. Pulley Design

The effective diameter of the screw pulley is determined as given by [9]:

$$N_1 d_1 = N_2 d_2 \quad (6)$$

Where N_1 is the speed of the electric motor, d_1 is the diameter of the pulley on the electric motor, $N_2$is the speed of the screw shaft and d_2 is the diameter of the pulley on the screw shaft.

v. Belt design

To select an appropriate belt to drive the screw conveyor, relevant belt parameters such as centre distance, pulley-belt contact angle and length of the belt must be determined.

The centre-to-centre distance was determined as follows:

$$C = \frac{d_1 + d_2}{2} + d_1 \quad (7)$$

The length of the belt was determined with the equation below:

$$L = \frac{\pi}{2}(d_1 + d_2) + 2C + \frac{(d_1 - d_2)^2}{4C} \quad (8)$$

The designed poached egg processing machine calculated parameters are presented in Table 1.

III. Results and Discussion

A. Performance Evaluation of the Egg Processing Machine

Testing or evaluation is a vital step in the machine development process. After design and construction, testing is necessary to

determine the performance efficiency of the machine, and thereafter, identify areas of possible improvement where necessary.

Table 1: Results of Designed Poached Egg Processing Machine Calculated Parameters

Parameters	Symbols	Value	Unit
Volume of chamber	V	6.28	cm^3
Helix Angle	A_e	14.11	o (degree)
Screw Power	P_r	0.933	kW
Pulley diameter	D_2	500	mm
Belt length	L	1701	mm

The machine performance was evaluated based on the material capacity and throughput capacity. Material capacity is the measurement of the volume of required material that passes through the machine per hour. It is expressed as kilograms per hour or tons per hour. The formula for material capacity is the total volume divided by hours used to harvest the volume. Throughput capacity is the measurement of the volume of total material (required and unrequired) that passes through the machine per hour. It is also expressed as kilograms per hour or tons per hour. The material capacity was calculated to be 548.4 kg/hr, while the throughput capacity was calculated to be 301.4kg/hr. This means that the machine can process 548.4 kg of poached egg in an hour and can process 301.4 kg of both eggshells and poached egg in an hour.

Figure 7: The Egg Processing Machine

Figure 8: Produced Poached Egg

B. Comparison of the Proximate Analysis of Raw and Poached Eggs

The data obtained from the proximate analysis were summarized using descriptive statistics as presented in Table 2. The results show that the different samples (Raw egg samples and Poached egg samples) have different proximate compositions, with the moisture content being the highest composition with a mean value greater than 80%. The ash content had the lowest composition, with a mean value of less than one. Throughout the samples, the amount of each composition increased in the order of ash content, fat, protein, carbohydrate and then moisture content. Moisture content appeared to be greater in the raw egg samples, having a mean value of 80.536%, as compared to the poached egg samples having a mean value of 80.196%. Ash content had a mean value of 0.5695% for the raw egg samples and increased in the poached egg samples to a mean value of 0.655%. The fat content also increased in the poached egg samples to a mean value of 6.733% from 6.344% in the raw egg samples. Protein content was greater in the poached egg samples with a mean value of 10.798%, as compared to its mean value of 9.849% in the raw egg samples. The result also shows that the carbohydrate content decreased from 63.442% in raw eggs to

Table 2: Descriptive Statistics of Proximate Analysis.

Proximate Composition		No.	Mean (%)	Standard Deviation (%)
Moisture Content	Raw Egg	10	80.536	$\pm 0.16222^a$
	Poached Egg		80.196	$\pm 0.20844^b$
Ash content	Raw Egg	10	0.569	$\pm 0.02234^b$
	Poached Egg		0.655	$\pm 0.01716^a$
Protein	Raw Egg	10	9.849	$\pm 0.02885^b$
	Poached Egg		10.751	$\pm 0.03635^a$
Fat content	Raw Egg	10	6.344	$\pm 0.05929^b$
	Poached Egg		6.722	$\pm 0.08967^a$
Carbohydrate	Raw Egg	10	63.422	$\pm 0.21760^a$
	Poached Egg		62.419	$\pm 0.19986^b$

Note: superscripts represent significant differences (P ≤0.005)

62.419% in poached eggs. Some of these values are similar to those obtained by [10] for egg-based ready-to-eat (RTE) products while some values are either higher or lower than those reported for egg white powders [11], pre-treated pawpaw and mango fruits [12], [13].

IV. Conclusion

An egg processing machine for the production of poached eggs was successfully designed and fabricated with separating and cooking units. The egg processing machine was used to produced poached eggs and the proximate compositions of the poached and raw eggs were compared. It was observed that there was no significant difference in the ash, protein and fat contents of the poached and raw eggs. It was concluded that the developed machine can process eggs into poached eggs with desirable proximate qualities.

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