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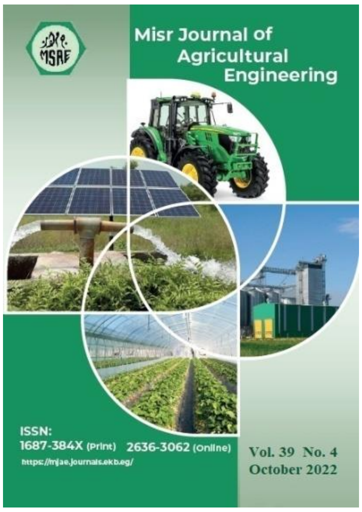
EFFECT OF SOME ENGINEERING PARAMETERS ON THE PERFORMANCE OF A LOCALLY MADE FISH FEED EXTRUDER

Islam F. El-Adly[1&*], Adel H. Bahnasawy[2], Samir A. Ali[2] and El-Sayed G. Khater[3]

[1] PhD Stud., Ag. Eng. Dept., Fac. of Ag., Benha U., Egypt.
[2] Prof. of Ag. Eng., Fac. of Ag., Benha U., Egypt.
[3] Assoc. Prof. of Ag. Eng., Fac. of Ag., Benha U., Egypt.
* E-mail: islamfawzy712@gmail.com



Keywords:
Productivity; Screw speed; Feed; Die; Cost; Fish feed extruder.

ABSTRACT

Fish feed extruders performance is deeply affected by the operational conditions. Unproper operational condition cause poor quality of feed and affect the productively of such machine, therefore, the main aim of the present work is to study the effect of some engineering parameters (screw speed, feeding rate and die hole diameter) on the performance of a locally made feed extruder. To achieve that, the extruder productivity, total losses percentage, energy consumption and cost per kg of feed were studied at three different screw speeds for main motor of extruder (200, 250 and 300 rpm), three different feeding rates (70, 100 and 130 kgh^{-1}) and three different die hole dimeters were 3, 4 and 5 mm extruder. The results indicated that extruder productivity ranged from 62.24 at 200 rpm , 3mm and 70 kg h^{-1} to 107.58 kg h^{-1} at 300 rpm , 5mm and 130 kg h^{-1} . The highest rate of the losses percentage was 4.64 % which happened at the smallest screw speed (200 rpm), the smallest feeding rate (70 kg h^{-1}) and the largest die hole dimeter (5mm) respectively. The specific energy consumption ranged from 0.126 at 200 rpm , 5mm and 130 kg h^{-1} to 0.233 kWh kg^{-1} at 300 rpm , 3mm and 70 kg h^{-1}. The operating cost of fish feed production decreases with the increase of the screw speed, feeding rate and die hole dimeter, the costs of extrusion processing ranged from 0.628 to 1.081 LE kg^{-1} of feed for all treatments under study.

1. INTRODUCTION

Production of high-quality floating aquatic feed has accounted more than 65% of the market needs of fish feed recently. Most of fish feed factories have tended to develop their production lines by adding extrusion units to produce floating fish feed after increasing demand from farmers for this type of feed for many reasons, such as: the high conversion rates than sinking feed, decreased the consumed amounts of fish feed in aquaculture farms about 30%. Extruders come in several designs, dependent upon their application. Some extruders are designed simply to convey the raw materials, while others are designed to mix and knead them; most, however, are designed to impart mechanical and thermal energy to the raw materials to bring about desired physico-chemical changes. Extruders can be broadly categorized on the basis of the number of screws. The most used extruders are single- and twin-screw. Extruders with more than two screws have been used in the plastics industry but not in food processing **(Karwe *et al.*, 1992)**

The extruders used in the feed industry can be generally divided into two types, single screw and twin screw. There are several factors which contribute to the production of high-quality feeds in the extrusion process. These factors include various feed parameters aquaculture and extrusion processing parameters **(Nehu *et al.*, 2005)**.

Fayose *et al*. (2017) designed and tested a single screw starch extruder has been using locally available material sued to process cassava flour as a means of arresting post-harvest losses of starch-based crops. The extruder is the dry type, it has a capacity of 107.615 Mg h^{-1} (27.12 kg s^{-1}), approximately 4.5: 1 compression ratio and is powered by a 5.5 kW electric motor, a maximum temperature of 114°C was attained through viscous dissipation, up to an actual screw speed of 98.96 rpm and extruder efficiency of 64%. Barrel temperature varied directly with extrusion time in a polynomial trend while actual extruder screw speed and efficiency varied inversely with extrusion time and it is best fitted with a polynomial trend.

Ojo *et al*. (2014) evaluated the performance of a developed floating fish feed extruder was evaluated. They studied the effect of some parameters such as screw speeds (100, 150 and 200 rpm), moisture content of ration (20, 25, 30 and 35%), and die diameters (3, 5 and 9 mm) on specific mechanical energy requirements, expansion ratio, bulk density and pelleting efficiency were determined. Results showed that increasing the screw speed from 100 to 150 rpm tend to increase in extrusion efficiency from 63.25 to 68.50 %. And decrease in bulk density from 1.05 g cm^{-3} to 0.94 g m^{-3}, decrease in specific mechanical energy from 24.70 to 22.30 kJ kg^{-1}. By increasing the die diameter from 3 to 5 mm, the specific mechanical energy tends to reduce from 28.44 to 26.46 $kJkg^{-1}$. And increase extrusion efficiency from 63.25 to 68.00 %. Results also showed that increase in moisture content from 20 to 25 % tend to reduce the specific mechanical energy from 28.44 to 24.99 kJ kg^{-1} and increase the extrusion efficiency from 63.25 to 72 %.

Ojomo *et al*. (2006) designed and fabricated a pelletizing machine to produce fish feed. The performance evaluation of the machine was carried out to investigate the effects of moisture contents and the speed of operation on the performance of the machine. It was observed that the pelletizing efficiency, throughput capacity and the percentage recovery of the machine increased with the increase in moisture content and the speed of the machine. The machine showed higher throughput capacity of 19.7 kg h^{-1} with maximum pelletizing efficiency of 87.6%. Moisture content constituted a greater portion of variability in efficiency than speed.

Morad *et al*. (2007) evaluated the effect of some engineering parameters (screw speed, feed rate, number of die holes and effective hole thickness) on the performance of fish pelleting machine to produce high quality fish pellets. Evaluation of the fish pelleting machine performance was carried out taking into consideration extruder productivity, pelleting efficiency, pellets bulk density, pellets durability, energy requirements and pelleting cost. The obtained results revealed that pelleting machine has a high efficiency and minimum production cost and conditions of screw speed of 2.11 m s^{-1}. and feed rate of 432 kg h^{-1}. To minimize pelleting energy and high-quality fish pellets, effective hole thickness of 15 mm. and 31 die holes were used.

Fang *et al*. (2003) indicated that extruder feeding rate depends on the screw speed, screw configurations, extruder feeding system, and feed formulation moisture content. Feeding rate influences retention time, extruder torque, extruder barrel pressure and formula temperature.

Kaddour *et al*. (2006) evaluated the performance of extrusion machine by studying parameters (productivity, energy requirements and total losses). It was 0.399 Mg h^{-1}, 114.04 kW. h. Mg^{-1} and 5.21%, respectively.

Elleuch *et al*. (2010) indicated that higher screw speed (250 vs 200 rpm) decreased die pressure and torque percentage but increased specific energy. The increase in screw speed decreased radial expansion and bulk density but increased axial expansion and breaking strength. They found that for a given temperature and feed moisture, screw speed must be above a critical minimum value, typically 160-180 rpm at 150°C and 36-40% moisture content of extrusion texturing of defatted soy grits.

Fish feed extruders performance is deeply affected by the operational conditions. Unproper operational condition cause poor quality of feed and affect the productively of such machine, therefore, the main aim of the present work is to study and evaluate the effect of different operating and engineering parameters (screw speeds, feeding rates and die hole dimeters) on the performance of a locally made fish feed extruder (the productivity, total losses, energy consumption and costs).

1. MATERIALS AND METHODS.

The experiment was carried out at the laboratory of Agricultural and Bio-Systems Engineering Department, Faculty of Agriculture Moshtohor, Benha University, Kalubia Governorate, Egypt, during the period of June to October, 2021 season to determine the performance of a locally made extruder. It was affected by screw speed, feeding rate and die hole diameter.

2.1. Materials:

2.1.1. Description of the extruder machine:

The extruder consists of main parts main frame, feeding unit, extrusion unit, cutter unit and machine control panel as shown in Fig. (1).

2.1.1.1. Main frame:

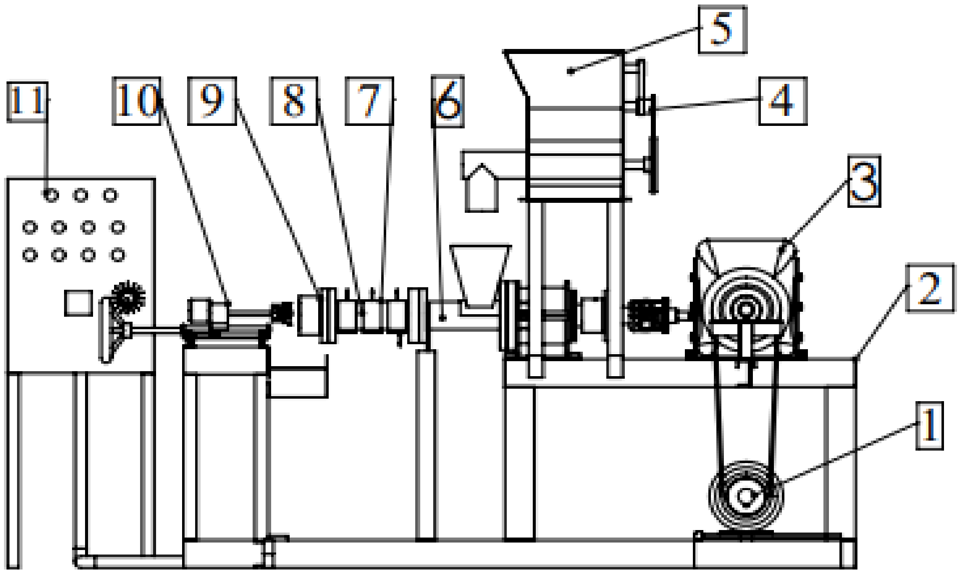
The main frame of extruder machine is of the main base which carrying all parts of the machine as main electric motor, means of movements, feeder unit, extrusion unit and cutters.

2.1.1.2. Feeding unit:

Feeding unit consists of feed hopper, feed screw and feed mixer.

- **Feed hopper:**

It is the part in which the ration prepared before extrusion stage. It constructed of iron sheet metal (3 mm thickness), with 300 mm length, 300 mm width and 300 mm height. Maximum capacity of feed hopper is about 10.5 kg. There is a gate at the bottom of the hopper to allow ration to flow to the extrusion unit.



1	Main motor(screw) 20 hp (15 kW)	7	Auger screw
2	Main frame base	8	Heaters
3	Gear box (corona)	9	Die
4	Feeding motor 0.375 kW	10	Cutter knifes
5	feeder	11	Control panel
6	Barrel		Dimension in mm

Fig. (1): Schematic diagram of the components of extruder.

- **Feed screw:**

A screw was fixed at the bottom of the feed hopper to transmit ration from feed unit to extrusion unit. The feed screw dimensions of 500 mm length, 100 mm diameter and 100 mm pitch, feed screw is powered by an electrical variable speed motor by means of two gears and sprocket. The motor gear is of 15 teeth and the screw shaft gear is of 15 teeth. Feed screw is powered by speed electrical motor.

- **Feed mixer:**

It is working inside the middle of feed hopper to mix and turn the ration. It consists of a shaft which has dimensions of 20 mm diameter and 200 mm lengths. Feeder shaft mixer takes the power from feeding screw shaft by two gears 1:1.

2.1.1.3. Extrusion unit

This unit is responsible for compressing and cooking the ration before the forming zone. It consists of barrel and main screw.

- **The barrel:**

It covered the screw and calculated all extrusion units. It has made of hard steel. it consists of two parts. the first part length of 2655 mm and pitch of 20 mm. the scend part length of 2550 mm and pitch of 20 mm, there were three heaters on this part, 2.2 A for each on connected to sensors to digital screen on the control panel to show temperature during working machine. The barrel is supported by two bearings.

- **Extruder screw:**

It considered the main pressing shaft. It has made of hard steel. It is one shaft dimensions of 600 mm length and 60 mm diameter. The screw consists of three zones Each zone has different dimensions. The first zone was 170 mm length, 40 mm diameter and pitch length of 45 mm replicated 5 times. The second zone was 170 mm length, 45 mm diameter and pitch length of 35 mm replicated 6 times. The third zone was 170 mm length, 50 mm diameter and pitch length of 35 mm replicated 7 times. The thickness of the pitch of 10mm. The tail of the shaft diameter of 20 mm where there is an incision at was end of the shaft to assemble as a keyway, to prevent slipping of extruder screw on the main shaft.

2.1.1.4. Forming unit: Feed unit consists of forming room, die and cutters knife

- **Forming room:**

It is the part which blocked the last cylinder from the end of extruder screw. The entry is of conical shape press and form ration through the hole to get the final product (pellets) and to help ration to flow easily inside the die hole. Clearance between the die and extruder screw was about 5 mm.

- **Die:**

The die (output area) at the end of can be changed to adapt the experimental ration treatment to control specification of the obtained pellets. There are holes on the die surface.

- **Cutter knifes:**

The knifes turn in a circular motion on die surface were used to cut the final product into small parts. It consists of four sharps blades. It was controlled by DC motor 24 rpm and 5 A. Obtained pellets length are controlled by changing knife speed through the motor speed, which controls cutting motor shaft speed.

2.1.2. Power transmission and electric control:

- **Main motor:**

The machine was powered by an electrical motor three face of 15 kW, 18 A and 1000 rpm. The power is transmitted to the extruder shaft by pulleys and V belts. The shaft diameter of the motor 115 mm. It connected with variable mechanical gearbox (corona)with reduction percentage 2.7:1 is used to control motor shaft speed.

- **Feeder motor:**

It was single face 0.3 hp ,0.8 A and 21 rpm. It is operated by pulleys, V belts and chains to change feed rate. Motor shaft speed ranged from 5 to 9 rpm. Power transmitted to feeder screw shaft and feeder mixer shaft by gears and sprockets.

- **Cutter motor**:

It connected to cutter knife by a shaft having dimensions of 200 mm length and 20 mm diameter. It was controlled by DC motor of 24 rpm and 5 A.

2.1.3. Measuring devices and tools:

The following measuring devices were used in this study:

- The clamp meter was used to determine the power requirement (kW) by recording the voltage and current strength (Model DT266 - Measuring range of 200/1000A and 750/1000V with an accuracy of ± 0.01, China) to measure the line current strength (I) and the potential difference value (V).

- Mobile stopwatch with 0.01 s accuracy was used to record the time to calculate the productivity.
- Digital balance was used to determine the mass of samples of pellets for measuring the productivity and losses (Model CG-12K – range 0 to 200 kg – accuracy ± 0. 01 kg, Japan).

2.2. Methods:

Experiments were conducted to optimize some operating and engineering parameters affecting the performance of fish pelleting extruder. To achieve that, the productivity, total losses, energy consumption and costs at three different screw speeds for extruder (200, 250 and 300 rpm) and three different feeding rates (70, 100 and 130 kg h^{-1} at three different screw speeds 5,7 and 9 rpm) at three different die hole dimeter (3, 4 and 5 mm) were studied.

2.3. Measurements and determinations:

2.3.1. Machine productivity:

The machine productivity (kg/h) was determined as the amount of the fish pellets mass during operation time. The machine productivity was estimated from the following equation:

$$\text{Pr} = \frac{L}{T} \qquad (1)$$

Where:

Pr is the machine productivity, kg h^{-1}

L is the wight of product, kg

T is the operation time, h

2.3.2. Total losses percentage:

Total losses percentage incurred by machine was estimated as follows:

$$P.L = \frac{Mass\ of\ respi - Mass\ of\ pelts}{Mass\ of\ respi} * 100 \qquad (2)$$

Where:

P.L is the percentage of loss, %

2.3.3. Power and energy requirement for extruder fish feed:

The total power requirement (electrical and human) for component of the machine was calculated. The procedures used could be explained as follows:

Electrical power requirements for the main motor was estimated from equation (3). A single face motors power of feeder and cutter were estimated from equation (4). The heaters were estimated from the measured electric current and voltage values and estimated according to **Kurt (l979)** as follows:

$$E_p = \frac{\sqrt{3} \times I \times V \times \eta \times \cos\varphi}{1000} \qquad (3)$$

$$EP = \frac{I \times V \times cos\,\theta}{1000} \quad (4)$$

Where:

E_p is the electrical energy, kW
I is the electric current, A
η is the mechanical efficiency assumed to be 0.95 **(Metwally, 2010).**
V is the electrical voltage, V
cos φ is the power factor being equal to 0.84

According to **Odigboh (1997)**, at the maximum continuous energy consumption rate of 0.30 kW and conversion efficiency of 25%, the physical power output of a normal human labor in tropical climates is approximately 0.075 kW sustained for an 8–10 h workday. This was calculated mathematically as:

$$E_m = 0.075N \quad (5)$$

Where:

E_m is the human power, kW
N is the number of persons involved in an operation.

The specific energy consumption was estimated by using the following equation:

$$SEC = \frac{P}{\text{Pr}} \quad (6)$$

Where:

P is the total power requirement, kW
SEC is the specific energy consumption, kW kg^{-1}

2.3.4. Total Costs

The cost calculation based on the following parameters was also performed:

2. 3.4.1. Fixed costs (Fc):

- Depreciation costs (D_c):

$$D_c = \frac{P_d - S_r}{L_d} \quad (7)$$

Where:

Dc is the depreciation cost, LE $year^{-1}$.

P_d is the extruder price, 65000 LE.

Sr is the salvage rate ($0.1P_d$) LE.

Ld is the extruder life, 5 years.

- Interest costs (In):

$$I_n = \frac{P_d + S_r}{2} \times i_n \quad (8)$$

Where:

I_n is the interest, LE $year^{-1}$.
i_n is the interest as compounded annually, decimal. (12%)

- Shelter, taxes and insurance costs (Si):

Shelter, taxes and insurance costs were assumed to be 3 % of the purchase price of the extruder (P_m).

Then:

$$\text{Fixed cost (LE h}^{-1}) = Dc + In + 0.03\ Pm \,/\, \text{hour of use per year} \quad (9)$$

2. 3.4.2. Variable (operating) costs (V_c): F

- Repair and maintenance costs (R_m):

$$R_m = 100\ \%\ \text{deprecation cost / hour of use per year} \quad (10)$$

- Energy costs (E):

$$E = EC \times EP \quad (11)$$

Where:

E is the energy costs, LE h^{-1}.

EC is the electrical energy consumption, kWh.

EP is the energy price, 0.57 LE kW^{-1}.

- Labor costs (La):

$$La = \text{Salary of one worker} \times \text{No. of workers} \quad (12)$$

Where:

La is the Labor costs, LE h^{-1}.

Salary of one worker = 10 LE h^{-1}.

No. of workers = 3

Then:

$$\text{Variable costs (LE h}^{-1}) = R_m + E + La \quad (13)$$

Total costs (Tc):

$$\text{Total costs (LE h}^{-1}) = \text{Fixed costs (LE h}^{-1}) + \text{Variable costs (LE h}^{-1}) \quad (14)$$

3. RESULTS AND DISCUSSIONS

3.1. Machine productivity:

The results indicated in figure (3) shows that the machine productivity is greatly affected by those factors where, it increased by increasing the obtained factors. The obtained results indicated that increasing screw speed from 200 to 300 rpm increased the extruder productivity from 62.24 to 63.52 kg h^{-1}, 84.8 to 85.63 kg h^{-1} and 103.39 to 105.09 kg h^{-1} when feeding rate 70 ,100, 130 kg h^{-1}, respectively at constant die hole dimeter of 3 mm.

The same trend was noticed with die hole dimeter of 4, 5 mm and increasing screw speed from 200 to 300 rpm when feeding rate increased 70 to 130 kg h^{-1}. The machine productivity increased from 62.91 to 64.05 kg h^{-1}, 84.99 to 86.36 kg h^{-1} and 105.09 to 106.56 kg h^{-1}, respectively at die hole dimeter 4 mm, but it was 63.65 to 64.65 kg h^{-1}, 86.08 to 87.27 kg h^{-1} and 106.33 to 107.58 kg h^{-1}, respectively at die hole dimeter 5mm.

The results also indicated that the highest rate of machine productivity 107.58 kg h^{-1} which was consumed at the highest values for screw speed, feeding rate and die hole dimeter which estimated 300 rpm, 130 kg h^{-1}, 5mm respectively. On the other hand, the lowest rate of machine productivity 62.24 kg h^{-1} which was obtained at the lowest screw speed, feeding rate and die hole dimeter 200 rpm, 70 kg h^{-1}, 3 mm respectively. which means using the lowest speed could took longer time to get the two amounts of feed pellets compared to higher speed. Generally, machine productivity at the highest screw speed, feeding rate and die hole dimeter were almost twice, when using lowest screw speed, feeding rate and die hole dimeter.

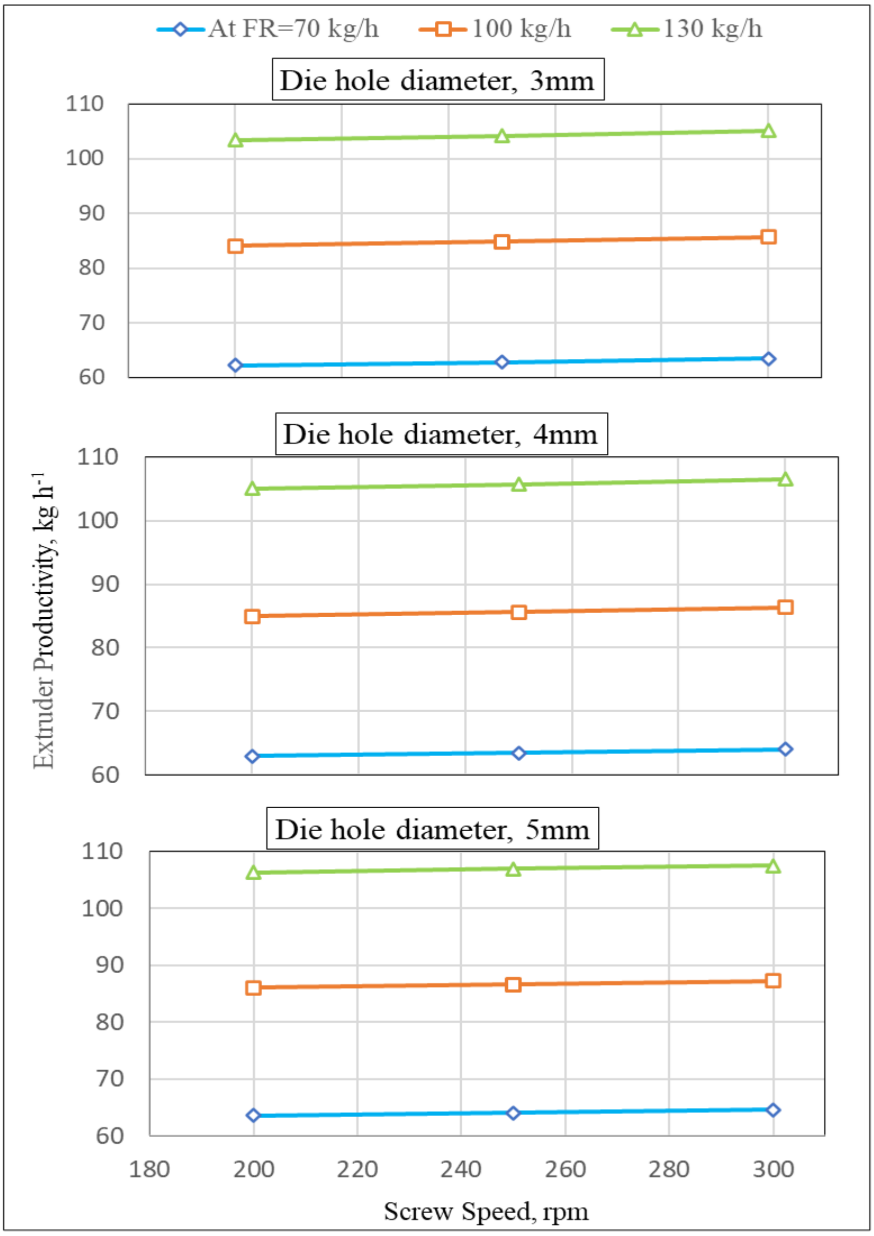


Fig. (3): Effect of screw speed, feeding rate and die hole dimeter on the fish feed extruder productivity.

The increase in machine productivity by increasing the speed of main motor can be due to the increase in ration quantities that pass through the extruder in short time. Increasing the extruder production rate by increasing the feeding rate can be due to the increase in ration quantities that pass through the extruder and exit the die slots in the same unit time. The increase in extruder production by increasing the die hole diameter on the same outlet surface can be due to the increased output area which helps the recipe to quickly eject the die holes, resulting in a noticeable reduction in processing time. Those results agree with those obtained by **Morad *et al* (2007).**

Multiple regression analysis was carried out to obtain a relationship between the extruder productivity as dependent variable screw speed, feeding rate and die hole diameter as independent variables. The best fit for this relationship is presented in the following equation:

$$EP = 0.013\,(SS) + 0.70\,(FR) + 0.97\,(DD) + 7.44 \qquad R^2 = 0.99 \qquad (15)$$

Where:

EP: is the extruder productivity, kg h^{-1}

SS: is the screw speed, rpm.

FR: is the feeding rate, kg h^{-1}

DD: is the die hole diameter, mm.

R^2: is the coefficient of determination.

This equation is valid in the range of 200 to 300 rpm for SS, 70 to 130 kg h^{-1} for FR and from 3 to 5 mm for DD, respectively.

3.2. Total losses percentage of extrudate:

Figure (4) shows effect of different screw speeds of main motor, feeding rate and die hole dimeter (output area) on extrude total losses percentage. The results indicate that the total losses percentage decreased by increasing both screw speeds of main motor and feeding rate but increased by increasing die hole dimeter (output area). The results indicated that increasing screw speed from 200 to 300 rpm and feeding rate changed from 70 to 130 kg h^{-1} at constant die hole dimeter of 3 mm, the total losses percentage decreased from 3.48 to 2.68 %, 3.01 to 2.14 %, and 2.65 to 1.69 %, The same trend was noticed with die hole dimeters of 4 and 5 mm. The total losses percentage also decreased from 3.96 to 3.01 %, 3.39 to 2.40 % and 3 to 2.08 %, respectively at die hole dimeter 4 mm, but it was 4.64 to 3.55 %, 3.91 to 2.81 % and 3.46 to 2.82 %, respectively at die hole dimeter 5mm.

The results also indicated that the highest rate of the losses percentage 4.64 % which happened at the smallest screw speed (200 rpm), the smallest feeding rate (70 kg h^{-1}) and the largest die hole dimeter (5mm) respectively. On the other hand, the lowest rate of the losses percentage was 1.69 % which was obtained at the highest screw speed, the highest feeding rate and the smallest die hole dimeter 300 rpm, 130 kg h^{-1}, 5mm respectively which means using the higher feeding rates may decreased the losses. This is due to the barrel in extrusion unit was fully loaded with recipe so increased the compression.

Multiple regression analysis was carried out to obtain a relationship between the total losses percentage as dependent variable screw speed, feeding rate and die hole diameter as independent variables. The best fit for this relationship is presented in the following equation: -

$$TL = -0.01\,(SS) - 0.015\,(FR) + 0.64\,(DD) + 5.06 \qquad R^2 = 0.97 \qquad (16)$$

Where:

TL: is the total losses percentage, %

This equation is valid in the range of 200 to 300 rpm for SS, 70 to 130 kg h^{-1} for FR and from 3 to 5 mm for DD, respectively.

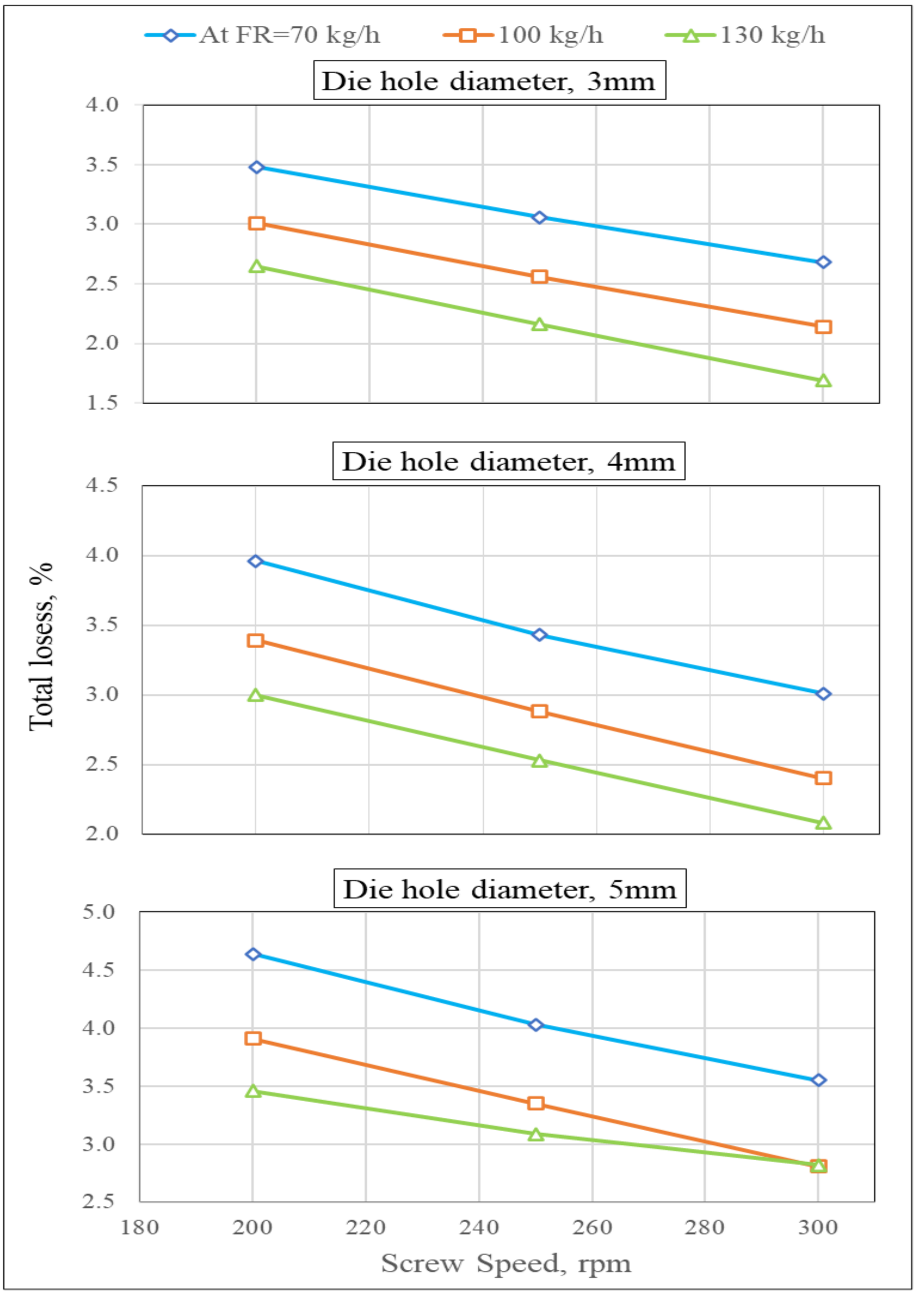


Fig. (4): Effect of screw speed, feeding rate and die hole dimeter on the total losses percentage of extrudate.

3.3. The specific energy consumption for extrusion process (SEC):

The extruded aquatic feed pellets energy requirements depend theoretically on consumed power and productivity, also depend practically on the effect of the different operating parameters such as, screw speed, feed rate. and die hole diameter. Figure (5) shows effect of different screw speeds of main motor, feeding rate and die hole dimeter (output area) on the specific energy consumption. The results indicate that the energy requirements increased by increasing screw speeds of main motor, but it decreased by increasing both die hole dimeter (output area) and feeding rate. Increasing screw speed from 200 to 300 rpm and feeding rate changed from 70, 100 to 130 kg h^{-1} at constant die hole dimeter of 3 mm increased the energy consumed from 0.218 to 0.223 kWh kg^{-1}, 0.172 to 0.180 kWh kg^{-1}, and 0.148 to 0.151 kWh kg^{-1}, The same trend was noticed with die hole dimeters of 4 and 5 mm.

The energy requirements increased from 0.204 to 0.217 kWh kg^{-1}, 0.157 to 0.167 kWh kg^{-1} and 0.132 to 0.139 kWh kg^{-1}, respectively at die hole dimeter 4 mm, but it was 0.200 to 0.210 kWh kg^{-1}, 0.154 to 0.158 kWh kg^{-1} and 0.126 to 0.132 kWh kg^{-1}, respectively at die hole dimeter 5mm.

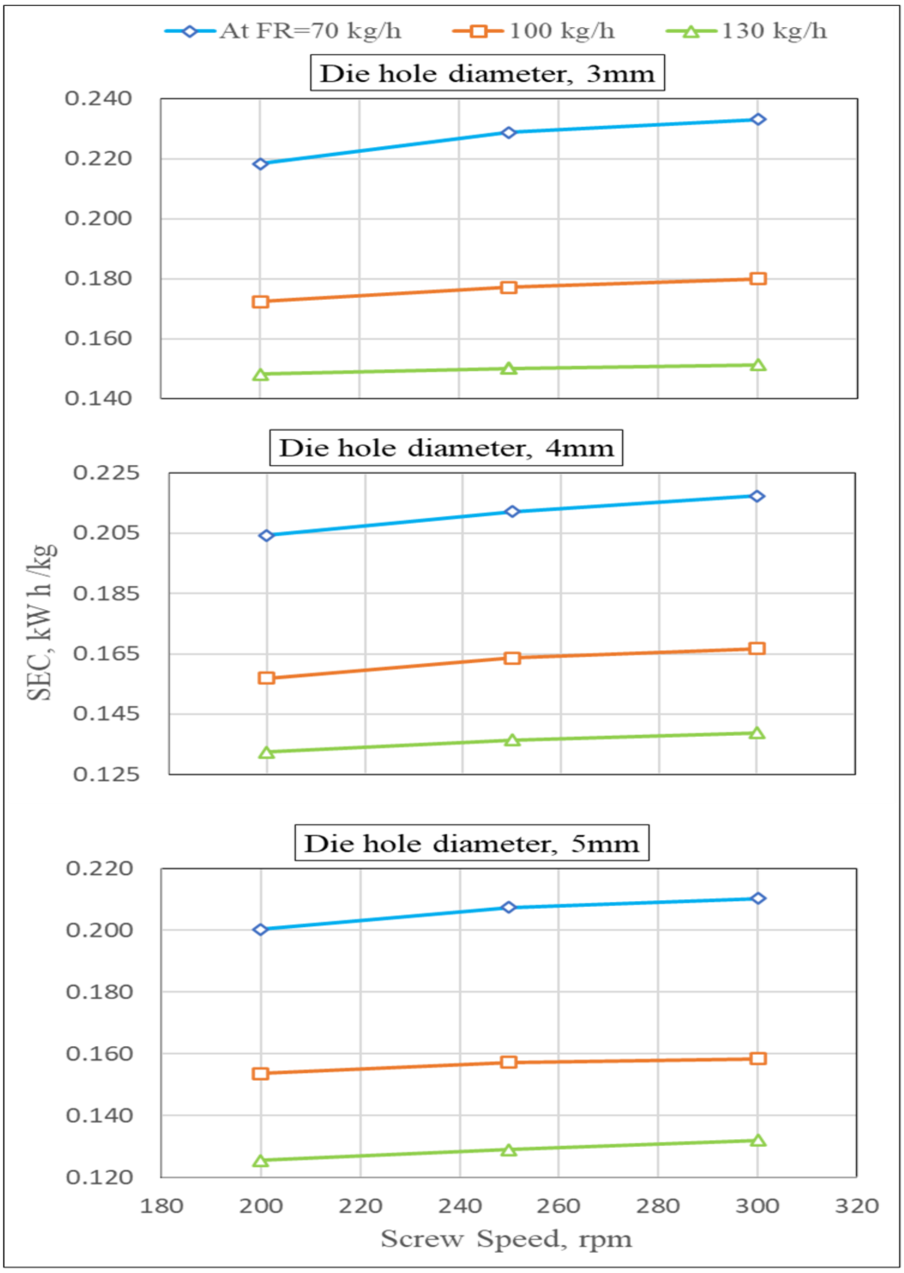


Fig. (5): Effect of screw speed, feeding rate and die hole dimeter on the specific energy consumption for fish feed extruder.

The results also indicated that the highest rate of the energy requirements approximately 0.233 kWh kg^{-1} which was happened at the largest screw speed (300 rpm), the lowest feeding rate (70 kg h^{-1}) and the smallest die hole dimeter which recorded 3 mm. On the other hand, the smallest rate of the energy requirements approximately 0.126 kWh kg^{-1} which was obtained at the smallest screw speed, the largest feeding rate and the largest die hole dimeter 200 rpm, 130 kg h^{-1}, 5mm respectively which means using the higher feeding rates may decreased the energy requirements.

The increase in energy requirements by increasing screw speed could be due to the high increase in the required power and at the same time insignificant increase in production rate was occurred. While the decrease in energy requirements by increasing feed rate, could be due to the increase in extruder productivity in the same time unit more than the increase of the required power.

The decrease of energy requirements by increasing die hole diameter could be due to the increase in output area that caused a decrease in the pressure load and the required power and increases the treatment production rate at the same time.

Multiple regression analysis was carried out to obtain a relationship between the specific energy consumption as dependent variable screw speed, feeding rate and die hole diameter as independent variables. The best fit for this relationship is presented in the following equation:

$$SEC = 8.4E - 5\,(SS) - 0.001(FR) - 0.01\,(DD) + 0.32 \qquad R^2 = 0.96 \quad (17)$$

Where: SEC: is the specific energy consumption, kWh kg^{-1}

This equation is valid in the range of 200 to 300 rpm for SS, 70 to 130 kg h^{-1} for FR and from 3 to 5 mm for DD, respectively.

3.4. Total costs of fish feed production

Decreasing the industrial cost is considered one of the most important aims of any project. The selection of operating parameters which decreases operating cost with high quality product still very difficult question in fish feed industry field. Figure (6) shows effect of different screw speeds of main motor, feeding rate and die hole dimeter (output area) on the total costs for extrusion process.

The data show that increasing both the screw speed, feeding rate and die hole dimeter, pelleting cost decreased. Increasing screw speed from 200 to 300 rpm and feeding rate changed from 70 to 130 kg h^{-1} at constant die hole dimeter of 3 mm the cost increased from 1.081 to 1.070 LE kg^{-1}, 0.806 to 0.798 LE kg^{-1}, and 0.660 to 0.653 LE kg^{-1}, the same trend was noticed with die hole dimeter of 4, 5 mm. The cost also increased from 1.062 to 1.053 LE kg^{-1}, 0.790 to 0.784 LE kg^{-1}, and 0.642 to 0.638 LE kg^{-1}, respectively at die hole dimeter 4 mm, but it was 1.049 to 1.040 LE kg^{-1}, 0.779 to 0.772 LE kg^{-1}, and 0.631 to 0.628 LE kg^{-1}, respectively at die hole dimeter 5mm. The results also indicated that the highest rate of the cost approximately 1.081 LE kg^{-1} which was consumed at the lowest screw speed, the smallest feeding rate and the smallest die hole dimeter which recorded 200 rpm, 70kg h^{-1}, 3 mm respectively. On the other hand, the smallest rate of the cost approximately 0.628 LE kg^{-1} which was obtained at the highest screw speed, the highest feeding rate and the highest die hole dimeter 300 rpm, 130 kg h^{-1}, 5mm, respectively.

Pelleting cost decreased by increasing the screw speed because of increase in extruder productivity during the same time. While the high decrease of pelleting costs by increasing feed rate could be due to the high increase in extruder productivity with low increase in extruder power consumed. The sharply decrease in pelleting costs by increasing the die holes dimeter could be due to the increase in die opening area, it caused more increase in extruder productivity and decreased the load on extruder motor caused high decrease in extruder power consumed.

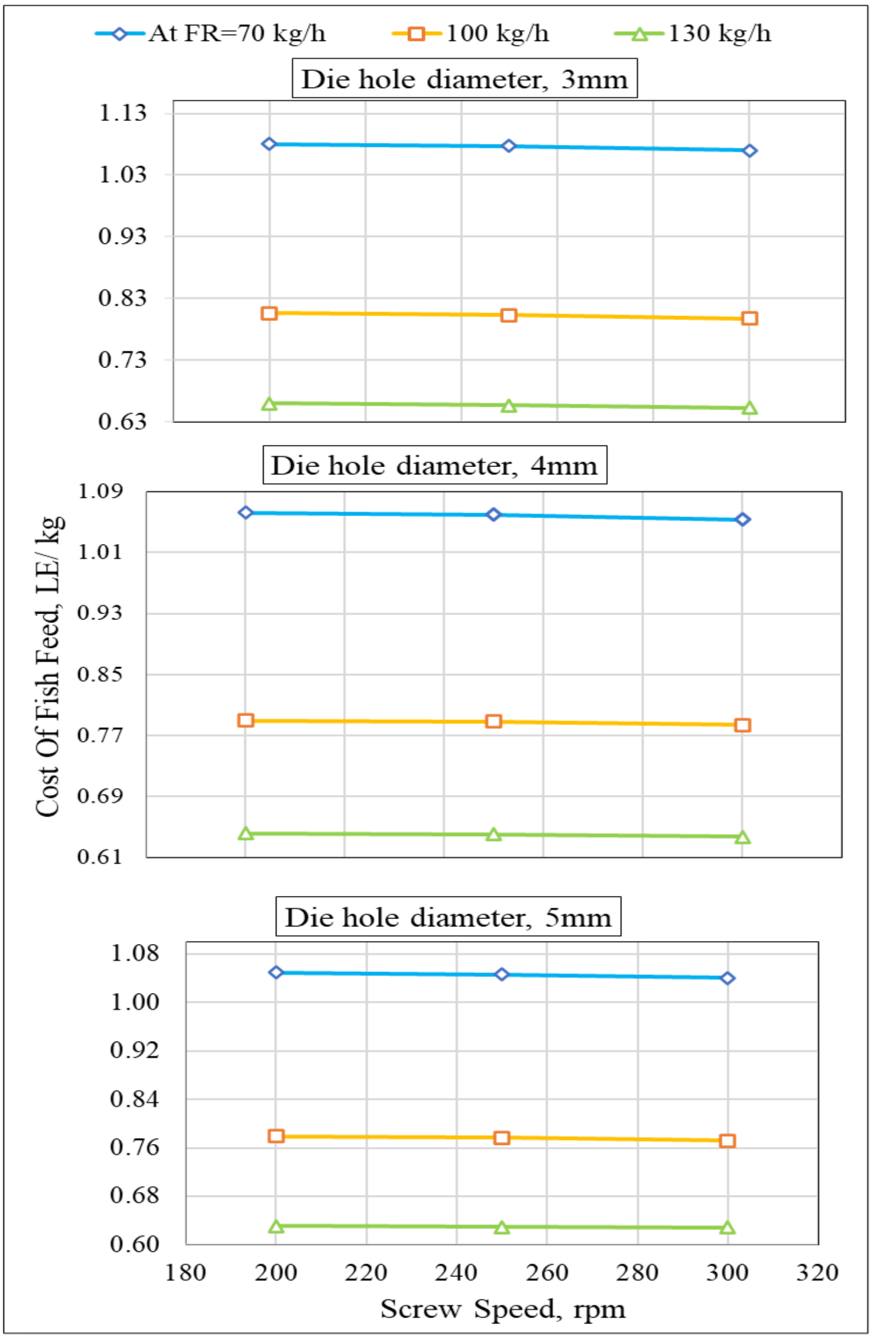


Fig. (6): Effect of screw speed, feeding rate and die hole dimeter on the cost of fish feed extruder.

Multiple regression analysis was carried out to obtain a relationship between the cost per kg of feed as dependent variable screw speed, feeding rate and die hole diameter as independent variables. The best fit for this relationship is presented in the following equation: -

$$C = -7.2E - 5\,(SS) - 0.007(FR) - 0.01\,(DD) + 1.6 \quad R^2 = 0.96 \qquad (18)$$

Where: C is the cost per kg of feed, LE kg^{-1}

This equation is valid in the range of 200 to 300 rpm for SS, 70 to 130 kg h^{-1} for FR and from 3 to 5 mm for DD, respectively.

3.5. The relationship between the extruder productivity (EP)**, the specific energy consumption (SEC), and the cost of fish feed production (C):**

Table (1) shows the relationship between EP, SEC and C as affected by different screw speeds (SS), feeding rates (FR) and die hole diameters (DD). At 70 kgh^{-1}FR, the minimum EP 62.6 kgh^{-1} consumed 0.228 kWh kg^{-1} and costed 1.077 LE kg^{-1} at different SS and DD 3mm, Meanwhile, the maximum EP 64.2 kgh^{-1} was obtained at DD 5mm and consumed 0.208 kWh kg^{-1} and costed 1.045 LE kg^{-1}. At 100 kgh^{-1} FR, EP ranged from 84.81 to 86.7 kgh^{-1}, ESC decreased from 0.177 to 0.157 kWh kg^{-1} and C decreased from 0.803 to 0.776 LE kg^{-1} of fish feed when SS ranged from 200 to 300 rpm and DD ranged from 3 to 5mm. At 130 kgh^{-1} FR, EP increased from 104 to 106.8 kgh^{-1} when SS increased from 200 to 300 rpm. Energy consumed decreased from 0.15 to 0.128 kWh kg^{-1} and C decreased from 0.657 to 0.63 LE kg^{-1} of fish feed.

Table (1): The relationship between P, SEC, and C as affected by SS, FR and DD.

FR, kg h^{-1}	DD, mm	SS, rpm	EP, kg h^{-1}	SEC, kW h kg^{-1}	C, LE kg^{-1}
70	3	200	62.6	0.228	1.077
		250			
		300			
	4	200	63.5	0.214	1.059
		250			
		300			
	5	200	64.2	0.208	1.045
		250			
		300			
100	3	200	84.81	0.177	0.803
		250			
		300			
	4	200	85.63	0.164	0.788
		250			
		300			
	5	200	86.7	0.157	0.776
		250			
		300			
130	3	200	104	0.15	0.657
		250			
		300			
	4	200	105	0.137	0.64
		250			
		300			
	5	200	106.8	0.128	0.63
		250			
		300			

4. CONCLUSION

The effect of some engineering parameters (screw speed, feeding rate and die hole diameter) on the performance of a locally made extruder were studied. The results indicated that the extruder productivity increases with increasing screw speed, feeding rate and die hole diameter. The total losses percentage ranged from 1.69 to 4.64 %. The specific energy consumption ranged from 0.126 to 0.233 kWh kg^{-1}. Also, the cost of fish feed extruder ranged from 0.628 to 1.081 LE kg^{-1} of fish feed. The results also indicated that the extruder productivity increased but the specific energy consumption and the cost of fish feed decreased by increasing screw speed, feeding rate and die hole diameter.

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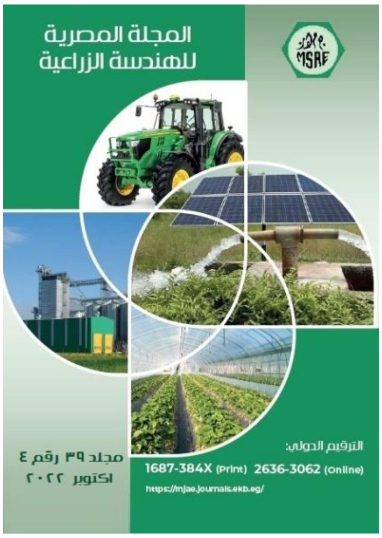
تأثير بعض العوامل الهندسيه على أداء باثق لاعلاف الأسماك مصنع محليا

إسلام العادلى[١]، وعادل حامد بهنساوى[٢]، سمير أحمد على[٢] والسيد جمعه خاطر[٣]

[١] طالب دكتوراة - قسم هندسة النظم الزراعية والحيوية - كلية الزراعة - جامعة بنها - مصر.

[٢] استاذ - قسم هندسة النظم الزراعية والحيوية - كلية الزراعة - جامعة بنها - مصر.

[٣] استاذ مساعد - قسم هندسة النظم الزراعية والحيوية - كلية الزراعة - جامعة بنها - مصر.



الكلمات المفتاحية:
الانتاجية؛ سرعة اللولب؛ الطاقة المستهلكة؛ التكاليف؛ باثق أعلاف الاسماك.

الملخص العربي

الهدف الرئيسي من هذا البحث هو دراسة وتقييم تأثير بعض المتغيرات الهندسية (سرعة اللولب، معدل التغذية وقطر فتحه الخروج من الطارد) على أداء آلة باثق محلية الصنع. تمت دراسة إنتاجية الماكينة ونسبة الفاقد الإجمالية واستهلاك الطاقة والتكلفة لكل كيلوغرام من العلف بثلاث سرعات دورانيه مختلفة للمحرك الرئيسي للطارد (٢٠٠ و٢٥٠ و٣٠٠ لفه في الدقيقة) وثلاث معدلات تغذية مختلفة (٧٠ و ١٠٠و ١٣٠ كجم / ساعة) وثلاثة مقاييس مختلفة لقطر فتحه الخروج من الطارد (٣ و ٤ و ٥ مم).

أشارت النتائج إلى أن إنتاجية الماكينة تتراوح بين ٦٢,٢٤ و١٠٧,٥٨ كجم /ساعة عند سرعة دورانيه ٢٠٠ و ٣٠٠ لفه في الدقيقة وقطر فتحة خروج ٣ و ٥مم ومعدل تغذية٧٠ و١٣٠ كجم / ساعة على الترتيب. كما أظهرت النتائج ان اعلى معدل الفاقد في الانتاجية وسببه عوامل التشغيل والفقد فى المحتوى الرطوبى لمادة العليقة كانت ٦٤,٦٤% عن اقل سرعة دورانية (٢٠٠ لفة/دقيقة) واقل معدل تغذية (٧٠ كجم / ساعة) واكبر قطر لفتحة الخروج من الطارد (٥ مم). تراوحت نسبة الخسائر الإجمالية من ١,٦٩ إلى ٤,٦٤٪. تراوح استهلاك الطاقة المحدد من ٠,١٢٦ إلى ٠,٢٣٣ كيلو واط ساعة /كجم. كما تراوحت تكاليف تشغيل الباثق من ٠,٦٢٨ إلى ١,٠٨١ جنيه مصري /كجم من العلف لكل العوامل تحت الدراسة.