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Impact of Die Surface Holes Distribution Patterns of Fish Feed Extruder on Performance Indicators and Pellets Quality

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Radwan, M. E.[1]; R. I. Zaki[1] ; A. F. El-Said[1] and K. A. Metwally[2*]

[1]Central Laboratory for Aquaculture Research, Agriculture Research Center, Abbassa, Abu-Hammad, Sharkia, Egypt
[2] Soil and Water Sciences Department, Faculty of Technology and Development, Zagazig University, 44511 Zagazig, Egypt

ABSTRACT

Die holes distribution is the most important factor of any feed pelleting system, as far as machine efficiency is concerned. This study was carried out with fish diet, where had been processed without steam addition (cold pelleting). The aim of the study was to explore the impact of fish feed extruder die surface holes distribution patterns on extruder productivity, total consumed power, specific energy requirements, pelleting efficiency, pellets bulk density and durability and economical evaluation. The optimum results were recorded with die that had holes distributed in the surface of die in star pattern, observed improvement in extruder productivity, pellets durability and pelleting efficiency by up to 10.75 and 15.64 %, 0.51 and 4.74 % , 0.53 and 1.63 %, respectively at constant moisture content of 36 % and screw speed of 96 rpm(12.7 m. min-1), comparing to triangular pattern and scattering pattern respectively, and decreased, bulk density, total consumed power, specific energy requirements and pelleting cost by up to 1.86 and 6.27 %, 14.98 and 47.34%, 12.2 and 6.2 % , 28.8 and 35.6%, respectively at constant moisture content of 36 % and screw speed of 96 rpm (12.7 m. min-1), compared to triangular pattern and scattering pattern respectively.

Keywords: Extruder Performance - Holes Patterns - Pellets Quality - Fish Feed

INTRODUCTION

Physical quality enhancement of extruded fish feed pellets, approaches some of the biggest challenges within the production of high performance feed (Dethlefsen, 2017). Extrusion can be an alternative process for aquaculture feed production, increasing the digestibility, and functional properties of the aquaculture feed, such as water stability and floatability, the thermal process during extrusion decreases the antinutritional factors present in legumes or other agro-industrial by-products, such as trypsin inhibitors and lectins (Delgado and Reyes-Jaquez, 2018). There are several factors that affect pellet quality or pellet durability index, pellet quality is influenced by factors unrelated to the pelleting process. In other words, only 40, 20, 15 and 5% of pellet quality is dictated by the pellet mill, conditioning, die specification and cooling and drying of the pellets respectively (Reimer, 1992). The physical consistency of a pelleted fish feed is determined by the functional properties of feed ingredients, which account for 40% of pellet quality, as well as the machinery, processing, and system variables used in the manufacturing process. The most important factor associated with pelleting in the die because of the large number of variables associated with the number and position of the holes, and overall die diameter and length. These last two parameters and their relationship will give the pellet mill compaction capacity for a given die length, the wider the hole, the lower the pressure and the lower the compaction, equally the longer the hole, the longer the time the meal will take to leave and the bigger the compaction.They showed that the length of pellets ranging between 0.8 and 1 cm (Balss and Wisman, 1998). Extrusion process parameters like the type of extruder, length of barrel, feed rate, speed, screw configuration; moisture content and so on can also be attributed to the system parameters, system parameter are a type of extruder, length of the barrel, feed rate, screw speed, moisture content, screw configuration etc. and momentum transfer parameters are; viscosity, torque, specific mechanical energy, extrusion pressure, and mass flow rate *etc* and thus to optimize and scale up the process appropriately (Kokini *et al.* 1992; Bouvier, 2001). The geometry of the extrusion die, as well as operating conditions such as temperature of control, flow rate, and melt theological parameters, affect extrusion defects (such as weld lines, a fairly uniform exit velocity distribution within the extrusion, and problems with stagnation zones) (Lebaal, *et al.* 2005). Four different die patterns and numerous operating requirements (including temperature and moisture level) were measured to evaluate a die design procedure that yielded a uniform velocity profile of extruded, the operating terms that influenced the velocity profile, the velocity deviations among the center and edge of extruded were more than 10% at the studied conditions, the die pattern was the main factor in realizing uniformity in velocity profile and thickness of extruded, when a concave-concave die with proper curvature was used, while uniform speed and thickness of extruded were attained, with less than 5% speed deviations and thickness deviations between center and edge of extruded of mostly less than 10 % (Yeh and Hwang, 1995). The following are the operating conditions that have affected the consistency of pellet feed; a) Die thickness as related to the diameter of the hole is a factor in quality; b) Speed of ration should be also considered for each die thickness/hole diameter combination; c) The speed at which feed is introduced into the feed conditioning chamber affects the moisture content and temperature relationship which, in turn relates to the quality of pellet (Hasting, 2003). Rising of extruder speed of single screw from 1.01 to 1.4 and

*** Corresponding author.**
E-mail address: khametwally@zu.edu.eg
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up to 1.81 m/s leads to plummeting the consumed power by 12.72 and 16.20% with milling fineness degree of 2 mm, holes number of 22 using effective diameter of hole of 25.5 mm moreover raised the consumed power by rising the effective hole from 19.5 to 25.5 mm, by 8.89, 11.72 and 17.80 % at screw speed of 1.81 m/s. and holes number of 22 using fine quality degree of 1, 2, and 3 mm, respectively, and increasing the holes number up to 30 holes decreased the energy requirement by 75.23% by using a screw speed of 1.81 m/s. and effective hole of 25.5 mm. using a milling fineness degree of 2 mm (Kaddour, 2003). Both ingredients components and the geometrical size of die are the main effective measurements that affect the pelleting machine efficiency and the quality of produced pellets, the pelleting machine with different dies was used for the two different types of rations and acquired into account the profitable design measurements, percentage of die opening area and thickness of die, machine parameters (productivity, energy consumption and total losses), and quality of pellets (pellets durability, pellets density, and hardness of pellets) the optimum conditions for producing a good quality of pellets from standard ration were 1.92 L/D ratio, 18 mm hole entry diameter, 5.33 % die opening area, and 30 mm thickness of die (Kaddour, *et al*. 2006). Design and fabricated of a fish feed extruder with improved qualities and affordable cost, the design was carried out using engineering principles with due consideration to cost, ease of operation, serviceability, durability and performance (Odesola *et al*., 2016). Design and produced of a fish feed pelletizing machine, the test determined the performance of the pelletizer was carried out which showed a throughput capacity of 17 $kg.h^{-1}$, efficiency of machine and pelletizing of 73.33 and 90.90% respectively, with low mechanical damage of 9.10%, the cylindrical pellets size produced by the pelletizer was in the range of 2–8 mm diameter, which is suitable for fish and poultry farming (Okolie *et al*., 2019). A fish feed pelletizing machine's design, fabrication, and performance evaluation, using different die diameters of 2, 4 and 6 mm, and different moisture content of 10, 15, 20, 25, 30 and 35% wet basis, the pelletizing efficiency increased as moisture content and die diameter increased, the machine productivity also increases with both moisture content and die diameter and highest efficiency of 98% was obtained when the moisture content was maintained at 25% wet basis, the feed materials were made to pass through 6 mm die diameter (Orimaye, 2019). The performance evaluation of floating fish feed extruder from where of machine parameters such as; screw rotational speeds of 158.5, 225 and 334 rpm, die size of 4, 6 and 8 mm and feed materials moisture content of 20, 30, 40 and 50%, on specific energy requirements, expansion ratio, bulk density and pelleting efficiency were determined, increasing of the speed from 158.5 to 225 rpm due to increase extrusion efficiency from 64 to 68 %, decrease in the bulk density from 1.05 to 0.95 g,cm^{-3} and decrease in specific energy from 26.40 to 24.20 $kJ.kg^{-1}$, by enlarging the die size from 3 to 5 mm, due to reduce in specific energy from 28.40 to 26.60 $kJ.kg^{-1}$ and bulk density from 1.05 to 0.95 $g.cm^{-3}$ in contrary, increase extrusion efficiency from 64.00 to 68.00% and increase in moisture content from 20 % to 30 % tend to reduce the specific mechanical energy from 28.40 to 26.60 $kJ.kg^{-1}$, reduce bulk density from 1.05 to 1.00 $g.cm^{-3}$, and increase the extrusion efficiency from 64.00 to 72.00 %. (Ogundana *et al*., 2021). So, the main aim of this work is studying the impact of fish feed extruder die surface holes distribution patterns on indicators to machine/extruder (productivity, total consumed power, and specific energy requirements) and on feed pellets quality - indicators to ration- (efficiency, bulk density and durability) and economical evaluation.

MATERIALS AND METHODS

The main experiments were carried out in central laboratory for aquaculture research in Abbassa village, Sharkia Governorate.

1- Composition of the experiment ration.

The trial ration prepared by a hammer mill, the ration particles fineness were average 1mm mixed in forage mixer with 25 , 35 , 45% moisture of total mass moisture content. The composition of the trial ration is shown in table (1) according to the obtained knowledge from fish feeding researches section of central lab for Aquaculture Res. Agric Res. Center, Egypt.

Table 1. Ingredients of trial ration

Ingredients	%
Yellow Corn grains	31
Soy-bean meal	32.1
Wheat bran	21.33
Fish meal	8
Fish oil	2.38
Grain oil	1.19
Premix	1
Binding agent (starch)	2
Salt	1

2- Pelleting machine /extruder

The tested machine was fabricated in Italy model l 5 to produce fish feed with diameter of pellet 3mm the construction feature of the machine mainly consist of the following units Fig. 1:

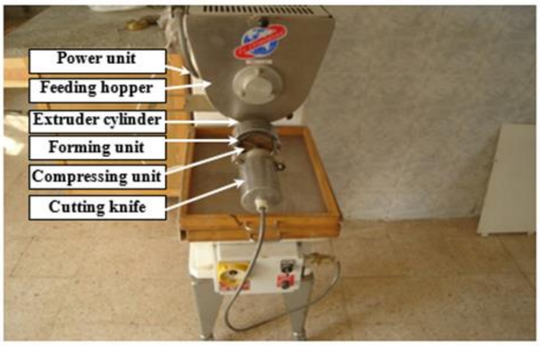


Fig.1. Extruder pelleting machine

Feeding hopper:

Feeding hopper is the part that contains the prepared ration before extrusion stage. It made from iron steel metal 2mm thickness, with 360 mm. length, 280 mm. width and 620 mm. height. Its maximum capacity is about 8 kg., and has a gate at the bottom to control of the ration flow through it to the extrusion unit. There is also a mixer inside the middle of feeding hopper for mixing the ration. It consists of a shaft with dimensions of 22 mm. diameter and 360 mm. lengths. 6 blades are fixed on the shaft and take the power from the main motor of the machine.

Extrusion unit:

This unit is responsible for compressing the ration before the forming zone, it consist from:

a- Extruder cylinder:

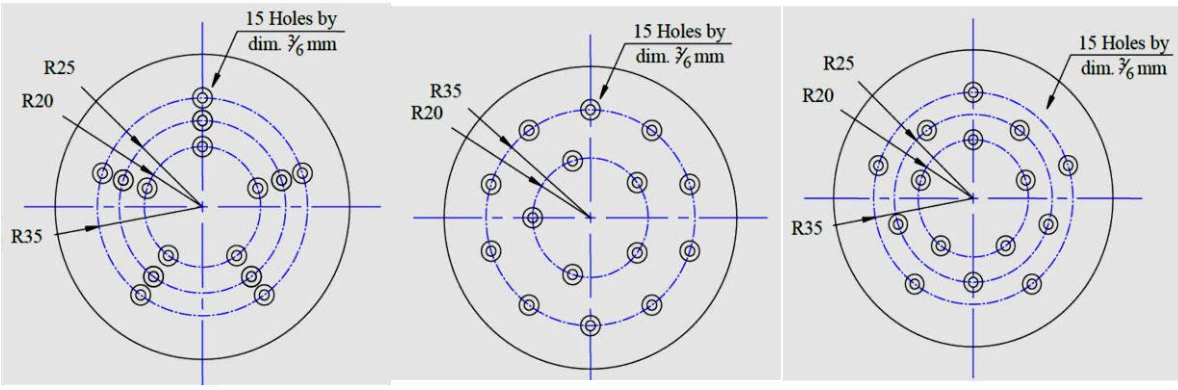
The extruder cylinder made of steel used for covering compressing screw unit. There is a square hole in cylinder under feeding unit to receive the ration. the dimension of extruder cylinder was (450 mm long, 50 mm internal diameter, and 6mm thick) , whereas the last cylinder unit named die house with dimension of (70mm long, 80 mm internal diameter and 40mm thick) and content two bolts to hold cutter knife motor. the internal surface of the cylinder has incisions to impress the meal pass forward with the screw direction.

b- Compressing unit:

Compressing unit consists of shaft and screw fixed on shaft, made of steel metal, and shaft has dimensions of 50 mm length 16 mm diameter and screw has dimension of 400 mm length, 42 mm diameter and pitch of 20 mm.

Forming unit (die):

Forming unit is the last blind part of the cylinder which contain the extruder screw, that called a die, clearance between the die and machine screw around 10 mm. The die dimensions are 90 and 80 mm. diameter external and internal, respectively, and 25 mm. total thicknesses, it's named die effective hole thickness which has a straight distance to press and form ration throw the hole to get the final product (pellets), number of holes were 15 holes, Holes distributed on the surface of the die in three of patterns, star pattern as Fig. (2,a), triangular pattern as Fig. (2,b) and scattering pattern as Fig. (2,c). Each hole consists of interior diameter has dimensions of 6 mm. diameter , and 15 mm. length, and exterior diameter has dimensions of 3 mm. diameter and 5 mm. length.



(a) Star pattern **(b)Triangular pattern** **(c) Scattering pattern**

Fig. 2. Different patterns/shapes of surface holes distribution of extruder die

Cutter knife:

Cutter knife rotates on die surface to cut the pellet into small parts by two sharp blades. The pellets length is controlled with the knife speeds by using a digital inverter.

Power unit:

The main power unit was an electric motor with 1400 rpm rotational speed at 0.75 kW rated power, with 5.4 A. it was used to operate the machine through reducer pulley and belt and gears box.

3- Instruments devices:

Voltmeter, vernier caliper, micrometer, digital weighing balance, pellets shaker and stopwatch were used

Study parameters:

The performance of the tested of the machine/extruder at using different patterns of holes distribution on extruder die surface such as; (machine/extruder productivity, power and energy requirements, and pelleting cost) and the quality of pellets such as; (pellets bulk density and durability)

a) Parameters related to the machine

1- Compression screw speed: three levels of screw speed rotation were studies of 36 (4.6), 66 (8.7) and 96 (12.7) rpm (m. min^{-1}).

2- Holes distribution on die surface: three patterns of holes distribution on die surface were studies star, triangular and scattering pattern.

b) Parameters related to the ration

1- Moisture content: three levels of moisture content were studies (25, 35 and 45% wet basis).

Measuring indicators as follow;

1- Extruder productivity:

$$\text{Extruder productivity, kg.h}^{-1} = \frac{W_p}{T} \times 3.6$$

Where: W_p, pellets mass, g. and T, consumed time, s.

2-Pelleting efficiency:

$$\text{pelleting efficiency, \%} = \frac{W_p}{W_m} \times 100$$

Where: Wm, ration sample mass, g.

3-Pellets bulk density:

$$\text{Pellets bulk density, g.cm}^{-3} = \frac{W_d}{V_d}$$

Where: W_d, pellets sample mass, g and V_d, pellets sample volume, cm^3.

4- Pellets durability:

$$\text{Durability, \%} = \frac{W_a}{W_b} \times 100$$

Where: W_a, pellets mass after shaker treatment, g and .
W_b, pellets mass before shaker treatment, g.

5- Total consumed power:

$$\text{Total consumed power, kW} = \frac{\sqrt{3}\, I\, V\, \eta\, \cos\theta}{1000}$$

Where:

I, line current strength in amperes; V, potential difference (Voltage) being equal to 380 V; Cosθ, power factor (being equal to 0.84); $\sqrt{3}$, coefficient current three phase (being equal 1.73) and η, mechanical efficiency assumed (90 %).

6- Specific Energy requirements (SER): It was obtained using the following equation:

$$\text{Specific energy requirement, kW. Mg}^{-1}\text{ h}^{-1} = \frac{\text{Total consumed power, kW}}{\text{Extruder productivity, Mg h}^{-1}}$$

7- Pelleting cost: Pelleting cost was calculated using the following formula:

$$\text{Pelleting cost, L.E.Mg}^{-1} = \frac{\text{Extruder hourly cost, L.E.h}^{-1}}{\text{Extruder productivity, Mg h}^{-1}}$$

The hourly extruder cost was determined by using the following formula (Awady *et al*., 2003) as follow;

$$C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + W.e + \frac{m}{144}$$

Where:

C, extruder hourly cost, L.E. h^{-1}; P, price of machine, L.E. (5000 L.E.); h, yearly working, h (2500 h); a, life expectancy of the machine, year, (10 years) ; i, interest rate. year^{-1} (10%); t, taxes and over heads ratio,% (2.5%); r, repairs and maintenance ratio,% (10%); W, total consumed power, kW (from experiment treatments, kW); e, hourly cost kW^{-1}.h^{-1} (0.65 L.E.); m, the monthly average wage (only one labor *2500 L.E for four extruders) L.E.; 144, the monthly average working hours.

RESULTS AND DISCUSSION

1- Effect of holes distribution on die surface on machine productivity at different parameter:

Many variables significantly impact productivity, including moisture content, holes distribution on die surface, and screw speed rotation. Relating to the effect of the distribution of holes on die surface on machine productivity, results showed that by using star pattern compared to triangular and scattering pattern, the machine productivity increased by 14.55 and 31.12 %., and by 13.48 and 26.23 %., and by 25.68 and 38.47 % under screw speed of 36 rpm and different moisture content of 25, 35 and 45 % respectively. The same trend was shown with rotation screw speed of 66 rpm where the productivity increased at used star pattern compared to triangular and scattering pattern respectively by 9.56 and 23.17 % and by 7.46 and 22.45 % and by 12.97 and 29.92 % at a different moisture content of 25, 35 and 45 % respectively. And by 11.08 and 18.23 % and by 10.75 and 15.64 % and by 14.30 and 23.88 % under rotation screw speed of 96 rpm and different moisture content of 25, 35 and 45% respectively, Fig. 3. as opposed to triangular and scattering patterns, the star form may be contrasted with the ration amounts that passed through the extruder system and outputted from the holes pattern in less time since the greasing effect reduced pressure through the die and expand of ration amounts that passed through the extruder unit and outputted from the pattern of holes at the same time unit.

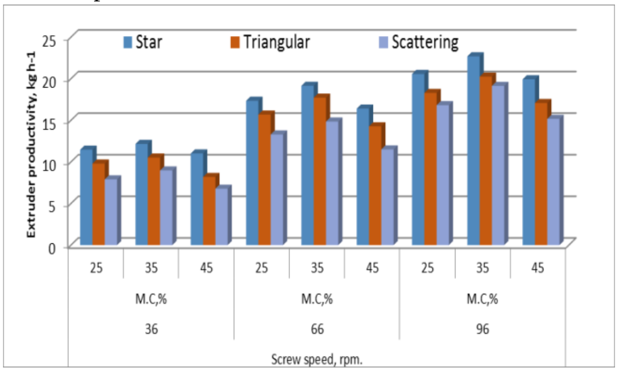


Fig. 3. Influence of extruder screw speed on productivity at various moisture content and holes distribution on the die surface.

Viewing the effect of moisture content on machine production data showed that increasing the production rate by increasing the moisture content from 25 to 36 % might result in the increments of ration quantities passed through the extruder outputted from the die holes at the same time unit. The decrease of extruder productivity by using moisture content could be due to less ration which transfers from the compression screws zone to the die zone and rising the resistance force of open holes on die surface compared to compression screw which transfers the ration to die through constant output area that tends to decrease machine productivity. these results were similar to previous studies of (Skoch,*et al*., 1983a; Mortiz,*et al*., 2001; Kaddour, 2003; Zaki, *et al*., 2009; Odesola *et al*., 2016; Orimaye, 2019; Okolie *et al*., 2019; Ogundana *et al*., 2021)

2- Effect of holes distribution on die surface on pelleting efficiency at different study factors:

Efficiency is affected by many factors: holes distribution on the die surface, rotation screw speed, and moisture content. The obtained results showed that by using star pattern compared to triangular and scattering pattern, the efficiency increased by 1.59 and 6.5 %., and by 3.01 and 5.48 %., and by 1.00 and 5.49 % under screw speed of 36 rpm and different moisture content of 25, 35 and 45 % respectively. The same pattern was investigated with a rotation screw speed of 66 rpm where the machine productivity increased at used star pattern compared to triangular and scattering pattern respectively by 3.46 and 6.39 % and by 1.26 and 4.64 % and by 1.79 and 3.65 % at a different moisture content of 25, 35 and 45 % respectively. And by 1.70 and 3.20 % and by 0.53 and 1.63 % and by 0.94 and 2.62 % under screw speed of 96 rpm and different moisture content of 25, 35 and 45 % respectively. Fig. 4 the improvements of efficiency by using star pattern may be related to the high amounts of mixture leading to more pressure that produced higher temperature enough to formed the water into steam to make the ration has bulking structure.

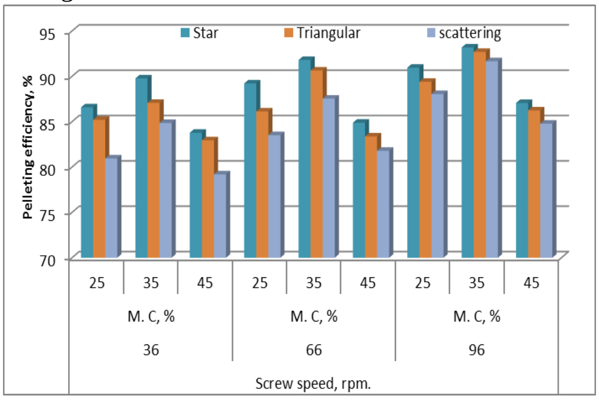


Fig. 4. Influence of extruder screw speed on pelleting effectiveness at various moisture content and holes distribution on the die surface.

The speed of the screw affects efficiency, while an increase in efficiency is noticed by increasing rotation screw speed from 36 to 96 rpm. that increase may result in increments in both temperature degree and compressing pressure.(Moritz, *et al*., 2001; kaddour, *et al*., 2006; and Zaki, *et al*. 2009; Odesola *et al*., 2016;Orimaye, 2019;Okolie *et al*., 2019; Ogundana *et al*., 2021)

3- Effect of holes distribution on die surface on bulk density at different study parameters:

Density is the main aquatic pellets measurements, and it is related to the form of aquatic feed manufactured. Many factors affect the bulk density, like screw speed, division of holes on die surface and moisture content. results showed that by using star pattern compared to triangular and scattering pattern, the density increased by 2.06 and 8.23 %., and by 3.06 and 8.38 %., and by 2.95 and 8.36 % under screw speed of 36 rpm and different moisture content of 25, 35 and 45 % respectively. The same trend was noticed with screw speed rotation of 66 rpm where the density increased at used star pattern compared to triangular and scattering pattern respectively by 2.09 and 8.34 % and by 2.05 and 5.56 % and by 2.72 and 7.5 % at a different moisture content of 25, 35 and 45 % respectively. And by 2.82 and 7.04 % and by 1.86 and

6.27 % and by 4.23 and 8.04 % under screw speed rotation of 96 rpm and different moisture content of 25, 35 and 45 % respectively. Fig 5. the raise of bulk density by using star pattern might be correlated with the high quantities of raw materials on the die zone, increasing the pressure of materials granules, so the ration volume in the constant mass of die holes will increase. The increase in bulk density by raising screw speed rotation may be due to the enhancement in homogenizing of ration with steam and moisture, causing additional compressing of the raw ingredients in the patternr zone, which means growing in ration volume in the same mass of patternr holes for the gained pellets according to (Kaddour *et al*., 2006).

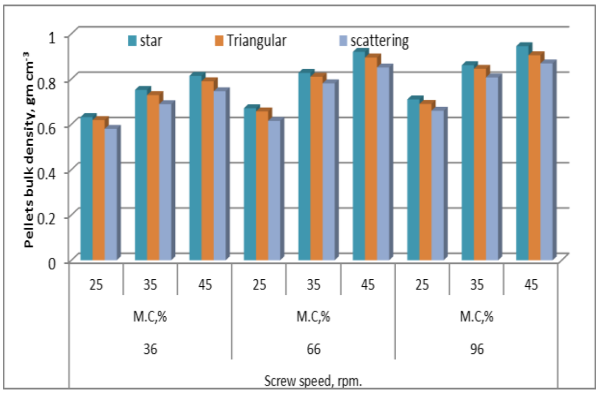


Fig. 5. Influence of extruder screw speed on pellets bulk density at various moisture content and holes distribution on the die surface.

4- Effect of holes distribution on die surface on pellet durability at different study parameters.

One of the most critical indicators of pellet quality is pellet durability. All manufacture operators, such as speed of the screw, die surface hole number, the rate of feeding, die-effective hole thickness, and moisture level, significantly influence pellet durability. Considering the obtained results of the effect of the distribution of holes on die surface on pellets durability showed that by using star pattern compared to triangular and scattering pattern, the durability of pellets increased by 2.99 and 3.98 %., and by 2.88 and 4.9 %, and by 0.96 and 4.15 %.,under screw speed of 36 rpm and different moisture content of 25, 35 and 45 % respectively. The same trend was detected with screw speed rotation of 66 rpm where the machine productivity increased at used star pattern compared to triangular and scattering pattern respectively by 1.80 and 4.96 % and by 2.80 and 3.74 % and by 1.71 and 3.79 % at different moisture content of 25, 35 and 45 % respectively. And by 1.67 and 3.72 % and by 0.51 and 4.74 % and by 2.94 and 5.10 % under screw speed rotation of 96 rpm and different moisture content of 25, 35 and 45 % respectively. Fig. 6 the use of a star type to improve pellet durability may be integrated to maximize the ration that enters the die zone in the same time unit. It means increasing pressure and temperature inside the die and more compaction for the pellets is expected. Viewing the effect of compression screw speed on pellets durability data showed higher durability of pellets by increasing screw speed rotation from 36 to 96 rpm. Growing screw speed can increase pellet durability by increasing pellet compression in the die area, as well as increasing temperature, which evaporates the moisture around the cells between the granules, making the pellets too solid with high tolerance to cracking and breakage, according to (Kaddour, *et al*., 2006 and Zaki, *et al*., 2009)

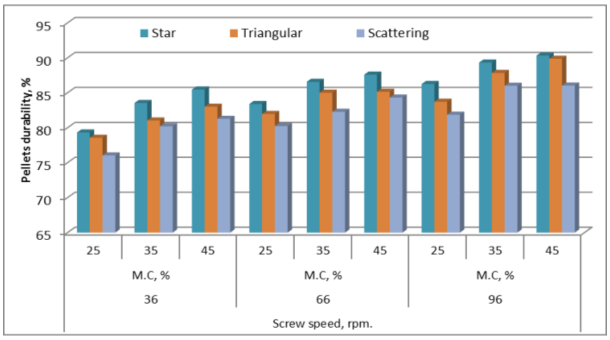


Fig. 6. Influence of extruder screw speed on pellets durability at various moisture content and holes distribution on the die surface.

5- Effect of holes distribution on die surface on total consumed power at different study parameters.

Recording the impact of holes distribution on die surface on total consumed power, allowing for the effect of distribution of holes on die surface on extruder power, results showed that by using star pattern compared to triangular and scattering pattern, the power decreased by 12.96 and 23.77 %., and by 11.03 and 48.40 %., and by 26.31 and 50.87 % under screw speed rotation of 36 rpm and different moisture content of 25, 35 and 45 % respectively. The same pattern was observed with a screw speed of 66 rpm where the total consumed power decreased at used star pattern compared to triangular and scattering pattern respectively by 15.42 and 49.00 % and by 17.6 and 54.47 % and by 17.92 and 56.94 % at a different moisture content of 25, 35 and 45 % respectively. And by 13.53 and 43.01 % and by 14.48 and 47.34 % and by 7.96 and 46.02 % under rotation screw speed of 96 rpm and different moisture content of 25, 35 and 45 % respectively. Fig. 7. decreasing of power consumption by using star pattern may be because of the increase of machine productivity over the required power.

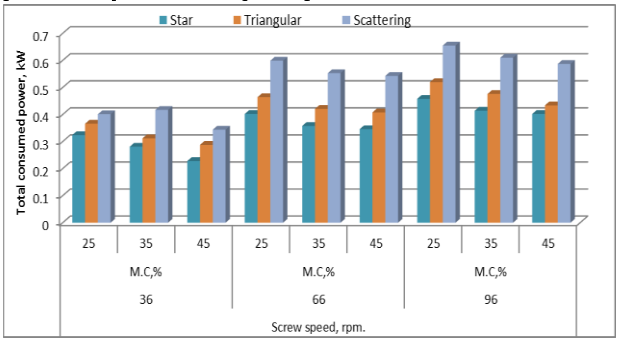


Fig. 7. Effect of extruder screw speed on total consumed power at different moisture content and holes distribution on the die surface.

Viewing the effect of compression screw speed on total consumed power data showed diminishing required power by increasing rotation screw speed from 36 to 96 rpm. Increasing screw speed can lead to an increase in energy requirements and an insignificant increase in productivity rate was occurred according to (Skoch, *et al*., 1993a; mortiz, *et al*., 2001; Morad, *et al*., 2007; Zaki, *et al*., 2009)

6- Effect of holes distribution on die surface on specific energy requirement at different study parameters:

The basic energy needs of extruded aquatic feed pellets are potentially dependent on productivity and consumed power and the impact of various operating parameters such as screw speed, effective hole thickness, die hole quantities, distribution patterns, and feed rate. One of the most critical goals is to reduce the actual energy consumption, and one of the best ways to do that is to use the best operating parameters. Obtained results and Fig. 8. indicate that by increasing of moisture content from 25 to 45 % the specific energy requirements decreasing by 28.6 % at a screw speed of 36 rpm and with the stare pattern the same trend were the triangular and scattering pattern, by increasing of screw speed from 36 to 96 rpm the specific energy requirements decreasing by 21.4 % at the moisture content of 25% with the stare pattern the same trend were the triangular and scattering pattern.

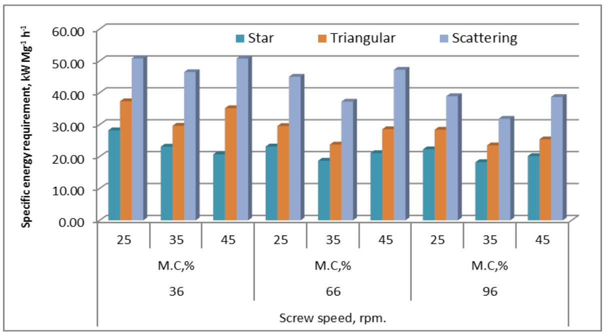


Fig. 8. Effect of extruder screw speed on specific energy requirement at different moisture content and holes distribution on the die surface.

The maximum value of the specific energy requirements was 50.74 kW Mg^{-1} h^{-1} by the scattering pattern at the moisture content of 45%, screw speed from 36 rpm but the minimum value of the specific energy requirements was 18.25 kW Mg^{-1} h^{-1} by the staring pattern at the moisture content of 35%, screw speed from 96 rpm. The decrease in energy requirements by increasing screw speed and moisture content could be due to the high decrease in the total consumed power and at the same time insignificant increase in extruder productivity has occurred (Morad, *et al*., 2007; Zaki, *et al*,. 2009; Odesola *et al*., 2016; Orimaye, 2019). On the other hand, the increments in energy demands by modifying holes' pattern from scattering to stare might be due to the significantly reduced extruder productivity and the marked improvement in the consumed energy in this treatment. That is meaning a lot of power is being used while only a little is being generated.

7- Effect of holes distribution on die surface on pelleting cost at different study parameters:

One of the most relevant industry goals is to reduce manufacturing costs. The selection of optimum operating parameters for decreasing operating costs with high-quality products is still a challenge in the fish industry. Regarding the effects of the whole distribution on the die surface costs, the obtained results showed that by using star pattern compared to triangular and scattering pattern, Fig. 9 shows that the costs decreased by 17.18 and 31.33 %., and by 15.7 and 36.2 %., and by 34.8 and 63 % under screw speed rotation of 36 rpm and different moisture content of 25, 35 and 45 % respectively. The same pattern was observed with a screw speed of 66 rpm where the costs decreased at used star pattern compared to triangular and scattering pattern respectively by 10.8 and 18.4 % and by 8.3 and 19.8 % and by 15.1 and 24.6 % at a different moisture content of 25, 35 and 45 % respectively. And by 12.7and 9.1 % and by 12.2 and 6.2 % and by 16.8 and 13.1 % under screw speed of 96 rpm and different moisture content of 25, 35 and 45 % respectively. Fig. 9 the reduction of the pelleting costs by using star pattern might be correlated with the high increments in the rate of the extruder productivity with a low improvement in the total consumed power, while the insignificant decline in costs by rising screw speed may be incorporated with the decrease in extruder productivity. Viewing the effect of compression screw speed on costs data showed decreasing costs by increasing screw speed from 36 to 96 rpm. The cost of pelleting recorded a high degree by rising the screw speed due to the improvement in total consumed power with a slight increase in machine productivity; similar results were observed by (Morad, *et al*., 2007; Zaki, *et al*,. 2009; Odesola *et al*., 2016; Orimaye, 2019)

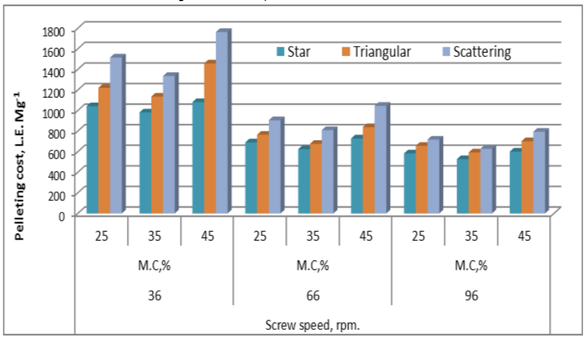


Fig. 9. Influence of extruder screw speed on the cost of pelleting process at different moisture content and holes distribution on the die surface.

CONCLUSION

This study assessed the impact of fish feed extruder die surface holes distribution patterns on indicators to machine/extruder (productivity, totally consumed power, and specific energy requirements) and on feed pellets quality - indicators to ration- (efficiency, bulk density and durability) and economical evaluation. The optimum results were recorded with the die that had holes distributed in the surface of the die in a star pattern, observed improvement in extruder productivity, pellets durability and pelleting efficiency by up to 10.75 and 15.64 %, 0.51 and 4.74 % , 0.53 and 1.63 %, respectively at a constant moisture content of 36 % and screw speed of 96 rpm, comparing to a triangular pattern and scattering pattern respectively, and decreased, bulk density, total consumed power, specific energy requirements and pelleting cost by up to 1.86 and 6.27 %, 14.98 and 47.34%, 12.2 and 6.2 % , 28.8 and 35.6%, respectively at a constant moisture content of 36 % and screw speed of 96 rpm, compared to a triangular pattern and scattering pattern respectively.

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تأثير أنماط توزيع الثقوب السطحية لإسطوانة مصبع أعلاف الأسماك على مؤشرات الآداء وجودة المصبعات

محمد السيد اسماعيل[1] ، رضا ابراهيم زكى[1] ، عادل فتحى السعيد[1] وخالد عبدالسلام السيد متولى[2]
[1]المعمل المركزى لبحوث الثروة السمكية بالعباسة – مركز البحوث الزراعية - العباسة أبوحماد – محافظة الشرقية- مصر
[2]قسم علوم الأراضى والمياه – كلية التكنولوجيا والتنمية – جامعة الزقازيق – الزقازيق - مصر

تعتبر عملية توزيع الثقوب على سطح إسطوانة مشكل العلف (الداى) لآلة تصبيع/ تكعيب الأعلاف بالبثق (Extruder) من العوامل الهامة التى يجب أخذها فى الإعتبار عند تصنيع الداى حيث أن ذلك يؤثر على كفاءة الآلة وجودة العلف المصبع، من العوامل الهامة التى يجب أخذها فى الإعتبار عند تصنيع مشكل العلف قرب وبعد الثقوب من محيط بريمة الضغط، عدد المستويات التى يتم توزيع الثقوب عليها، الأنماط المختلفة التى يتم بها توزيع الثقوب على سطح مشكل العلف، عدد ثقوب مشكل العلف (الداى) وسرعة بريمة الضغط حيث تم فى هذه الدراسة إختبار تأثير بعضها. نفذت تلك التجربة على أعلاف الاسماك وصنعت التركيبة العلفية عن طريق التكعيب أوالتصبيع على البارد بدون إستخدام البخار. حيث تم إجراء الدراسة تحت العوامل الاتية: ثلاث سرعات لبريمة الضغط ٣٦، ٦٦ ، ٩٦ لفة/دقيقة (4،6، 8،7، 12،7 م/دقيقة) على الترتيب، ثلاث أنماط مختلفة لتوزيع الثقوب على سطح الداى (النمط النجمى – النمط المثلثى – النمط المتناثر أو الغير منتظم) وثلاث مستويات للمحتوى الرطوبى للخلطة ٢٥ ، ٣٥،٤٥ ٪. وذلك لمعرفة تأثيرهذه الأنماط على كل من القياسات التالية: قياسات خاصة بالآلة وهى معدل إنتاج الآله، كفاءة التكعيب أو التصبيع، القدرة الكلية المستهلكة والطاقة النوعية المطلوبة - قياسات خاصة بجودة العلف وهى تحمل العلف للصدمات، كثافة العلف وتكلفة عملية التكعيب أوالتصبيع. أوضحت الدراسة أن أفضل النتائج التى تم الحصول عليها مع الداى ذو الشكل النجمى مقارنة بالنمط المثلثى والنمط المتناثر وكانت كالآتى:1- زيادة فى الإنتاجية بإستخدام الداى ذو النمط النجمى بمعدل ١٠،٧٥ ، ١٥،٦٤٪ عند السرعة ٩٦ لفة/دقيقة (12،7 م/دقيقة) والمحتوى الرطوبى ٣٥٪ مقارنة بالنمط المثلثى والنمط المتناثر على التوالى. 2-زيادة فى تحمل العلف للصدمات بإستخدام الداى ذو النمط النجمى بمعدل ١،٦٧ ، ٣،٧٢٪ عند السرعة ٩٩ لفة/دقيقة (12،7 م/دقيقة) والمحتوى الرطوبى ٣٥٪ مقارنة بالنمط المثلثى والنمط المتناثر على التوالى.3- زيادة فى كفاءة التصبيع بإستخدام الداى ذو النمط النجمى بمعدل ٠،٥٣، ١،٦٣٪ عند السرعة ٩٦ لفة/دقيقة (12،7 م/دقيقة) والمحتوى الرطوبى ٣٥٪ مقارنة بالنمط المثلثى والنمط المتناثر على التوالى.4- زيادة فى كثافة العلف بإستخدام الداى ذو النمط النجمى بمعدل ١،٨٦ ، ٦،٢٧٪ عند السرعة ٩٦ لفة / دقيقة (12،7 م/دقيقة) والمحتوى الرطوبى ٣٥٪ على التوالى5- نقص فى الطاقة اللازمة للتشغيل بإستخدام الداى ذو النمط النجمى بمعدل 12،2 ، 6،2 ٪ عند السرعة ٩٦ لفة/دقيقة (12،7 م/دقيقة) والمحتوى الرطوبى ٣٥٪ مقارنة بالنمط المثلثى والنمط المتناثر على التوالى.6- نقص فى تكلفة الطن بإستخدام الداى ذو النمط النجمى بمعدل 28،8 ، 35،6٪ عند السرعة ٩٦ لفة/دقيقة (12،7 م/دقيقة) والمحتوى الرطوبى ٣٥٪ مقارنة بالنمط المثلثى والمتناثر على التوالى. بناءً على ماسبق وما تم إستخدامه من أنماط مختلفة لتوزيع الثقوب على سطح الداى كالنمط النجمى، النمط المثلثى والمتناثر الغير منتظم. ومن النتائج المتحصل عليها يوصى بإستخدام الداى ذو النمط النجمى وذلك لدوره فى رفع وتحسين كفاءة الآلة وجودة العلف.