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The Effect of Extruder Mechanical Shear and Temperature on Aquatic Feed Pellets Micro Structure and Feed Quality

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ABSTRACT

Extrusion as new technology in aquatic feed producing need to understanding the extruder advantage and parameters effect because extruder is sensitive machine ,the production and quality clearly depend on many physical and mechanical parameters, the most affecting physical factor is the feed formulation and the most affecting mechanical factors is the extruder shear properties screw profile (high or low shear) and extruder zones temperature specialist die zone temperature all this factors judging the extruder performance and product quality. The study focuses on study the effect of extruder shear, (high or low shear), die zone temperature of 105, 120, 135 and 150 C^{o} and tow kind of feed formulations (sinking and floating formula) on extruder performance and product quality. The results reported that for producing sinking feed, the optimum parameters at using low shear screw profile and control the die zone temperature at 105C^{o}, the obtained results were 4.911Mg/h production rate, 98.54% sinking pellets percentage, 0.56 m/s sinking velocity, 1.03 expansion ratio, 561,11kg/m3 pellets bulk density and 63% sinking pellets water stability after one hour. For producing floating fish feed the optimum parameters at using high shear screw profile and 135Co die zone temperature, the obtained results were 3.636Mg/h production rate, 97,34% floating pellets percentage, 472min pellets floating time, 1.69 expansion ratio, 383.26 kg/m3 pellets bulk density and 100% floating pellets water stability after one hour. The electronic scanning images explicated the obtained data by measuring the void cells dimensions and the gelatinization degree.

Keywords: Fish feed - Extruder- Mico structure - sinking velocity - Floating time- pellets water stability

INTRODUCTION

In aquaculture, the fastest growing animal production sector all over the world, fishmeal as animal protein has customary been a most major component of aquatic feed. However, due to the lack of availability and high prices, the feed producers' factories rely on vegetable protein as the major protein source in fish feed, (FAO, 2016). In most of these studies, the plant-based fishmeal alternatives were suitable for the production of fish feed regarding certain nutritional characteristics (low levels of fiber, starch and anti-nutrients, high levels of protein content, nutrient digestibility and palatability), but their implementation was often accompanied by a reduced feed quality. Additionally, these protein raw materials are historically more expensive relative to fishmeal and their availability is limited (Naylor *et al.*, 2009, Draganovic *et al.*, 2013, Zhang *et al.*, 2012). Another study focusses about the current limitations of plant-derived protein meals, oilseed press cakes have been evaluated because they are side products of de-oiling industry and are therefore widely available at a low cost. In addition, they have high protein contents 22–60 g/100 g. (Ghosh and Mandal, 2015; Murray *et al.*, 2014; Tyapkova *et al.*, 2016). Assessed rapeseed press cake (RPC) as fishmeal replacement, including the effect of rapeseed peel (RP), by testing its effect on extruder response and the physical quality of feed pellets. The fish feed pellet quality measurements are (expansion indices, bulk density, sinking velocity, specific hardness, water stability and pellets durability) affecting by extrusion process parameters such as (pressure at the die, SME, product temperature and torque). Anna *et al.* (2019) indicated that the influence of extruder barrel temperature on the extruder response and pellet quality parameters was generally higher than the impact of screw speed in the range investigated. Expansion is the most relevant pellet production parameter because it influences quality characteristics such as the sinking velocity, bulk density or specific hardness.

Replacing fish protein sources with fish meal necessitated use the new technologies to study the structural composition of animal feed pellets products in particular, the aquatic feed sinking and floating pellets, It gives a clear and accurate perception of the feed produced quality and the extent of the feed ingredients homogeneity, such as pellets density , expansion ratio, gelatinization degree, sinking velocity, number of air bubblies, volume of air bubblies, air bubblies density and the pellets water stability.

Utilizing the electronic microscopy (EM) three-dimension technologies being increasingly to study and understanding the effect of food and feed industrial processing conditions and raw material ingredients on food and feed product structure, only last few years we recognized the full potential of three-dimension electron microscopy (Wilson, 1991). The developments in the electronic microscopy scanning have affected not only the product structure but also provided us with more information about this structure. Three-dimensional microscopy imaging also provides minimal sample

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interference errors, along with an increased estimation of image analysis power to extract quantitative information from microscopic images. (Aguilera, *et al.* 2000 and Falcone, *et al.* 2006). Scanning electron microscopy (SEM) is a very most common tool to envisage food structure because; it combines different ways the best advantage of (LM) light microscopy and (TEM) transmission electron microscopy. (Aguilera, and Stanley 1999). Also (SEM) scanning electron microscopy technique used to elucidate characterize of the final product with concern on changes that happen to starch ingredients. A study by Mohammed, *et al.* (2014) expound the utilizing of SEM for assaying the changes that happened to starch granules after exposing sorghum and barley grains to pelleting and extrusion feed processing methods. SEM images analysis is belayed to be a useful tool to recognize the changes that occur to grains after a different processing method. SEM showed that the expansion of starch granules is affected by the different processing method. In case of pelleting process, the oval shape of starch granules still the same after the pelleting process; while, oval shape of starch granules vanish after the extrusion process. Also, the scanning electron microscope (SEM) photographs and the particle size distributions of brown coal and rice bran were measured by Yooko and Takahiro(2017) the results showed that, the particle sizes were quite different for the two products. While the average particle size of the rice bran was 130 µm, the value for brown coal was only 5µm, and thus, it consisted of fine particles. Note that dense and hard pellets were formed if the brown coal ratio was high, and fragile and easily collapsible pellets were formed if the rice bran ratio was high.

The extrusion process is defined as a high temperature short time treatment where feed material is exposed to friction and shearing forces. Different microscopy techniques, such as scanning electron microscopy (SEM) have been reported to be applied into food and feed industry for quality control purposes and particularly in cereal products to determine the extent of starch gelatinization and characteristics in final product (Lee *et al.*, 2000; Srikaeo *et al.*, 2006; Srikaeo, 2008; Olav and Svihus, 2011). On the other side extrusion process involves higher levels of heat, moisture and pressure than pelleting process diets manufactured through extrusion process have high water stability degradation of some heat labile anti-nutritional factors, high starch gelatinization and high digestibility. Moreover, there is also a higher chance that extrusion would create floating feeds (Kannadhason *et al*., 2011, Lundblad *et al.*, 2012., Rout and Bandyopadhyay, 1999, and Glencross *et al.,* 2011).

Temperature is one of the most important factors in steam-conditioning, which affects the pellet quality, nutritional quality and feeding value of animals (Selle *et al.,* 2013). In the process of conditioning, the characteristics of the pellets and the structure of the main nutrients, such as starch and protein, will change with the conditioning temperature. An appropriate conditioning temperature will increase starch gelatinization and hardness, which may promote the growth performance and digestibility of animals (Lewis *et al.,* 2015). The frictional heat generated in the mechanical press due to compression and extrusion helps to activate many of the biomass components. For some densification systems, such as screw extruder, external heat is also provided. Various components of the biomass interact differently by the application of pressure and temperature in the presence of moisture (Tumuluru, *et al.* 2011). On the other hand, a low conditioning temperature may decrease starch gelatinization and cause insufficient feed viscosity, resulting in low durability and poor pellet quality, accompanied by low protein digestibility (Park *et al.*, 2013). Typically, increased starch gelatinization increases water solubility as well as pellet durability. These are desirable characteristics in aquaculture since they can reduce feed costs associated with excessive wastage and, subsequently, water quality deterioration (Sriburi, *et al*., 1999).

Shi *et al.* (2016) reported the effects of pelleted feed and extruded feed on gibel carp growth performance and found gibel carp fed extruded diet showed better growth than fish fed pelleted diet due to extrusion process improving the nutrient digestibility's in extruded diet. While, Naga, *et al.* (2018) conducted an experiment to compare dietary corn starch (CS) or tapioca starch (TS), with or without being pre-gelatinized (PG), Mash was then pelleted through a 1.0 mm diameter die and extruded through a single-screw extruder. The barrel length and diameter of the extruder were 420 mm and 19 mm, respectively, with a length to diameter ratio of 22:1. The compression ratio inside the barrel was 2:1 and the maximum screw torque was 150 newton meters. The three-barrel temperatures were maintained at 90–100–100 C^{o} and the die head temperature were set at 130 C^{o}. The surface microstructures of the experimental diets they generally appeared smoother for the PG diets, particularly when compared to the native CS diet. The cross sections of the pellets are generally the TS and PG-TS diets appeared smoother than the CS or PG-CS diets, but there were no obvious air pockets in any of the pellets.

The extrusion processing needs so professional operator because the extruder is so sensitive machine and the quality of aquatic feed affecting by the combination between the physical and mechanical parameters through the production processing that including control the die zone temperature and the shear inside the extruder barrel.

For that, the objective of this research was to study the effect of extruder mechanical shear ,die zone temperature and formula ingredients as physical parameter on aquatic feed quality, to get a complete visualization for pellets water stability, pellets density, floating time, sinking velocity and pellets density, and study the effect of this factors on feed pellets microstructure using scanning electron microscopy (SEM).

MATERIALS AND METHODS

The experiments were carried out in one of the extruder fish feed factories at Gamsa city - Dakhlia governorate. The extrusion factory produces all kind of aquatic feed for aquaculture and marine farms. Most of extrusion factory production quantity is fish feed pellet sinking and floating 30% protein.

Material

1-The composition of floating and sinking fish feed formulations:

The extruder fish feed factory uses them brand formulations, tow kind of formulations used under this study both were 30 % protein, one is sinking formula and the other for floating feed formula. The sinking formula were soybean meal 36.5%, rice bran 25.7%, corn mill 9%, wheat flour 25.7%, fish meal 3.5%, corn gluten 6.5%, limestone powder1%, calcium monophosphate 1%, premix 0.4%, choline chloride 0.2%, vitamin C 0.04%, calcium 0.2% , soy oil 1% and fish oil 1%.

While the floating formula were soybean meal 36.3%, rice bran 20.45%, corn mill 23.02%, wheat flour 55.5%, fish meal 3.5%, corn Gluten 6.4%, limestone powder1%, calcium monophosphate 1%, premix 0.4%, choline chloride 0.2%, vitamin C 0.04%, calcium 0.2%, soy oil 1% and fish oil 1%

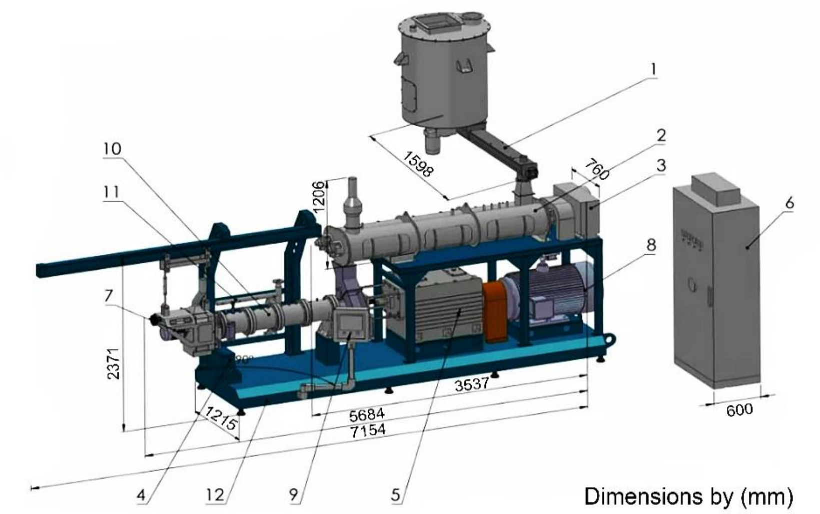
2- The specification of the single screw extruder:

Single screw extruder used for producing floating and sinking fish feed model SPHS218 it used for studying the impact of extruder shear and temperature on microstructure and quality of feed. The specification of the extruder under study were:

Extruder base and total dimensions: The extruder has main base made from U shape steel bar with thickness of 50mm and covered by steel sheet with thickness of 10mm. The base dimension was 4720x1200mm length and width.

Extruder feeding bin: The extruder bin has cylindrical shape with 1000mmØ, 1200 mm length and 4mm thickness, the bottom of extruder bin connecting with the extruder feeder screw.

Extruder feeder: The extruder feeder consists of feeder case cylindrical shape has diameter of 360mm, 1772 mm length and 4mm thickness and feeding screw has 355mmØ and 223 mm pith all feeding system made from stainless steel, the feeding device drive by electric motor1.5kW, 380v 50hz with variable speed drive.



Machine List			
1	Feeder	7	Cutting
2	Pre Conditionar	8	Main Motor
3	Pre Conditionar Motor	9	Touch Screen Control
4	Extruder	10	Barrel
5	Gear Box	11	Steam Hoes Connection System
6	Controller Box	12	Extruder Frame

Fig.1. Single screw extruder parts and layout

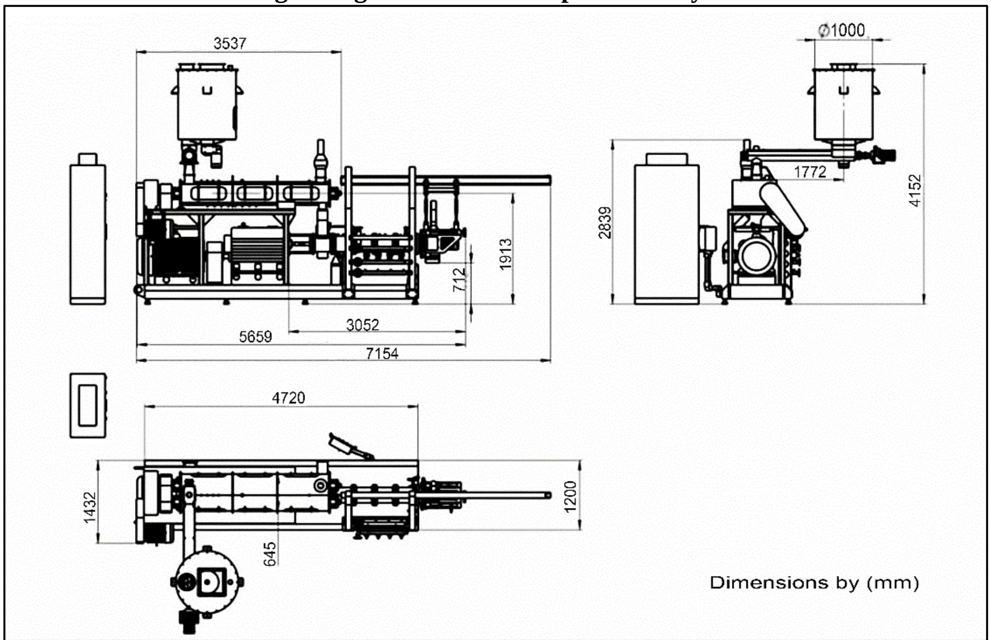


Fig. 2. Elevation, side view and plan of the single screw extruder

Extruder pre-conditioner: Dual axis conditioner ,DDC pre- conditioner made from stainless steel consists of conditioner case has 645mmØ and 3537mm length, and both conditioning shafts has 3600mm length, and 255mmØ, each shaft including group of conditioning speculators with interchanged shape has dimensions of 300 x 160 x 8mm , with angle on vertical axe of 45^o whole conditioner shaft and speculators made from stainless steel , pre conditioner device drive by 18.5kW, 380V 50Hz gearbox connection, belt transmission motor; with steam adding port, steam pressure ≤0.6MPa, water adding nozzles, water pressure 0.4-0.6MPa ; and material conditioning time: 1.5~4min.

Extruder main machine: The main extruder consist of extruder barrel and extruder screws shaft, the extruder barrel with multi-layers, with steam heating and water cooling channels, consists of five parts with 124mmØ and 134mmØ internal and external diameter, the barrel total length were 2450mm, made from special alloy steel, the barrel parts represent extruder zones (feeding zone, transmission zone, kneading zone, cooking zone and die zone).The extruder main shaft has 110mmØ and 2710 mm length, the main shaft hold the extruder screws, the screws set consists of six screws with 120mmØ with L/D ratio of 1:20 , the screws made from 38CrMoAl alloy and easy change the screws profile depends on the kind of fish feed. The screws main shaft drive by extruder main motor 200kW, 380V 50Hz frequency variable drive through distribution gear box lubrication with external water cooling, the cooling pump:0.75kW, 380V 50Hz.

Extruder cutter knives: cutter knives consist of cutter assembly hold eight knives made from hard steel 38CrMoAl alloy, the cutter knives drive by 3kW, 380V 50Hz motor has cutting speed: 0-3000 rpm adjustable.

Extruder computerized control system: Computerized control system consists of (1) Motor Control Cabinet including frequency inverters for all extruder motors, PLC for extrusion process control, ampere meter and voltage meter, one set of breaker and contactors and thermal relays etc. (2) One set of valves for water and steam flow control including flow control valves, communication with PLC and special support frame for steam, water valves and piping elements fixing. (3) Touch screen control panel including interfaces for following actions (all motors start up and stop; feed in speed adjustment; cutter speed control; water and steam flow control;), warning alarms automatic emerges and all process parameters memory.

Extruder dies: for sinking and floating formulations, the dies have 134mmØ and 25mm thickness with holes 3mmØ. With opening area of 74.32% and 61.43% for sinking and floating formulation respectively (Fig 3).

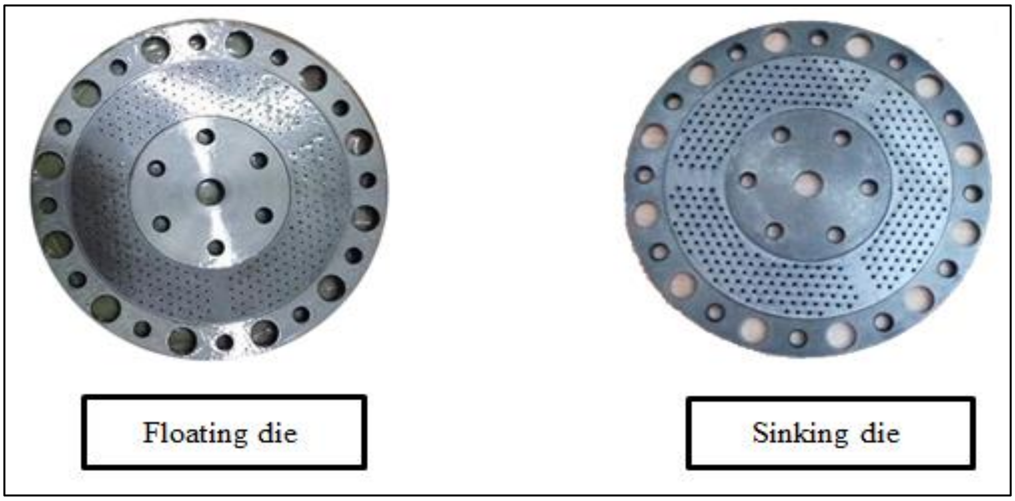


Fig. 3. The utilized dies of floating and sinking aquatic feed.

Methods:

Experiment's conditions:

The experimental were carried out to study the effect of extruder shear and die zone temperature on the micro structure and quality of sinking and floating aquatic feed using the electronic microscope.

The parameters under the study and evaluation were:

- Kind of formulations of (Sinking formula and Floating formula)
- Die zone temperature of (105, 120, 135 and 150C^o)
- Extruder shear by controlling the extruder screw profile of (Low shear screws and High shear screws)
- Low shear screws profile was (five units single- one-unit double flight)
- High shear screws profile was (two units single flight – three units double flight- one-unit double cut flight).

The constant condition of the experimental extruder running for sinking formula were, the feeding rate 67kg/min, formula moisture content after conditioner 17-18%, die holes of 3mmØ has opening area of 74.32% and extruder screw speed of 405 rpm .While constant condition for floating formula the feeding rate were 74 kg/min, formula moisture content after conditioner 23-27%, die holes of 3mmØ has opening area of 61.43% and extruder screw speed of 448 rpm.

The instrument:

- Rotating speed measuring device leaser tachometer model made in china
- Stop watch Casio FX53
- Weighting scales maximum weight (5 kg) for measuring the pellets bulk density.
- Temperature and pressure of steam and conditioner control panel scales.

- Mini infra-Red Thermometer model Hcjyet made in china.
- Electronic microscope model (Quanta –FEG 250) National Research Center.
-Digital Vernier scale 0-300 mm –Stainless hardened-battery 1.55 V.

Evaluation of the single screw extruder performance and produced aquatic feed pellets quality:

The extruder evaluation was performed under the same normal operating conditions and all measurements were taken for all the parameter after extruder starting by 30 minutes to ensure the stability of the extruder performance.

-Extruder production rate: Extruder production rate measured for each treatment by collect sample for 2 min after line running steady .

- Sinking and floating percentage: Sinking and floating percentage measurement is carried out by taking 100 pieces of produced sinking and floating pellets as a random sample and was estimate the number of sinking or floating pellets to the total number of samples.

- Sinking pellets velocity: The sinking velocity was measured by put the sinking pellets in glass bin with length of 500mm, and was measured the consumed time that pellets take from top to bottom in water

- **Pellets floating time:** The floating time was measured by calculating the consumed time that pellets still float before become sinking in glass tank.

- Aquatic feed pellets bulk density: Was calculated using standard method of feed manufacture .

- Sectional Expansion Ratio/Index (SEI): was calculated by measuring the pellet diameter after extruded using the formula

$$SEI = \frac{D_e^{\,2}}{D_d^{\,2}}(ratio)$$

Where: ***D_e: Extruded pellet diameter (mm) D_d: Die holes diameter (mm)***

- Aquatic feed pellets water stability:

was calculated by put the pellet in glass water and measure the number of pellets still stable in water after (60, 120, 180 and 180 min) using sinking and floating formulations:

Pellet water stability = Nst / Nt x 100

Where*: Nst*: Number of stable pellets in the water
***Nt*: Total pellets sample.**

All the previous measured must were according to (AACC, American Feed Industry Association, Inc., 2000).

Aquatic feed microstructure and void cells average diameter: Was scanned the microstructure of produced pellets (120x,260,280,500 and 600x) depends on the required scan for every parameter, using electron microscopy (SEM) (Quanta –FEG 250) at National Research Center- Giza-Egypt.

RESULTS AND DISCUSSION

- Extruder production rate

The aquatic extruder production rate affecting by many production parameters such as kind of fish feed (sinking or floating formula), extruder barrel shear, die zone temperature, and die holes profile…. etc. Data in Fig. (4) shows that increased the die zone temperature from 105C^O to 150 C^O linearly reduced the extruder production rate from 4.599 to 3.697 Mg/ h at high shear screw profile, and from 4.911 to 4.195 Mg/h at low shear screw profile using sinking feed formula., and from 4.177 to 3.249 Mg/ h at high shear screw profile, and from 4.496 to 3.690 Mg/h at low shear screw profile using floating feed formula. Same figure showed the effect of extruder shear on extruder production rate. Data indicated that changing the screw profile from low shear to high shear decreased the extruder production rate from4.911,4.774 , 4.505 and 4.195Mg/h to 4.599, 4.398, 4.077 and 3.697 Mg/h using sinking feed formula and from 4.496, 4.337,4.016 and 3.690 Mg/h using floating feed formula at die zone temperature of 105, 120, 135 and 150C^o, respectively. While, changing the feed formula from sinking to floating feed reduced also the extruder production rate with all die zone temperature from 4.599 to 4.177Mg/h and from 4.911 to 4.496Mg /h at die zone temperature of 105C^o using screw profile of low and high shear respectively. Same trend using die zone temperature of 150C^o, the extruder production rate decreased from3.697 to 3.249 Mg/h and from 4.195 to 3.650 Mg/h using screw profile of low and high shear respectively.

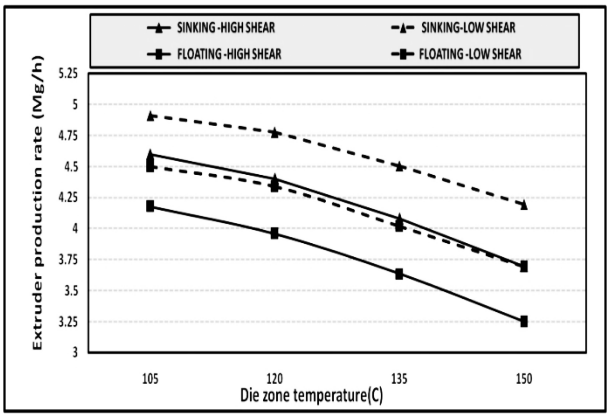
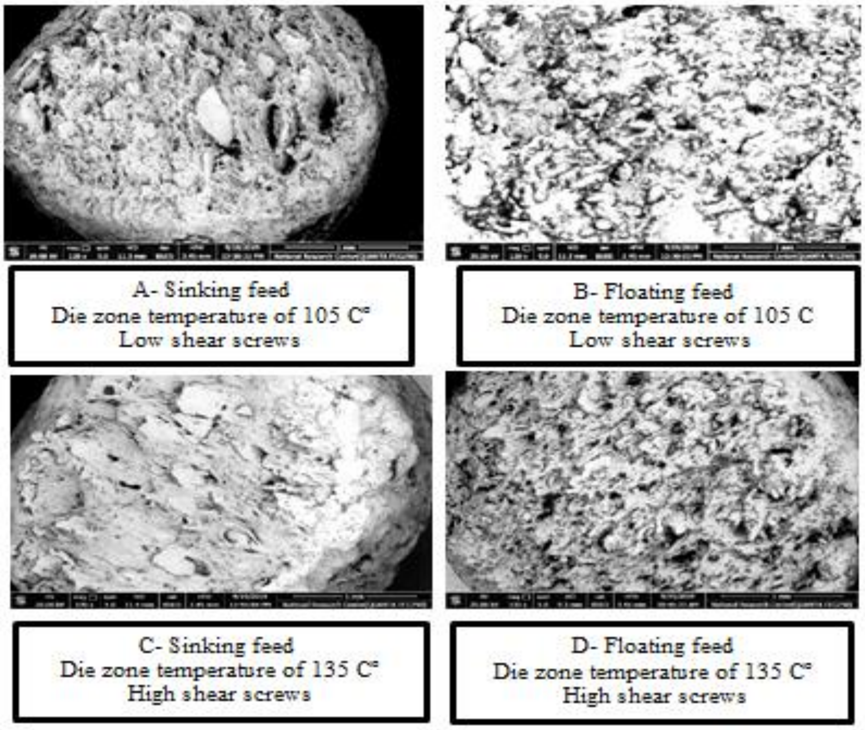


Fig 4. The effect of die zone temperature and extruder shear on extruder production rate for sinking and floating formula

The decrease in extruder production rate by increasing the die zone temperature and screw profile shear could be due to the increase in formula cooking and the increase in starch gelatinization ratio that lead to increase the pellets expansion with decrease in pellets mass in time unit .The clear decrease in production rate by changing the fish feed formula from sinking to floating formulation that could be due to the increase in corn percentage in floating formula that mean increase the starch percentage then increase the starch gelatinization ratio, with increase in void cells and reduce pellets mass in time unit.

Through the utilizing of scanning electron microscopes (SEM), the images showed an identical interpretation of the previous explain for the results (Fig. 5).The images and scanning results indicated that changed the formula from sinking to floating the pellet output diameter increased from 3.04 and 3.33mm to 3.28 and 3.90mm using low shear and high shear with die zone temperature of 105 and 135 C^o respectively, and that could be due to the increase of the corn percentage in floating formula than sinking formula and that lead to increase the starch percentage and gelatinization ratio. While it is clear to see the effect of screw profile shear and die zone temperature, scanning showed that increasing die zone temperature from 105 to 135C^{o} with change screw profile shear from low to high increased the void area percentage from 5.2 and 12.8 to 14.6 and 37.5% using sinking and floating feed formulation respectively, and that lead to decreasing the pellets mass so reduce the extruder production rate.



Measurement	A	B	C	D
Pellets average diameter (mm)	3.04	3.28	3.33	3.90
Void area percentage (%)	5.2	12.8	14.6	37.5
Production rate (Mg/h)	4.911	4.496	4.077	3.636

Fig. 5. SEM (120X) for sinking and floating aquatic feed showed the effect of die zone temperature and extruder shear on extruder productivity.

- Sinking and floating percentage

Sinking and floating percentage is a very important measurement in aquatic feed factories for quality control, when factory producing floating feed, the percentage of floating pellets should be up of 97% and same percentage when factory producing sinking feed. Data in Fig (6) showed the effect of die zone temperature on sinking and floating percentage, increasing the die zone temperature from 105to 120, 135 and 150C^{o} decreased the sinking percentage from 98.54 to 97.86, 95.13 and 93.67% using low shear screw profile and from 93.03to 91.73, 88.95 and 84.11% using high shear screw profile. Meanwhile increasing the die zone temprature increasing the floating percentage from 81.73 to 86.62,90.21 and 95.44% using low shear screw profile and from 94.95to 96.12, 97.34 and 99.62% using high shear screw profile.

The decrease in sinking percentage and increase in floating percentage by increasing the die zone temprature could be due to the increase in starch gelatinization ratio and that lead to increase in void cells in pellets and that reduce the pellets density then become float.

Regarding to the effect of screw profile shear on sinking and floating percentage. Data in Fig(6) explained that changing the screw profile from low shear to high shear decreased the sinking percentage from 98.54 , 97.86 95.13, and 93.67% to 93.03, 91.73,88.95 and 84.11% at 105, 120, 135 and 150C^{o} recpectively.While changing the screw profile from low shear to high shear increase the floating percentage from 81.73 , 86.62,90.21 and 95.44% to 94.95 , 96.12, 97.34 and 99.62 % at 105, 120, 135 and 150C^{o} recpectively. The decrease in sinking percentage and increase in floating percentage by change the extruder shear from low to high shear could be due to the increase in void cells by the increase in starch gelatinization ratio, that lead to produce percentage of sinking pellets as floating pellets and this is one of the losses of the production line when factory produce sinking aquatic feed.

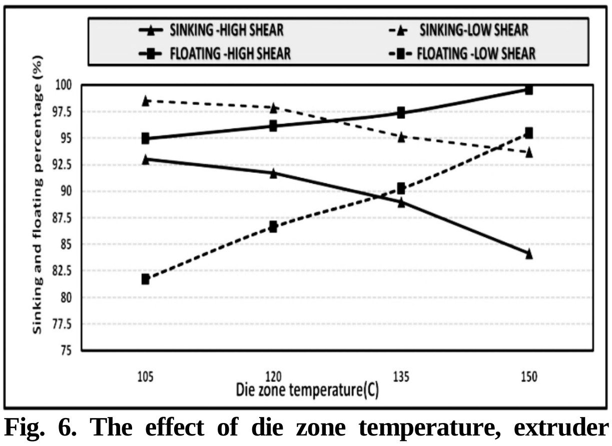
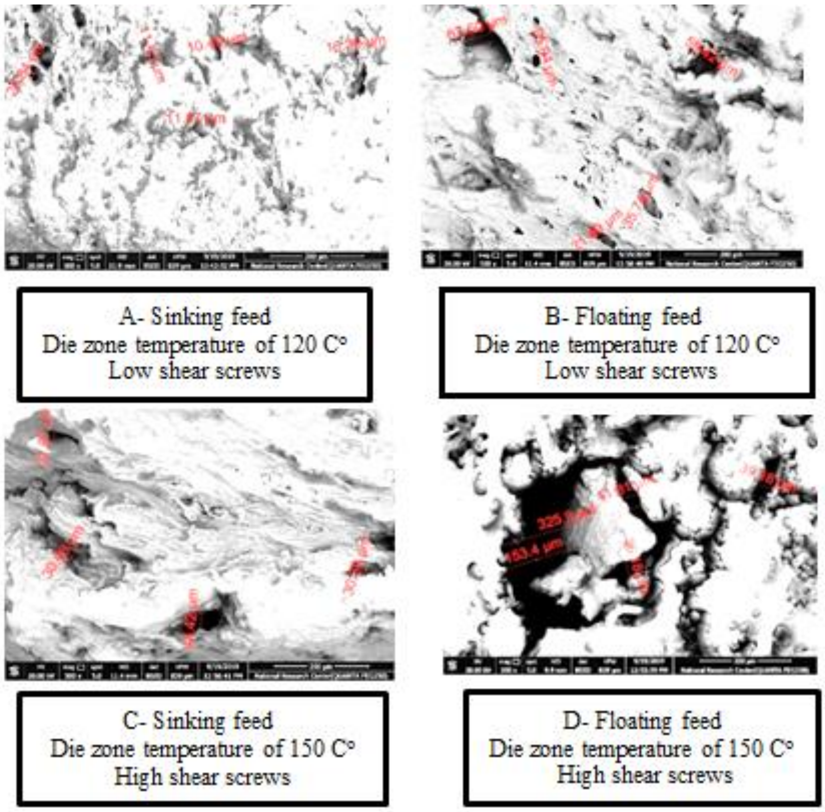


Fig. 6. The effect of die zone temperature, extruder shear and kind of formula on sinking and floating percentage

Electron microscope scanning (SEM) explained the measurement results of floating and sinking percentage in as Fig (7), the scanning images showed that for sinking feed increasing the die zone temperature from 120 to 150C^{o} and change the screw profile to high shear increase the void cells numbers and average diameter from 0.007 to 0.016mm, and that lead to increase the percentage of floating feed with the sinking feed and that increase the factory losses, meanwhile its decreased the sinking pellets percentage with the floating feed and generated large void cells has average diameter of 0.059mm.



Measurement	A	B	C	D
Pellets average diameter (mm)	3.09	3.52	3.58	4.31
Void cells average radius (mm)	0.007	0.021	0.016	0.059
Sinking/ floating percentage (%)	97.86	86.62	84.11	99.62

Fig. 7. SEM (500X) for sinking and floating aquatic feed showed the effect of die zone temperature and extruder shear on sinking and floating pellets percentage

- Sinking pellets velocity

Sinking velocity one of quality target for any factory produce extruded sinking fish feed, it is indicate for the time that sinking pellets take to arrive the bottom of ponds, producing sinking feed by pellet mill different than by extruder, pellet mill produce very high sinking pellets density so the pellets have very high velocity and most of pellets loss in bottom of ponds.

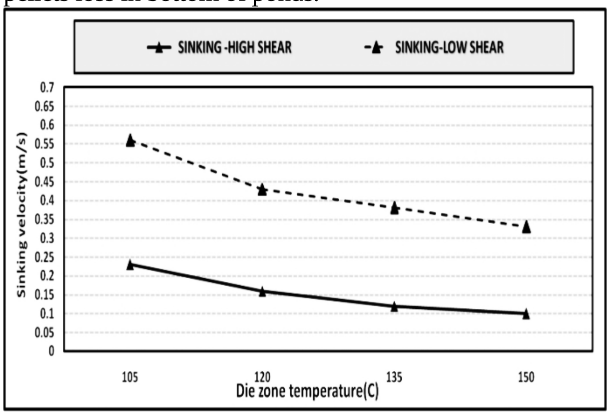
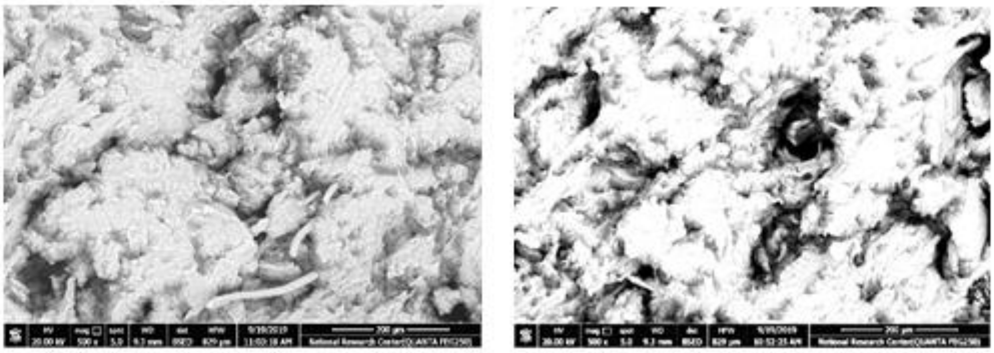


Fig. 8.The effect of die zone temperature and extruder shear on pellets sinking velocity

Data in Fig.(8) showed that increasing extruder die zone temprature from 105 to 120, 135 and 150C^{o} decreased the pellets sinking velocity from 0.56 , 0.43, 0.38 and 0.33 m/s using low shear extruder screw profile, and decreased from 0.23, 0.16 , 0.12and 0.10 m/s using high shear extruder screw profile.

Regarding to the effect of scew shear profile on sinking velocity,same figure indecated that changing the screw profile from low to high shear profile decreased the sinking velocity too, that clear in preivous data with all die zone tempratures under study . The reducing in sinking pellets velocity by increasing the die zone temprature and changing the screw shear profile to high shear could be due to the increase in barrel presure and temprature lead to increase the starch gelatinization ratio, that creat more quanitity of void cells and increase the void cells size then reduce the pellets denisity so lead to reduce the sinking velocity.

Studing the effect of extruder parameters on pellets sinking velocity by electron microscope scanning (SEM) 500X images as show in Fig(9), indicated that when the die zone temperature increased from 105 to 150C^{o} the sinking velocity decreased from 0.56 to 0.33 m/s using low shear screw profile and that clear from the electronic scanning , it shows an increase of starch gelatinization rate, which led to an increase in void cells number and size, which reduces the density of produced pellets , which reduces the speed of sinking velocity.



A- Sinking feed
Die zone temperature of 105 C°
Low shear screws

B- Sinking feed
Die zone temperature of 150 C°
Low shear screws

Measurement	A	B
Pellets average diameter (mm)	3.04	3.34
gelatinization ratio	16	38
Sinking velocity (m/s)	0.56	0.33

Fig. 9. SEM (500X) for sinking aquatic feed showed the effect of die zone temperature on pellets sinking velocity

- Pellets floating time

It is knowen that the floating time is the time that floating pellets can be resist the water saturation before become sinking feed.Data in Fig(10) showed that increaseing the die zone temprature from 105to 120, 135 and 150C°increased the pellets floating time from 165 to 189 , 246 and 416 minutes using low shear extruder screw profile, and from 294 to 336, 472 and 608 minutes using high shear extruder screw profile.Same peravious results showed the indicate of screw shear profile on pellets floating time,changing the screw profile from low shear to high shear increased the pellets floating time with all the die zone tempratures .

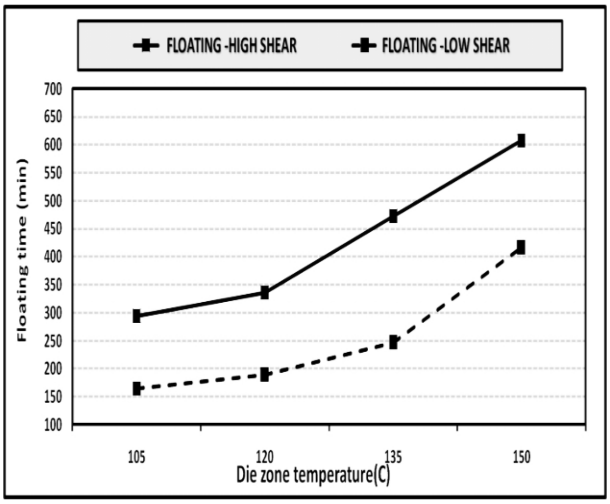
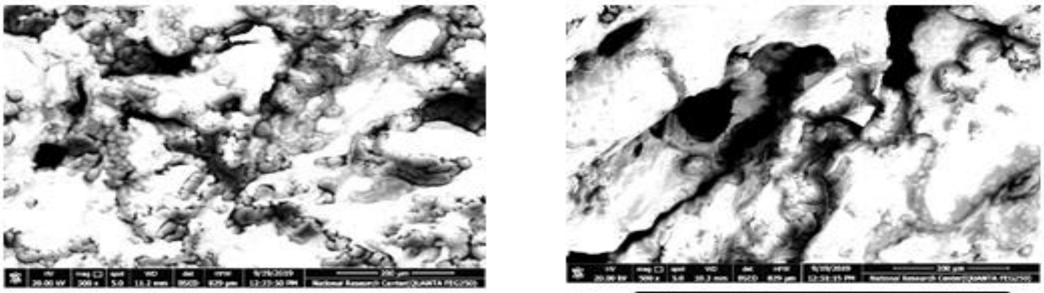


Fig. 10.The effect of die zone temperature and extruder shear on pellets floating time

The increasing in pellets floating time by increasing die zone tempraute and using high shear screw profile attributed to the increase in the starch gelatinization ratio by increasing barrel preasure and temprature that leads to generate more void cells , which increase the pellets resistance for water intake.

Electronic scanning of floating fish feed showed the effect of screw profile shear on pellets floating time, the images indecated that changed the screw profile shear from low shear to high shear profile increased the gelatinization ratio of starch from 41 to 66 and that lead to generate large void cells has gelatin walls ,this increases the time pellets needed to absorb more water and then increase the pellets mass and density so become sinking pellets, (Fig.11).

Aquatic feed pellets bulk density one of the most important measurement in any feed mill plant , and its indicate for the kind of produced fish feed (floating or sinking). Data in Fig(12) reported that for sinking formula, increasing the die zone temprature from 105 to 120, 135 and 150C° reduce linerly the pellets bulk density from 561.11 to 37.84 , 516.61 and 507.98 kg/m^3 using low shear screw profile and from 529.93 to 504.21,487.32 and 469.04 kg/m^3 using high shear screw profile. While for floating formula , its increased from 478.19 to 456.06,422.87 and 394.44 kg/m^3 using low shear screw profile and from 436 to 413.53, 383.26 and 341.05 kg/m^3 using high shear screw profile. The same pattern was recoded for the effect of changing the screw profile shear on sinking and floating pellets bulck density (Fig.12). The odtained data indecated that the bulk density decreased from561.11 to 529.93 and 507.98 to 469.04 kg/m^3 using sinking feed fornula and from 478.19 to 436 and 394.44 to 341.05 kg/m^3 using floating feed fornula at die zone temprature of 105 and 150C° recpectively.



A-Floating feed
Die zone temperature of 135 C°
Low shear screws

B-Floating feed
Die zone temperature of 135 C°
High shear screws

Measurement	A	B
Pellets average diameter (mm)	3.66	3.90
gelatinization ratio	41	66
Floating time (min)	246	472

Fig. 11. SEM (500X) for floating aquatic feed showed the effect of extruder shear on pellets floating time- Aquatic feed pellets bulk density

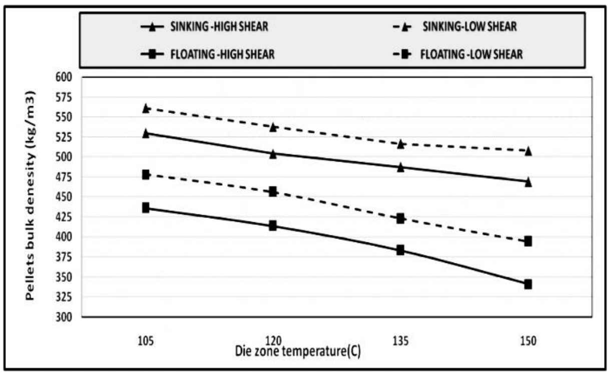
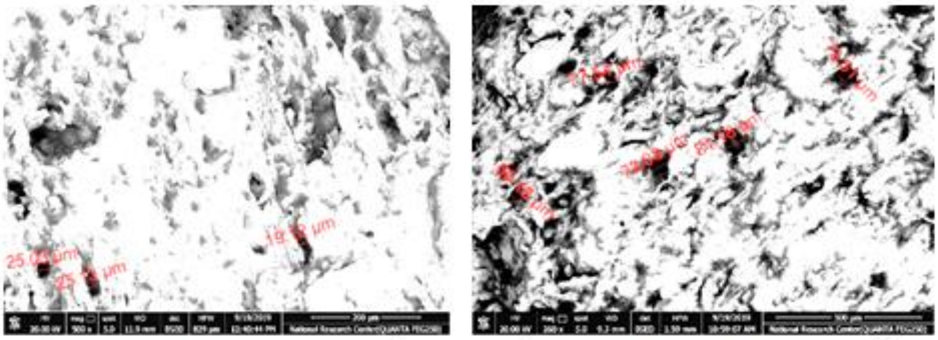


Fig . 12. The effect of die zone temperature and extruder shear on sinking and floating pellets bulk density

The previous data which showed that both high die zone temperature and high shear screw profile could be explained by the increased of formula cooking ,starch gelatinization ratio, number of void cells and bubbles diameter leads to the reduce of pellets mass and increase the pellets volume , hence reduce the sinking and floating bulk density.

Indecated the electronic scanning of sinking and floating fish feed pellets as showen in Fig(13) showed the effect of feed formulation and corn percentage as starch ratio index in feed composition on pellets bulk density ,images indecated that increasing the corn percentage in floating feed increased the number of void cells, cells diameter and improve cells distrabution on pellts scanning section. The average of void cells radius were 0.016 for sinking pellets increased to 0.037mm at die zone temprature of 105Co using high shear screw profile, that lead to reduce the peelts mass with increase the pellets volume so decrease the pellets density from 529.93 for sinking feed to 436 ^{3}kg/ m for floating pellets .



A- Sinking feed
Die zone temperature of 105 C°
High shear screws

B- Floating feed
Die zone temperature of 105 C°
High shear screws

Measurement	A	B
Pellets average diameter (mm)	3.17	3.51
Void cells average radius (mm)	0.016	0.037
Pellets bulk deni (kg/m)	529.93	436

Fig. 13. SEM (260X) for sinking and floating aquatic feed showed the effect of formulation on pellets bulk density

6-Sectional Expansion Ratio/Index (SEI):

Expansion ratio , it is considered a measurements that give an index for formula cooking degree , void cells generation, and density of produced pellets.Data in Fig(14) indecated that increaing the die zone temprature from 105 to 120, 135 and 150C^{o} increased the pellets expansion ratio from 1.03 to 1.06 1.10 and 1.24 using low shear screw profile and from1.12 to 1.17 , 1.23 and 1.42 using high shear screw profile for sinking feed formula. While for floating feed formula increased from 1.20 to 1.38, 1.49 and 1.87 using low shear screw profile and from 1.37 to 1.54, 1.69 and 2.06 using high shear screw profile for sinking feed formula.

The increase in sinking and floating pellets expansion ratio by increasing the die zone temprature from 105 to 120, 135 and 150C^{o}and by changing the extruder shear from low shear to high shear attributed to heat generated in the mechanical press due to compression and extrusion helps to increase the starch gelatinization degree and genrate the a lot of ar bubbles amount with big volume that lead to increase the pellets the pellets diameter mor the extruder die holes diameter and increase steadily the sectional expansion ratio index (SEI).

Electronic scanning of sinking and floating fish feed pellets in Fig(15) showed the effect of feed formulation and corn percentage as starch ratio index in feed composition on pellets sectional expansion ratio/index (SEI), images indecated that increasing the corn percentage in floating feed increased the starch gelatinization ratio from 48 for sinking feed to 56 for floating feed, also increased pellets daimeter from 3.24 to 3.72 mm and expansion ratio from 1.17 to 1.54 using sinking and floating feed ,recpectively.

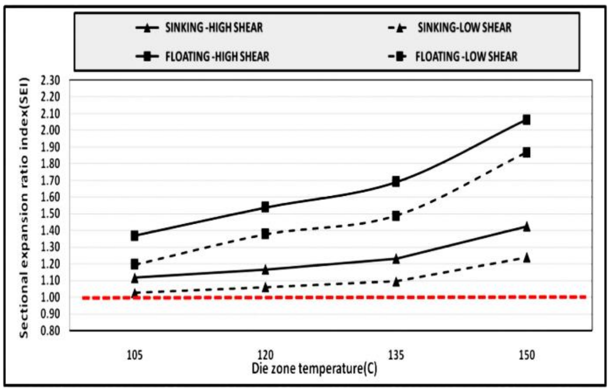
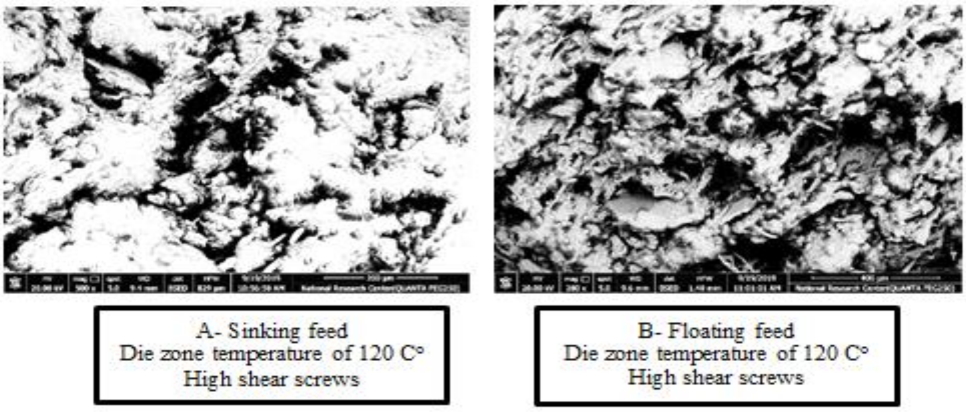


Fig. 14. The effect of die zone temperature, extruder shear on Sectional Expansion Ratio/Index (SEI)



Measurement	A	B
Pellets average diameter (mm)	3.24	3.72
gelatinization ratio	48	56
Expansion ratio	1.17	1.54

Fig. 15. SEM (500 and 260X) for sinking and floating aquatic feed pellets showed the effect of formula on pellets sectional expansion ratio.

- Aquatic feed pellets water stability

The aquatic feed pellets water stability is one of the quality requirements that the owners of fish farms do not give up, increasing the stability of the pellets in the water is an indicator for the quality of the fish feed producer factory. Data in Fig (16) showed that increasing the die zone temprature from 105 to 150C^{o} increased the sinking pellets water stability from 63 , 34, 11 and 0.0% to 86, 72, 46 and 23% using low shear screw profile. While Fig(17) showed it is increase from 87,66, 31 and 14% to 97, 93, 65 and 49% using high shear screw profile after sinking time 60, 120, 180 and 240 miutes, recpectively.

Meanwhile,data in Fig(18) showed that increasing the die zone temprature from 105 to 150C^{o} increased the floating pellets water stability from 83 , 75, 43 and 11% to 98, 90, 72 and 39% using low shear screw profile. While Fig(19) showed it increased from 96,92, 74 and 57% to 100, 100, 91 and 77% using high shear screw profile after floating time of 60, 120, 180 and 240 miutes, recpectively.

The perivous data explained strongly the effect of die zone temprature and extruder shear on sinking and floating pellets water stability.The increase in pellets water stability percentage and the increase in stability time by increasing the die zone temprature and high shear screw profile attributed to the increase in gelatinization degree of starch and that increase the time that water take to infiltrate through the void cells gelatin walls to replace the air cells before the pellets collapses.

Electronic scanning of sinking and floating fish feed pellets in Fig(20) showed the effect die zone temprature on sinking and floating pellets water stability, the images showed for sinking feed die zone temprature of 135C^{o} with low shear screw profile generated void cells has average diameter of 0.018 mm for low sinking velocity pellets has average diameter of 3.14mm , the water stability for the sinking pellets were 34% after 180 min the high water stability of sinking pellets could be due to the increase in gelatinization degree.

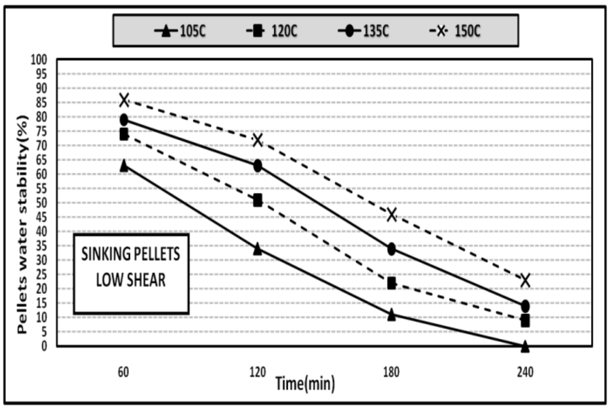


Fig.16.The effect of die zone temperature on sinking aquatic feed water stability using low shear screw profile

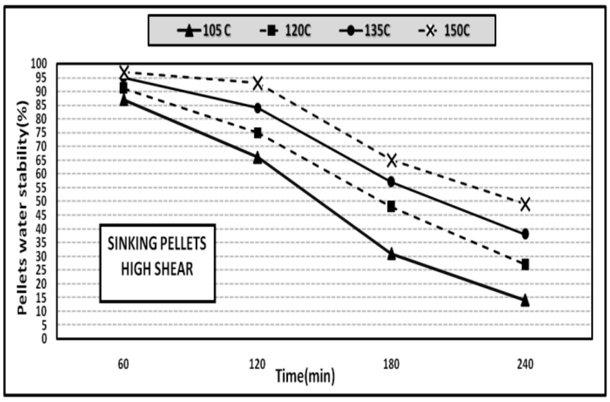


Fig. 17. The effect of die zone temperature on sinking aquatic feed water stability using high shear screw profile

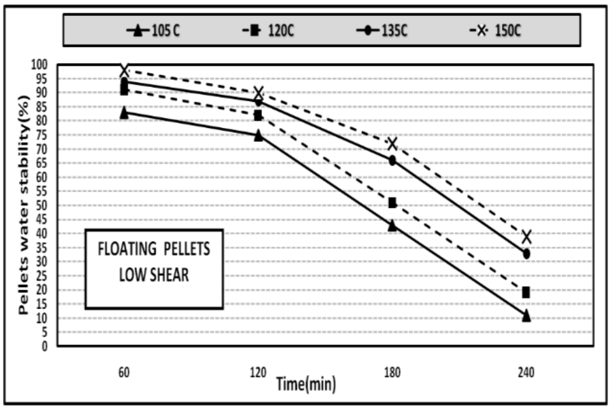


Fig. 18. The effect of die zone temperature on floating aquatic feed water stability using low shear screw profile

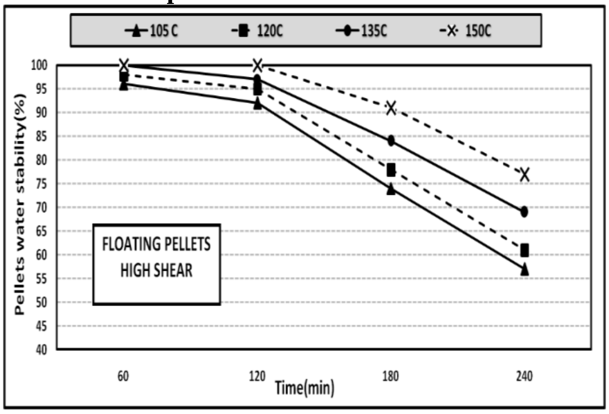
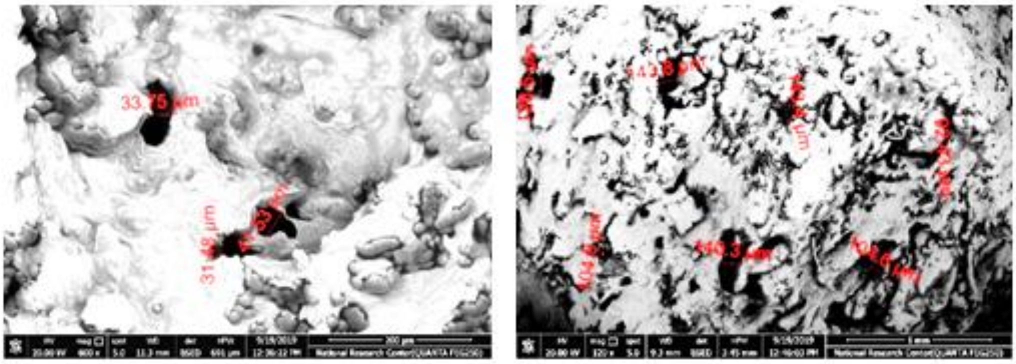


Fig. 19.The effect of die zone temperature on floating aquatic feed water stability using high shear screw profile



A- Sinking feed
Die zone temperature of 135 C°
Low shear screws

B- Floating feed
Die zone temperature of 150 C°
Low shear screws

Measurement	A	B
Pellets average diameter (mm)	3.14	4.1
Void cells average radius (mm)	0.018	0.061
Pellets water stability(%)	34	72

Fig. 20. SEM (600 and 120X) for sinking and floating aquatic feed showed the effect of die zone temperature on pellet water stability

While increase the die zone temprature for floating feed formula up to 150 C° with low shear screw profile increased the voild cells numbers but with very high cells distrabution and low void cells average diameter all over the scanning section and produced floating pellets has 72% water stability after 180 min.

CONCLUSION

This research concern to study the effect of extruder shear and die zone temperature on extruder performance and quality of sinking and floating fish feed using the scanning electronic microscope by analyzing the images of produced feed. The most mechanical factors affecting the extruder performance under investigation were the extruder shear, (high or low shear) screw profile and extruder zones temperature especial die zone temperature was 105, 120, 135 and 150 C^{o} and tow kind of feed formulations (sinking and floating formula).The study recommended for producing sinking feed, the optimum parameters were use low shear screw profile and control the die zone temperature at 105C^{o}, the obtained results were 4.911Mg/h production rate, 98.54% sinking pellets percentage, 0.56 m/s sinking velocity, 1.03 expansion ratio, 561,11kg/m^{3} pellets bulk density and 63% sinking pellets water stability after one hour. For producing floating fish feed the optimum parameters were use high shear screw profile and 135Co die zone temperature, the obtained results were 3.636Mg/h production rate, 97,34% floating pellets percentage, 472min pellets floating time, 1.69 expansion ratio, 383.26 kg/m3 pellets bulk density and 100% floating pellets water stability after one hour. The study recommended use the scanning electron microscopy images to get a complete visualization of sinking and floating feed quality by measuring the void cells dimensions and the gelatinization degree.

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دراسة تأثير القص ودرجات الحرارة في الاكسترودرعلي التركيب البنائي وجودة الاعلاف المائية الطافية والغاطسة

أسامة قدور

قسم العلوم الهندسية- كلية الثروة السمكية- جامعة السويس

اتخذت صناعة اعلاف الاسماك اتجاها جديدا في السنوات الاخيرة بالاتجاه لتصنيع اعلاف الاسماك عن طريق استخدام الاكسترودر بدلا من المكابس الحلقية الشائعة الاستخدام والذى يحتاج الي مشغل محترف للتحكم في الاكسترودر طبقا لطبيعة ومواصفات المنتج المستهدف انتاجة سواء كان طافي او غاطس بالإضافة إلى تحقيق مواصفات الجودة القياسية لكل منتج. ولقد تم دراسة العوامل التشغيلية التي تتحكم في اداء الاكسترودر من خلال هذا البحث والذى أوضح تأثير هذه العوامل على جودة العلف المنتج. وقد اجريت التجارب في مصنع خاص لإنتاج الأعلاف السمكية في مدينة جمصة - محافظة الدقهلية. لدراسة تأثير وضع البريمات ما يسمي معاملات القص وكذلك درجات الحرارة في منطقة الداي على التركيب البنائى وجودة الأعلاف المائية الغاطسه والطافية.وقد اجريت الدراسة تحت العوامل التاليه: نوع تركيبة الاعلاف (تركيبه علفية غاطسه- تركيبه علفية طافية). درجة حرارة الداى (105 ، 120 ، 135 و 150 درجة مئوية). معاملات القص (ترتيب ذو معاملات قص منخفضه – ترتيب ذومعاملات قص مرتفعة). وقد اظهرت النتائج المتحصل عليها وبعد تحليل صور المسح الالكتروني الاتي :استخدام معامل قص مرتفع لبريمات الضغط وكذلك ارتفاع درجات الحرارة في منطقة الطبخ القصوي (منطقة الداي) يؤدي الي زيادة درجة الجلتنة للنشا وزيادة في اعداد واقطار وتوزيع الخلايا الهوائية مما يؤدي الي انخفاض كثافة الاعلاف المنتجة وزيادة معامل انتفاخ الاعلاف وارتفاع ثبات الاعلاف بالماء. والعكس فى حالة استخدام معامل قص منخفض لبريمات الضغط وانخفاض درجات الحرارة في منطقة الطبخ القصوي (منطقة الداي). اثبتت التجارب والمسح الالكتروني للعينات أن ارتفاع كثافة اعلاف الاسماك ليس مؤشرا لارتفاع ثبات الاعلاف بالماء حيث ان عمليات الطبخ عن طريق استخدام عامل القص المرتفع وارتفاع درجات الحرارة يزيد درجات الجلتنه للنشا ويكون جدر الخلايا الهوائية من الجلاتين مما يصعب علي الماء اختراقها ليحل الماء محل الهواء داخل تلك الخلايا وهو ما يؤدي الي انهيار الاعلاف بالماء. اجراء عمليات المسح الالكتروني لعينات من خط الانتاج وخاصة عند حدوث تغيير في نسب التركيبات العلفية أعطى مؤشر واضح وحقيقي لطبيعة وجودة المنتج من حيث ثباته في الماء ومعامل الانتفاخ ونسب الاعلاف الطافيه للغاطسه والعكس . ومن خلال هذه الدراسة تم تحديد العوامل المثلي لكل نوع من اعلاف الاسماك الطافيه والغاطسة والتي اعطت مؤشرات اداء عاليه للاكسترودر وجودة الاعلاف المنتجه وكانت كالاتي:لانتاج اعلاف الاسماك الغاطسة كانت افضل المعاملات هي معاملات القص المنخفضة بوضعية عدد خمس قطع بريمات مفردة الخطوة وعدد واحد بريمة مذدوجة الخطوة مع ضبط درجة الحرارة في منطقة الداي علي 105 درجة مئوية واعطت النتائج الاتية 4.911 ميجا جرام / ساعة للانتاجية - 98.54% نسبة الاعلاف الغاطسة الي الطافية- 0.56 م/ث سرعة غطس حبيبات العلف- 1.03 معامل انتفاخ حبيبات العلف - 561.11 كجم/ م^3 كثافة الاعلاف المنتجة – 63% نسبة ثبات حبيبات العلف بعد ساعة واحدة من الغمر في الماء. لانتاج اعلاف الاسماك الطافية كانت افضل المعاملات هي معاملات القص العالية بوضعية عدد اثنين قطعة بريمات مفردة الخطوة وعدد ثلاث بريمة مذدوجة الخطوة وعدد واحد بريمة مذدوجة مقطوعة مع ضبط درجة الحرارة في منطقة الداي علي 135 درجة مئوية واعطت النتائج الاتية 3.636 ميجا جرام / ساعة للانتاجية - 97.34% نسبة الاعلاف االطافية الي الغاطسة- 472 دقيقة زمن طفو الحبيبات قبل ان تغطس- 1.69 معامل انتفاخ حبيبات العلف - 383.26 كجم/ م^3 كثافة الاعلاف المنتجة – 100% نسبة ثبات حبيبات العلف بعد ساعة واحدة في الماء