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DESIGN AND EVALUATION OF A PNEUMATIC FISH FEED DISTRIBUTOR FOR EGYPTIAN FISH FARMS

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ABSTRACT

A pneumatic fish feed distributor was designed and locally fabricated for Egyptian fish farms to ensure all the fish have equal access to the feed and avoid the manual feeding problems. The performance of the designed pneumatic fish feed distributor was evaluated based on fish pellet degradation, uniformity of fish feed distribution pattern and performance of feeding method. The evaluation was calculated at different operation conditions including different blower air speeds from 10 to 20 m/s, forward speed from 2.62 to 6.39 km/h (from 0.73 to 1.78 m/s, respectively) and feed rates from 10 to 25 kg/min.

The obtained results lead to the conclusion that:

- Using of pneumatic fish feed distributor gave the best results of feed distribution pattern uniformity, eliminated feed breakage wasted as dust and saved about 35%, in fish feeding cost under the optimum operating conditions of air blower speed of 15 m/s, forward speed ranging from 2.53 to 3.42 km/h and feed rate ranging from 20 to 25 kg/min.
- Using mechanical feeding method (pneumatic fish feed distributor) gained 208.18 ± 24.25 g as an average fish mass with coefficient of variation (*C.V*) about 11.47% and better feed conversion ratio (*FCR*) of 1.63 comparing with 183.46 ± 42.73g fish mass with *C.V* about 23.29% and poor FCR of 1.94 gained by using the hand feeding method at the end of production cycle.
- Using of pneumatic fish feed distributor is more suitable and acceptable mechanical feeding method to ensure that all the fish have equal access and similar opportunity to the feed which achieving higher uniformity in growth rate and good feed conversion ratio. In addition, it helps avoiding the manual feeding problems of water pollution due to eliminating waste of pellets dissolved in the water and reduces the feeding labor and cost. Consequently, it increases the benefit margins of fish farm production. Therefore, it is recommended to use pneumatic fish feed distributor under the previous optimum operating conditions.

INTRODUCTION

Tuominen and Esmark (2003) reported that the feeding method used for tilapia farming depends on the culture system used, the size of the farm/ponds and the availability and cost of manual labor. In most tilapia farms, where pelleted dry or moist feeds are used by broadcasting by hand is the preferred method of feeding. Broadcasting is also the recommended method since this allows the farmer to monitor the feeding behavior and general health of the fish, especially when extruded floating pellets are used. However, in very large ponds, a truck may be used with a feeder that blows pelleted feeds over a wider area of the pond to ensure even feed distribution.

NAERLS (2002) and Beveridge (2004) reported that fish can be fed supplementary feeds in two ways- manually or mechanically. Manual (hand) feeding is carried out by a process called broadcasting. This practice is however labor intensive, especially in large fish farms. It is however very suitable for small fish farms. Mechanical feeding is suitable for large-scale commercial fish farms where the labor cost is high. This method is used to reduce this cost, and increase the growth rate and reduce the FCR(feed conversation rate).

Noor (2008) reported that food and feeding are the keywords of growth and production. Their management being one of the main challenges for a aquaculture development. The adjustment of food delivery to match fish appetite plays a key role to maximize the income or benefit for aqua-industrialist. There are several major and minor problems that are being studied recently in order to improve feeding system and management. One of these major problems is to reduce cost of feeding and increase the efficiency of this task at the same time. Dunn (2008) indicated that the currently aquaculture farms are feeding fish by means of traditional hand feeders and automated feeding systems using hydro-acoustics and sensory feedback systems. These approaches however are not considered optimal feed intake. Social dominance using demand feeder does not allow even feeding distribution among all sizes of fish.

Hemeda et al. (2008) modified and evaluated a mounted type machine for fish feeds distribution by blowing air system under three machine parameters of tractor forward speed (2.22, 3.51, 4.83 and 6.13 km/h), blower speed (1500, 2000, 2500 and 3000 rpm), and aquatic feed rates (4, 8, 12 and 16 kg/min). Their results indicated that the optimum operating parameters for the modified feed blowing machine were 16 kg/min feeding rate, 3000 rpm for blower revolving speed (22.9 m/s air speed) and 4.83 km/h tractor speed which produce a satisfactory coefficient of uniformity (C.U.) of 0.947 and permissible coefficient of variation 12.92 %. Moreover, using these parameters gave the highest distribution width (10 m) which provides equal feeding opportunities for as many fish as possible. While, Osman (2008) illustrated that improved feed distributors such as demand feeders and hydraulic type automatic feeders promote more dense and stable pelleted feeds, which greatly reduces the quantity of fines and slows the leaching of nutrients. The demand feeders are easy to install and operate. These feeders are not suitable for young fish since they are not able to operate them. Hydraulic-type automatic feeders can be used on farms where electric energy supply is not available, but where there is a continuous water flow.

Steven and Helfrich (2009) indicated that fish can be fed by hand, by automatic feeders and by demand feeders. Many fish farmers like to hand-feed their fish each day to assure that the fish are healthy, feeding vigorously, and exhibiting no problems. Large catfish farms often drive feed trucks with compressed air blowers to distribute feed uniformly throughout the pond.

One challenge with dilute phase pneumatic conveying of feed pellets is formation of dust and small particles as pellets are conveyed through the pipelines but may also decrease the quality of pellets and cause contamination of pipelines; also decrease the quantity of feed available for fish. Fine powders or oilylsticky products will stick to and accumulate inside pipelines (Wypych, 2001) and may therefore result in blocking. Air speed and particle pickup velocity are also associated with fractures and dust. High air speed generates high drag force between air flow and feed particle surface, which increases the attrition, therefore more dust (Aarseth, 2004). Increasing the feeding rate may give a "frindly protection" effect, meaning that the pellets protect each other from collisions, thus reducing the generation of dust and fracture (Norambuena, 2005).

Three mechanisms are associated with animal feed degradation (Aarseth et al., 2006; Aas et al., 2011): (1) Surface attrition or abrasion: process where fines and small particles are removed from product surface. (2) Chipping: process where larger particles are removed from product surface. Corners and edges are susceptible to this damage. (3) Fragmentation: resulting from hard impacts producing the beak of the product into several smaller particles. The three mechanisms generate changes in the particle size, size distribution and bulk density of the feed product.

Problem statement and objectives

Fish production considers one of the major economic sectors due to its importance role, which shares to solve the problem of gap in protein. Meanwhile, the total Egyptian aquacultural farm areas decreased from 361,300 fed in 2009 to 305,000 fed in 2010 (about 15% decreasing) due to rising in labor and feed costs (El-Masry, 2008). Hand feeding is still the most common and simplest method to feed the fish in more than 90% of total aquaculture area in Egypt. However, it is labor intensive and requires skilled workers to avoid the wasting of pellets that are supplied to the fish. Also, it is less efficient due to the non-uniformity of the distributed feeds, which in turn, increased the competition for feed, increasing labor costs, increasing feed waste. The feeding operation may be delayed and may not be practical for large commercial fish farms.

It is necessary to increase fish production by increasing and encouraging aquaculture to produce more quantities and the production problems facing fish producers in Egypt, such as feeding losses, less effectiveness of manual feeding, limited pellet distribution area and high cost of imported feeding technology.

Therefore, the main objective of this study is to design, locally fabricate and evaluate a pneumatic fish feed distributor for Egyptian fish farms to obtain a uniform feed distribution pattern and ensure that all the fish have equal access to the feed. However, the specific objectives of this study are: to reduce the effect of water pollution due to elimination of pellets waste dissolved in the water and to increase the fish farmer profit margins due to increased feeding efficiency through achieving uniform growth rates of fish and obtaining better feed conversion ratio and to reduce the total feeding cost (labor and time costs).

MATERIALS AND METHODS

In this investigation, a pneumatic fish feed distributor was designed, locally fabricated and evaluated. It was designed to be mounted on the tractor's trailer beside fish feed bags. The fish feeding was conducted through uniform distribution of fish feed over water surface of fish farm using air blower stream of designed fish feed distributor. The prototype of fish feed distributor was fabricated at some private workshop in Damanhor city, Egypt in 2010.

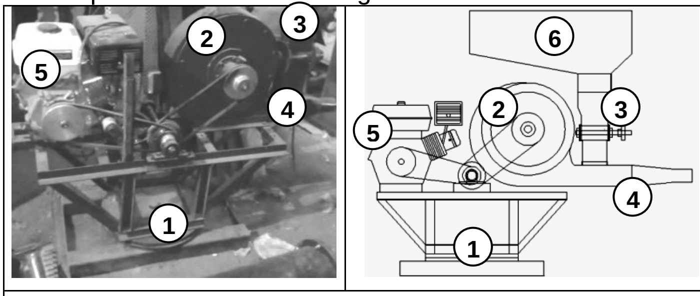
1-Materials

1-1- Fish feed distributor

The structure of the fish feed distributor can be divided into four components which are main frame, air blower unit, feeding unit and power source as shown in Fig. (1), while the technical specifications are summarized in Table (1).

a-Main frame

The fish feed distributor frame was constructed from mild steel square pipes and angles with different dimensions. It was divided in two parts: upper part for mounting the other components of fish feed distributor and lower part (machine base) for fixing the fish feed distributor on the trailer using flexible circular plate to facilitate turning to work on either the left or right side.



1. Main frame
2. Air blower
3. Feeding device
4. Distribution tube
5. Power source
6. Feed hopper

Fig. (1): Photos and schematic diagram of pneumatic fish feeder.

Table (1): Technical specifications of the designed fish feed distributor.

Item	Specification				
Overall dimensions	Length, mm	1500			
	Width, mm	855			
	Height, mm	1720			
Mass, kg	246				
Air blower	**Engine pulley diameter, mm**	**Blower pulley diameters, mm**	**Blower, rpm**	**Air speed, m/s**	**Air flow rate, m^3/min**
	150	180	2167	10	4.71
	150	140	2786	15	7.07
	150	100	3900	20	4.62
Feeding unit	**Engine pulley diameter, mm**	**Feeder gearbox pulley diameters, mm**	**Feeder gearbox pulley, rpm**	**Feeder speed, rpm**	
	50	325	400	50	
	50	217	600	75	
	50	163	800	100	
	50	130	1000	120	
Power source	Type	Gasoline engine, air cooled			
	Power, kW (hp)	3.73kW (5 hp)			

b- Air blower unit

An air rotary blower with a maximum rpm of 4500 was used to produce a compressed air stream. The blower consists of 50 cm cast impeller matched to a cast backing plate, and an engineered blower housing. The diameter and length of outlet pipe of air blower were 100 and 250 mm, respectively. The air speed was regulated by changing the speed ratio between engine and blower pulleys.

c - Feeding unit

The feeding unit consists of feed hopper, feeding device and distribution tube. The feed hopper was constructed from 1.5 mm thickness galvanized metal sheet with capacity of about 100kg of extruded floating fish feed pellets. The feed hopper was fixed on the feeding device to permit the fish feed pellets moving gradually to the feeding device without blocking. The feeding device (drum and housing) was fixed at the bottom of the feed hopper to control the feed rate of pellets and transport it from the hopper to the distribution tube. A distribution tube of feeding unit have the diameter and length of 100 and 800 mm, respectively was fixed on the outlet pipe of air blower to distribute fish feeds over water surface of fish farm. The feed rate can be adjusted using feeding device within given limits through speed ratio between engine pulley and feeding device gearbox.

d- Power source and power transmission

A gasoline engine of 3.73kW (5 hp) was used as the power source to drive the air blower and feeding device. The transmission system consists of two groups of pulleys and V-belts. One of them used to transmit the power from engine to air blower and the other to transmit the power to the feeding (metric) device. The feeding device was equipped with low rpm transmission gearbox (a worm gear and pinion with reduction ratio of 8:1) and four different diameter pulleys. The diameters of pulleys (mm) of the engine shaft, air blower and feeding device and their speeds (rpm) are listed in Table (1).

1-2- Tractor and trailer

A Nasr tractor of 44.8 kW (60hp) with forward speed ranging from 2.62 to 6.39 km/h was used to pull a trailer mounted by fish feed distributor and feed bags during evaluation experiments of fish feed distributor.

1-3- Fish feed

A locally manufactured floating type extruded fish pellets (supplied in 50 kg plastic bags) was used for evaluating the designed fish feed distributor under study variables.

3- Scope of variables

To study the performance of the designed pneumatic fish feed distributor, a series of practical experiments were carried out after mounting the fish feed distributor on trailer pulled by tractor under the following variables:

- Three different levels of blower air speed, namely: 10, 15 and 20 m/s. Four different forward speeds of fish feed distributor, namely: 2.62, 3.55, 4.65 and 6.39 km/h (0.73, 0.99, 1.29 and 1.78 m/s, respectively);
- Four different feed rate of fish feed pellets, namely: 10, 15, 20 and 25 kg/min

4- Performance test procedure

In order to study the factors affecting on the performance of fish feed distributor and the quality of distributed fish pellets over water surface of fish farm, three groups of tests were conducted as follows:

The first group of tests conducted to evaluate the effect of study variable levels of air speed and feed rate on the degradation of extruded floating fish feed pellets during distribution using pneumatic fish feed distributor.

The second group of tests was conducted to evaluate the effect of studied variable levels of forward speed, air speed and feed rate on the distribution pattern uniformity.

The third group of experiments was carried to study the effect of optimum operation conditions of fish feed distributor on the overall fish mass, fish growth uniformity and feed conversion ratio (FCR) comparing with traditional hand feeding method.

5- Measurements

The evaluating experiments were conducted at Rice Mechanization Center, Agric. Eng. Res. Institute and some private fish farms at Sidi-Salem, Kafr El-Shiekh Governorate, Egypt in 2011. The following measurements were taken under consideration during evaluating the fish feed distributor :-

5-1-Physical properties of fish feed pellets

Some physical properties of fish feed pellets used under study such as the dimension (diameter and length), bulk density, moisture content and hardness were measured. The average values were calculated and recorded in Table (2).

The dimensions of pellets were measured with a digital caliper (0.05 mm accuracy) with 25 replicates.

The moisture content of feed pellets was determined according to ASAE (2000) by leaving the samples for 24 hours at 103oC in the electric oven. The samples were about 25 and replicated three times.

The bulk density of the used pellets was measured by filling a columned container of 1 liter with pellets. The top of the pile scraped once to remove the redundant pellets exceeding container edge level. The mass and volume of the pellets sample with three replicates were measured and the bulk density was calculated using the following equation:

$$\rho = \frac{m}{v}$$

Where: ρ = Bulk density (g/cm3);

m = Mass of sample (g);

v = Volume of sample (cm3)

Twenty readings of the rupture point of fish feed pellets were determined as an indicator of pellets hardness using the portable hardness tester.

Table (2): Some physical properties of fish feed pellets

Item	Length, mm	Diameter, mm	M.C, %	Bulk density, g/cm3	Hardness, N
Average	5.45	4.89	11.07	0.46	16.84
SD	0.21	0.44	0.13	0.08	1.23

5-2- Air speed

The air speed of blower was measured using digital direct reading portable anemometer (Vane Probe – Extech, Hygro Thrmo, model 407412) which is capable of measuring velocities from 0.2 to 40.0 m/ s (0.1 m/s accuracy).

5-3- Rotational speed

A multi-range hand digital tachometer was used to measure the revolution speed (rpm) for engine pulley, air blower pulley and feeding device pulley.

5-4- Pellets dust and fracture percentages

Degradation of fish pellets (generation of dust and small particles of pellets) during using pneumatic fish feed distributor was determined in this investigation. Quantification of the dust amount and fracture in the fish pellets before and after distributed were carried out by using sieving procedure. In order to collect the pellets at the outlet of the distribution tube, a cotton stretch bed sheet was used. The bed sheet was attached to a wooden pole. Five samples of collected distributed pellets in the collector (300-350 g for each) were taken to run the sieving procedure. For the fish pellet size under study, a set of 4 mm and 1.5 mm sieving screens as well as a dust pan was chosen. Pellet particles larger than 4mm were considered as intact pellets. However, the pellet particles from 1.5 to 4 mm were denoted fracture, whereas particles <1.5 mm were denoted dust. After the samples were sieved, the materials collected on the sieves were weighed and the percentages of fracture and dust were calculated.

5-5- Uniformity of distribution pattern

The evaluating procedure of the fish feed distribution patterns were carried out according to ASABE Standard (2006) involving the following items: collection trays, a measuring tape and plastic bags. The dimensions of collection trays of 60x35x15 cm were chosen to prevent pellet particles from deflection, scattering and bunching either into or out of the trays. The trays used for collection of distributed fish pellets were placed in one row on a ground surface in a line perpendicular to the direction of travel. The feed hopper of fish feed distributor was filled with fish pellets used for experiments. Each test was replicated three times, then the values of coefficient of variation (*C.V*%) and coefficient of uniformity (*C.U*) of the feed distribution pattern were calculated according to ASABE Standard (2006) and recorded as an indicator for fish pellets distribution uniformity. The lower the *C.V*, the more uniform the distribution pattern (Logically the treatment exhibits low *C.V* value represents more uniformity and vice versa). The coefficient of variation (*C.V*%):

$$C.V = \frac{\delta}{x_a} \times 100$$

C.U = 1- C.V

Where: $\delta = \sqrt{\frac{\sum (x_i - x_a)^2}{n-1}}$ and $x_a = \frac{\sum x_i}{n}$

C.V % = coefficient of variation.

C.U = coefficient of uniformity

δ = standard deviation
x_a = the arithmetic mean of collection points across the distribution pattern swath
n = number of measurements
x_i = the individual amount of feed pellets in a collector in the distribution pattern swath

5-6- Performance of feeding method

The feeding method, administered to the fish, affects their access to the feed and subsequently plays a great role in influencing growth rate, uniformity in size and feed conversion ratio. Therefore, the feed conversion ratio (FCR), fish mass and its growth uniformity at the end of production cycle were taken as indicators of the performance of feeding method (fish feed distribution uniformity) using designed fish feed distributor in comparison with traditional hand feeding method.

Two tilapia fish farms, in the same place were, used to compare the application of mechanical and hand feeding methods. All production conditions and treatments such as farm size and area, type and age of fish, type and feed rate. are same in both fish farms. At the end of production cycle, five fish samples (each sample about 20 fishes) were taken randomly from both farms covering all the fish farm area and the mass of each fish was determined. The average values of fish mass, standard deviation and coefficient of variation (*C.V* %) were calculated to determine the fish growth uniformity. Also, the total amount of fish is harvested from each farm and the total amount of feed fed to the fish during production course was determined. The *FCR* was calculated using the following equation according to Jabeen et al. (2004):

$$FCR = \frac{Total\ amount\ of\ feed\ fed\ during\ prouction\ cycle\ (ton)}{Total\ amount\ of\ harvested\ fish\ (ton)}$$

5-7 Cost estimation

The mechanical and manual feeding costs were analyzed to clear the economic objective of this study. The total mechanical feeding cost (including the cost of tractor and trailer used to mount and transport the fish pellets bags between fish farms during mechanical feeding processes) was estimated and calculated according to the equation given by Awady, 1978 as follows:-

$$C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + m\right) + (A \times K \times f \times u) + b$$

where :

- C = total hourly cost, LE/h;
- P = initial price (7000, 90,000 and 30000LE for distributor, tractor and trailer, respectively, 2012 prices level*);
- h = estimated yearly operating hours (600, 10,000 and 1000 for distributor, tractor and trailer, respectively);
- a = estimated life expectancy of machine (7, 10 and 10 years for distributor, tractor and trailer, respectively);
- i = interest rate/year (10%);

* 1 U$ = 6.11 LE

t = taxes and overhead rates (2%);
m = maintenance and repairs ratio to capital head (18%),,
K = nominal power (60 and 5 hp for distributor and tractor, respectively);
A = ratio of rated power and lubrication related to fuel cost (0.75-0.9),
s = specific fuel consumption (l/hp.h);
u = price of fuel, (0.9 LE/L);
b = hourly wages, (6.25 LE/h).

The labor cost was calculated based on the fact that one labor was required to properly operate the machine and 50 LE/day for each labor (8 hours/day). The fuel cost of the machine was determined to be 0.9 LE/l at the study optimum operating variables of air blower speed of 15 m/s, forward speed ranging from 2.53 to 3.42 km/h and feed rate ranging from 20 to 25 kg/min. Considering that the tractor work rate was only 10 farms/day using the hand feeding method and 15 farms/day using mechanical feeding method. Also, the hand feeding cost(including the cost of tractor and trailer used to mount and transport the fish pellets bags between fish farms during feeding processes) was determined as average of required labor to feed one fish farm (1 feddan for each farm), assuming the need of 2 labors/farm and 50 LE/day for each, based on field experience reported by local farmers.

$$The\ total\ hand\ feeding\ cost\ (LE/farm) = Labor\ cost\ LE/farm + Tractor\ cost\ LE/farm$$

RESULTS AND DISCUSSION

1- Fish pellet degradation

The percentages of whole pellets (> 4.0 mm), fracture (1.5-4.0 mm) and dust (<1.5 mm)generated due to degradation of fish feed pellets using designed fish feed distributor and how the degradation was affected by air speed variables (10, 15 and 20 m/s) and feed rate variables (10, 15 , 20 and 25 kg/min) are shown in Fig. (2). It could be observed that the generation of dust and fracture increased as air speed increased at any given feed rate of fish pellets under study. These results may be due to that air flow exerts thrust force on the cross section of pellets and the drag force on their surface which accelerates them to move forward. The surface attrition of pellets caused by drag force of air is one of the most important factors generating dust during pneumatic feeding system. Increased drag force with increased air speed may result in more surface attrition and thus more dust.

Another reason for more dust generation with higher air speed is due to increased surface attrition among pellets caused by frictional force between pellets and distribution tube wall or between the metric (feeding) device and its housing. High air speed will generate more or less turbulent flow of pellets, even if the pellets are of big size and high density. Turbulent flow increases the attrition not only between pellets, but also between pellets and distribution tube wall, therefore, generating more dust. These results agree with the Aarseth's results (2004).

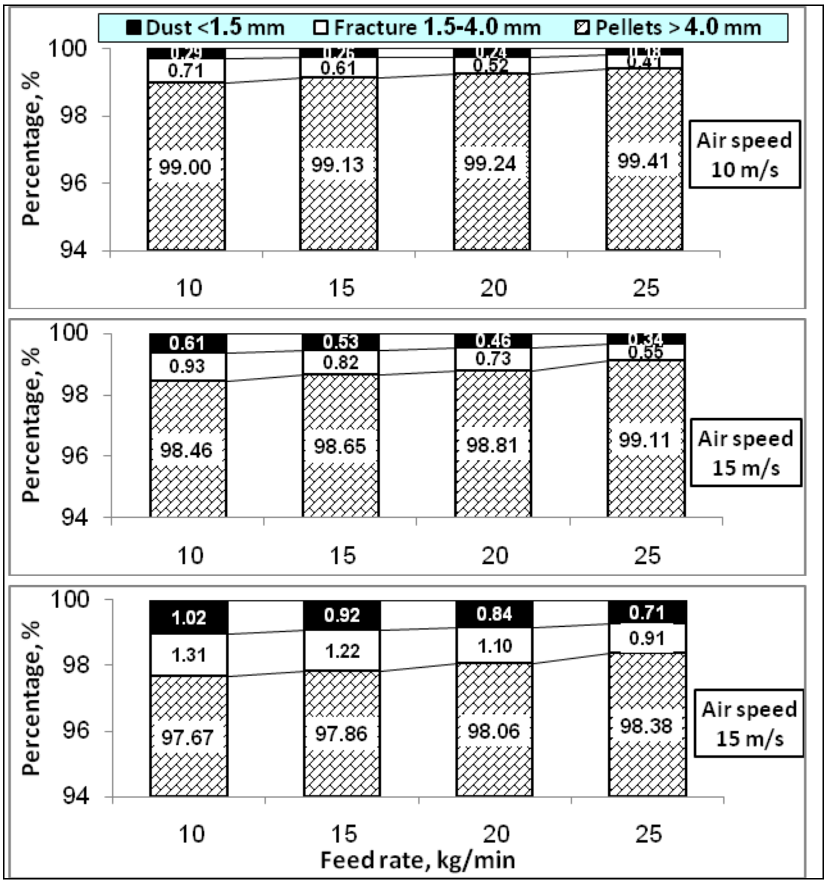


Fig. (2): Effect of air blower speed and feed rate on the degradation of fish feed pellets

Regarding the effect of feed rate, increasing feeding rate resulted in less dust and decreased generation of pellet fracture at any given air speed under study. These results cleared that the feeding rate was negatively correlated with generated dust and fracture and the impact of feeding rate was still quite small. Feeding rate adjusts the mass of fish pellets conveyed through the distribution tube. Increased feeding rate indicates that more pellets are conveyed and distributed at the cross section of distribution tube instantaneously reduces the air flow space in the bulk pellets, thus minimizing the effect of turbulent flow. The pellets stay at relatively stable status during pneumatic conveying and a friendly protection by pellets themselves is formed. Under this protection, the frictional force by air speed is reduced and therefore less dust is generated. The generation of fracture is also reduced due to the same mode of action. These results agree with Norambuera's results (2005).

Therefore, it could be concluded from the previous discussion that using of fish feed distributor insures maximum equipment performance and eliminates feed breakage which means that virtually no feed is wasted as dust by maintaining maximum feed integrity from the hopper into the air flow distribution unit resulting in improved fish feed conversion ratios.

2- Fish feed distribution pattern uniformity

The effect of feed rates (10, 15, 20 and 25 kg/min) of fish feed pellets, air blower speeds (10, 15 and 20 m/s) and the forward speeds (2.62, 3.55, 4.65 and 6.39 km/h) on the uniformity of feed distribution pattern using the designed fish feed distributor are listed in Table (3) and illustrated in Fig. (3). These results indicate that the feed distribution pattern uniformity is highly affected by forward speed. Increasing the forward speed increased the coefficient of variation (*C.V*%) and decreased the coefficient of uniformity (*C.U*) of feed distribution pattern, consequently, produced poor feed distribution pattern uniformity at any given feed rate air blower speed. However, the increment percentage in *C.V* values and decrement percentage in the CU values increased by increasing forward speed.

At specific air blower speed of 15 m/s and feed rate of 10 kg/min, increasing the forward speed from 2.62 to 3.55 or to 4.65 and to 6.39 km/h increased the coefficient of variation (*C.V*%) from 20.81to 27.94 or to 36.41 and to 46.77%, respectively and decreased the coefficient of uniformity (*C.U*) from 0.79 to 0.72 or to 0.64 and to 0.53, respectively of feed distribution pattern. These results may be due to increasing the vibration effect by increasing forward speed which results in an increment percentage in irregular feeding rate. Therefore, the 2.62 and 3.55 km/h are considered as the acceptable values of forward speeds producing lower values of the coefficient of variation for feed distribution pattern uniformity at any given feed rate and air blower speed in this study conditions.

Also, it could be mentioned that the feed distribution pattern uniformity is greatly affected by both air blower speed (m/s) and feed rate (kg/min) as shown in Table (3) and Fig. (3). Increasing or decreasing air blower speed than 15m/s results in an increment percentages in coefficient of variation (*C.V*%) values and a decrement percentages in the coefficient of uniformity (*C.U*) values of feed distribution pattern. These results may be due to the effect of the produced air stream speed on the feed distribution pattern uniformity. Decreasing the air speed from 15 to 10 m/s increased the quantity of feed distribution at the nearest side of fish farm because the produced air stream speed was not enough to distribute these rates of feeds uniformity over the width of fish farm. However, increasing the air blower speed from 15 to 20 m/s results in an over air stream speed which concentrate the distributed feeds on the farthest side of fish farm as shown in Fig. (3).

At specific forward speed of 3.55 km/h and feed rate of 20 kg/min, increasing the air blower speed from 10 to 15 m/s decreased the coefficient of variation (*C.V*) from 21.07 to 13.30% and increased the coefficient of uniformity (*C.U*) from 0.79 to 0.87. However increasing the air blower speed from 15 to 20 m/s increased the coefficient of variation (*C.V*) from 13.30 to 22.59% and decreased the coefficient of uniformity (*C.U*) from to 0.87 to 0.76. These results mean that, increasing the air blower speed from 10 to 15 m/s gave the lowest *C.V* values and the highest *C.U* values, consequently, improved the feed distribution pattern uniformity. Therefore, the air blower speed of 15 m/s is considered the acceptable air speed variable which gave the best results of the feed distribution pattern uniformity.

Table (3): The effect of air blower speed, forward speed and feed rates of feed pellets on the uniformity of fish feed distribution pattern

Feed rate kg/min	Item	Air blower speed = 10m/s				Air blower speed = 15m/s				Air blower speed = 20m/s			
		Forward speed, km/h				Forward speed, km/h				Forward speed, km/h			
		2.62	3.55	4.65	6.39	2.62	3.55	4.65	6.39	2.62	3.55	4.65	6.39
10	Av.	2.68	1.98	1.54	1.13	2.65	1.96	1.51	1.10	2.65	1.97	1.53	1.15
	SD	0.61	0.75	0.68	0.60	0.55	0.55	0.55	0.52	0.78	0.76	0.73	0.63
	C.V	22.85	37.67	44.08	52.80	20.81	27.94	36.41	46.77	29.41	38.70	47.48	55.38
	C.U	0.77	0.62	0.56	0.47	0.79	0.72	0.64	0.53	0.71	0.61	0.53	0.45
15	Av.	3.94	3.04	2.28	1.70	3.97	2.97	2.33	1.65	3.97	3.00	2.30	1.67
	SD	0.73	0.77	0.78	0.80	0.63	0.53	0.48	0.46	0.86	0.88	0.86	0.67
	C.V	18.54	25.40	34.22	47.25	15.78	17.92	20.57	27.58	21.59	29.23	37.31	40.20
	C.U	0.81	0.75	0.66	0.53	0.84	0.82	0.79	0.72	0.78	0.71	0.63	0.60
20	Av.	5.29	3.95	3.00	2.18	5.31	3.94	3.06	2.20	5.30	3.94	3.04	2.30
	SD	0.64	0.83	0.93	0.90	0.59	0.52	0.54	0.49	0.92	0.93	0.92	0.83
	C.V	12.15	21.07	30.96	41.00	11.12	13.30	17.78	22.15	17.38	23.59	30.40	36.31
	C.U	0.88	0.79	0.69	0.59	0.89	0.87	0.82	0.78	0.83	0.76	0.70	0.64
25	Av.	6.61	4.88	3.74	2.75	6.61	4.92	3.80	2.74	6.61	4.93	3.75	2.82
	SD	1.19	1.26	1.34	1.23	0.85	0.81	0.77	0.66	1.20	1.23	1.17	1.08
	C.V	17.92	25.88	35.75	44.80	12.88	16.46	20.27	24.22	18.08	25.01	31.29	38.28
	C.U	0.82	0.74	0.64	0.55	0.87	0.84	0.80	0.76	0.82	0.75	0.69	0.62

With respect to the effect of feed rate on the feed distribution pattern, the obtained results indicated that increasing feed rate up to 20 kg/min decreased the coefficient of variation (*C.V*) and increased the coefficient of uniformity (*C.U*) of feed distribution pattern. However, increasing the feed rate than 20 kg/min increased the coefficient of variation (*C.V*) and decreased the coefficient of uniformity (*C.U*) of feed distribution pattern, consequently produced poor feed distribution pattern uniformity. Distributed feed

At specific forward speed of 3.55 km/h and air blower speed of 15 m/s, increasing feed rate from 10 to 15 and to 20 kg/min decreased the coefficient of variation (*C.V*) from 27.94 to 17.92 and to 13.30% and increased the coefficient of uniformity (*C.U*) from 0.72 to 0.82 and to 0.87 of feed distribution pattern. However, by increasing feed rate from 20 to 25 kg/min at the same pervious forward speed and air blower speed, the coefficient of variation (*C.V*) increased from 13.30 to 16.46% and the coefficient of uniformity (*C.U*) decreased from 0.87 to 0.84. The best results of feed distribution pattern uniformity (lowest coefficient of variation *C.V* and highest coefficient of uniformity *C.U*) were obtained with feed rate of 20 kg/min at any given forward speed and air blower speed under study.

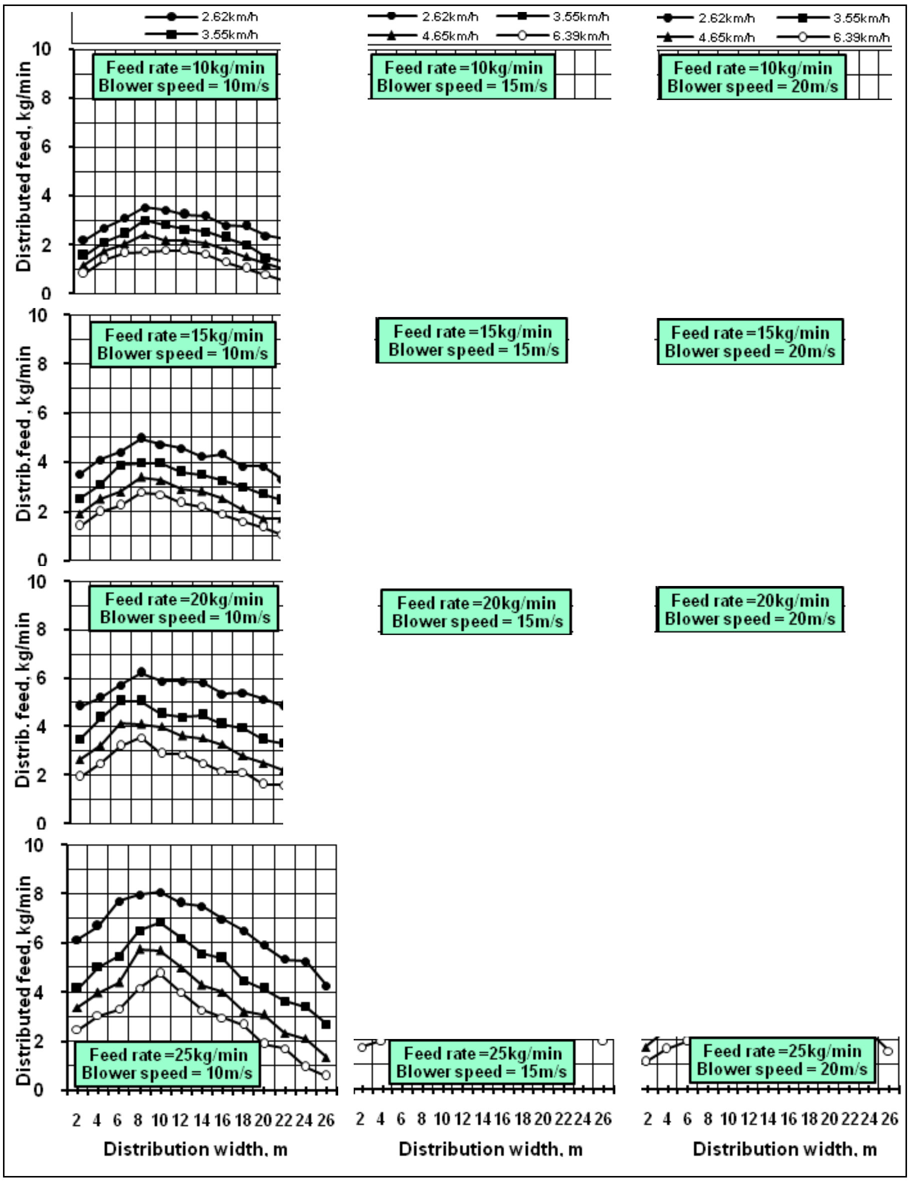


Fig. (3): The effect of air blower speed, forward speed and feed rates of feed pellets on the uniformity of fish feed distribution pattern.

3- Performance of feeding method

The performance of feeding method was investigated through determining the effect of mechanical feeding using pneumatic fish feed distributor on the uniformity of fish growth and feed conversion ratio (*FCR*) in comparison with hand feeding method. The comparison results indicated that using pneumatic fish feed distributor gave the highest overall fish mass and growth uniformity of fish. Meanwhile, the lowest growth rate and growth uniformity was by using hand feeding method.

Higher growth of fish indicated that using mechanical feeding method (pneumatic fish feed distributor) gained 208.18 ± 24.25 g as an average of fish mass with coefficient of variation (*C.V*) about 11.47% comparing with 183.46 ± 42.73g of fish mass with coefficient of variation (*C.V*) about 23.29% gained by using the hand feeding method at the end of production cycle.

Also, the comparison results clarified that better feed conversion ratio (lower value of *FCR*) of 1.63 was observed for harvested fish fed using pneumatic fish feed distributor (mechanical feeding method). However, poor feed conversion ratio (higher value of *FCR*) of 1.94 was observed for harvested fish fed using hand feeding method.

These results may be due to the higher variation in the fish distribution pattern uniformity between fish farm fed using mechanical feeding method and fish farm fed using hand feeding method. The higher uniformity of fish feed distribution pattern covering most of the area of fish farm was obtained using pneumatic fish feed distributor. This means that all the fish have equal access and similar opportunity to the feed and achieved higher uniformity in growth rate and feed conversion ratio (*FCR*). However, poor uniformity of fish feed distribution pattern obtained using hand feeding method was due to throwing the fish feed in one spot or in higher spacing spots over the fish farm, resulted in high competition on feed that limits the ability of some fish to feed and not provide equal feeding opportunities for all fish in the fish farm. This means that a greater quantity of fish feed was required for a unit mass growth of fish which reduces the benefit margins of fish farming.

4- Cost estimation

The cost analysis of feeding process using the designed pneumatic fish feed distributor concluded that the total mechanical feeding cost were 19.85 LE/farm comparing with 30.97 LE/farm when hand feeding was implemented. Therefore, utilizing the designed pneumatic fish feed distributor was proven to be very cost effective and was able to save about 35%, in fish feeding cost.

Conclusion

- Using of pneumatic fish feed distributor gave the best results of feed distribution pattern uniformity, eliminated feed breakage wasted as dust and saved about 35%, in fish feeding cost under the optimum operating conditions of air blower speed of 15 m/s, forward speed ranging from 2.53 to 3.42 km/h and feed rate ranging from 20 to 25 kg/min.
- Using mechanical feeding method (pneumatic fish feed distributor) gained 208.18 ± 24.25 g as an average fish mass with coefficient of variation (*C.V*) about 11.47% and better feed conversion ratio (*FCR*) of 1.63 comparing with 183.46 ± 42.73g fish mass with *C.V* about 23.29% and poor *FCR* of 1.94 gained by using the hand feeding method at the end of production cycle.

- Using of pneumatic fish feed distributor is more suitable and acceptable mechanical feeding method to ensure that all the fish have equal access and similar opportunity to the feed which achieving higher uniformity in growth rate and good feed conversion ratio. In addition, it helps avoiding the manual feeding problems of water pollution due to eliminating waste of pellets dissolved in the water and reduces the feeding labor and cost. Consequently, it increases the benefit margins of fish farm production. Therefore, it is recommended to use pneumatic fish feed distributor under the previous optimum operating conditions.

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تصميم وتقييم جهاز توزيع غذاء السمك باستخدام الهواء لمزارع الأسماك المصرية

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أجريت هذه الدراسة بهدف التصميم والتصنيع المحلى لجهاز توزيع عليقة (مصبعات) الأسماك باستخدام الهواء بخامات محلية بما يناسب ظروف مزارع الأسماك المصرية ، بهدف ضمان تكافؤ وتماثل فرص التغذية لجميع الأسماك بالمزرعة ، وما يترتب عليه من تقليل فاقد الغذاء وتلويثه للمياه ، وزيادة وانتظامية معدل النمو وكفاءة التحويل الغذائى. وقد تم تقييم أداء الآلة على أساس درجة تفتيت المصبعات بسبب استخدام الهواء ومعدلات انتظامية توزيع الغذاء وتأثير ذلك على انتظامية معدلات النمو ونسب التحويل الغذائى والتقييم الاقتصادى للتغذية باستخدام جهاز التوزيع تحت الدراسة ، مقارنة بالتغذية اليدوية المتبعة فى تلك المزارع. تم تقييم جهاز التوزيع المصمم تحت مستويات مختلفة تراوحت من سرعة هواء المروحة من 10 إلى 15 م/ثانية ، سرعات أمامية من 2.62 إلى 6.39 كم/ساعة (من 0.73 إلى 1.78 م/ثانية على التوالى) ومعدلات تغذية من 10 إلى 25 كج/دقيقة.

وكانت أهم النتائج المتحصل عليها كما يلى:-

- أدى استخدام جهاز توزيع مصبعات الأسماك باستخدام الهواء للحصول على أفضل معدلات انتظامية لنماذج توزيع الغذاء على سطح الماء فى مزارع الأسماك (اقل قيم لمعامل الاختلاف C.V وأكبر قيم لمعامل الانتظامية C.U) دون تأثير يذكر على درجة تفتيت المصبعات المستخدمة وتوفير حوالى 35% من تكاليف عملية التغذية، وذلك تحت ظروف التشغيل المثلى التالية: سرعة مروحة الهواء 15م/ثانية ، سرعات أمامية من 2.53 إلى 3.42 كم/ساعة و معدل تغذية من 20 إلى 25كج/دقيقة.
- أدى تطبيق التغذية الميكانيكية باستخدام جهاز توزيع عليقة الأسماك إلى زيادة متوسط وزن السمكة (208.18± 24.25 ج) بمعامل اختلاف منخفض (C.V) 11.47% ونسبة تحويل غذائى جيدة (FCR) حوالى1.63 مقارنة بمتوسط وزن السمكة (183.46± 42.73 ج) بمعامل اختلاف عالى (C.V) 23.29% ونسبة تحويل غذائى ضعيفة (FCR) حوالى1.94 عند تطبيق التغذية اليدوية لنفس ظروف التربية.
- لذلك يوصى باستخدام جهاز توزيع عليقة الأسماك باستخدام الهواء تحت ظروف التشغيل المثلى السابقة كطريقة ميكانيكية جيدة ومناسبة لتغذية مزارع الأسماك تضمن تكافؤ وتماثل فرص التغذية لجميع الأسماك بالمزرعة ، وما يترتب عليه من تقليل فاقد الغذاء وتلويثه للمياه وزيادة وانتظامية معدل النمو وكفاءة التحويل الغذائى وارتفاع هامش الربح للاستزراع السمكى.

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