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A technical review on feeders in aquaculture

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Abstract
Intensification, mechanization and automation in agriculture are very much popular worldwide. A similar path may be appropriate for aquaculture since automation of aquaculture systems will allow the industry to: site production near markets; improve environmental control; reduce catastrophic losses; minimize production costs; and improve product quality. The history of automated control in aquaculture is limited and needs more attention; most of the systems have been custom-designed. The current trend is toward the use of industrial process control systems composed of sensors/transducers, meters/transmitters, communication multiplexers, actuators/output devices, computer hardware and computer control software. These process control systems can be as simple as one computer or as sophisticated as distributed control systems (multiple networked microcomputers). Therefore, there is a need to present a systematic review on aquaculture systems. Hence, in the present study review on different types of automatic and demand based feeder used in aqua culture production systems are presented.

Keywords: Aquaculture, feeder, process control, automation

1. Introduction
In aquaculture systems the cost of feed is the highest operating cost. In an eel culture system, the cost of feed accounted for approximately 40% of the total operating cost [1]. It was estimated that more than 60% of the feed applied to aqua cultural system ends up as particulate matter [2]. The decomposition of solids leads to oxygen depletion and produce ammonia–nitrogen and other toxic compounds detrimental to aquatic life, such as hydrogen sulphide. Feeding pattern is a very important aspect to apply feed in an aqua culture system. Hence, feeding rhythms also affect feed conversion rates (FCR) and proximal composition of fish flesh [3].

2. Feeder Systems
Fish production in aquaculture is dependent on water quality and characterized by high loads of organic matter in the form of food and/or organic fertilizers [4]. Food excess causes unconsumed food deposits on the tank bottom; if settle able solids are allowed to remain within the system their decomposition will consume oxygen, produce ammonia-nitrogen and other toxic substances such as hydrogen sulphide [5]. On the other hand, when food is insufficient, competition and predation are fostered, causing alterations in endogenous fish feeding rhythms [6]; these modifications affect the feed conversion rate and the subsequent composition of fish flesh [3]. Competition behaviours are reduced if all fish are fed similarly throughout the tank, giving wide access to food [7]. A food ration is adequate if it is consumed with little waste and supports the potential growth of fish population [8]. To minimize fish feeding problems, various feeders and feed consumption monitoring systems have been proposed in scientific research. Juell *et al.* employed a hydro acoustic sensor to detect pellets in cages immersed in the sea, in which feeding availability depended on presence of food [9]. Foster *et al.* utilized a submersible camera to count the output of pellets using image analysis tools to determine the food quantity provided [10]. Mal proposed an automatic food dispenser that did not require electric energy [11]. This provider stays afloat in the tank and, when the pulley goes down; the wheel rotates and expands the movement in a horizontal direction, providing food. Fast *et al.* showed a new data-acquisition system configuration that uses off the- shelf components and demand feeders with an electronic data-logging system [12]. With this system feeding time and quantity of released food can be monitored and related to a wide

range of environmental parameters measured simultaneously. Ang and Petrell described feeding patterns in terms of general fish feeding behaviours that occurred while using different systems in field conditions [8]. Feeding fish behaviours and pellet waste were recorded prior, during feeding, and at feeding endpoint with the use of underwater cameras. Papandroulakis *et al*. utilized fuzzy-logic control to design, develop, and theoretically test a controller that estimated the daily feeding requirements of sea bream (*Sparus aurata*) larvae under intensive conditions in a pilot-scale rearing system with the pseudo green water method [13]. Fang *et al.* used a reflective-type photoelectric sensor to detect the gathering behaviour of eels, which was incorporated into the feedback concept; their results showed that stopping a feeding cycle before polluting the water is possible using floating food for eels [14]. Based on their previous studies, Chang *et al.* developed an intelligent controller for indoor intensive culturing of eel based on gathering behaviour, which was evaluated in a pilot-scale commercial fish farm [5]. The temperature and dissolve oxygen do not only influence food intake, but also feed conversion rate, since they affect the fish physiology functions reflected in fish growth, having a direct effect on quality, quantity, and time of yield, implying economic loss in intensive aquaculture systems [15-18]. Therefore, other control schemes must be applied in order to optimize feeding strategies in intensive aquaculture systems. Fuzzy-logic control is a practical alternative for a variety of control applications since it provides a convenient method for constructing nonlinear controllers via the use of heuristic information [19, 13]. For these reasons, in this work a new feeder with fuzzy-logic control was developed and tested on tilapia (*O. niloticus*) production. This system takes into account the temperature and dissolves oxygen conditions to adjust the feeding percentage considering fish age and body weight. The main objectives of the feeder with fuzzy-logic control are: (1) to develop a new feeding system for food management in intensive aquaculture systems and minimize the food waste, feed conversion rate, accordingly to the economic inversion, and (2) to reduce the high rates of water pollution caused by excess food provision when water conditions are inadequate for feeding.

Some methods were developed to detect left over feed in order to stop feeding. Shepherd and Bromage estimated food waste by suspending a sheet below the sea cage during the feeding period, retrieving it after feeding, and counting the left over feed pellets [20]. The hydro acoustic sensors were used to detect food pellets at 2.5 m depth in sea cages for feeding control [21, 22]. Foster *et al.* used an underwater camera and image analysis tool to detect and count left over pellets [10]. Similar system is now commercially available for sea cage applications, sensors used to include Doppler pellet sensor, CAS pellet sensor and camera sensor (Akvasmart, Norway). Kevin and Royann used the accuracy of a new machine-vision system for the identification of a feed wastage event and the response times are reported [23]. Without using a feedback mechanism, Fast *et al.* used demand feeders and an automated data acquisition system to assess fish feeding rhythms [12]. Acoustic and photoelectric sensors to detect turbidity of the effluent are also commercially available. Ultrasonic telemetric system was also used for automatic positioning of individual salmon in a sea cage [22]. At present, in fish farms, visual observation of fish appetite is often impeded by high fish density and water turbidity [24].

3. Demand Feeders

A number of feeding studies have been made in which fish are self-trained to obtain food on demand by pressing a lever. This technique has been used with the stomach less goldfish, (*Carassius auratus)* [25, 26] and blenny *B (lennius pholis)* [27]; flatfish (*Limanda limanda)* and rainbow trout (*Salmo gairdneri)* [28, 29]. The number of actuations of the trigger per unit time can be recorded and this enables the voluntary feeding behaviour of fish to be studied in relation to environmental variables such as light, temperature, food quality (energy content, palatability, etc.) and feeding regime (trigger availability). Under conditions of constant light and temperature, free-running feeding rhythms are established which are related to the time required for digestive and absorptive processes [28]. Statistical analysis of the actuations of the demand feeder can reveal the periodicity of the feeding rhythm. Each actuation of the demand feeder delivers a known quantity of food, enabling the quantity eaten in unit time to be measured. Any uneaten food must be removed and the record of the amount dispensed adjusted accordingly. The proportion of spurious actuations of the demand feeder by fish movement must be assessed as this may account for up to 10% of the actuations. Cubillo *et al.* evaluated the performance of deposit feeders in integrated multi-tropic aquaculture (IMTA) was analyzed through the application of mathematical models [30]. Loading of organic particulates to the benthos as a result of finfish cage culture and shellfish suspended culture was analyzed by means of a deposition model (ORGANIX), and an individual model for growth and environmental effects was developed for the California sea cucumber Parastichopus californicus. Mattos *et al.* evaluated the ability of Pirarucu (*Arapaima gigas*) to feed through self-demand feeders, and also determined daily feeding rhythm and locomotors activity [31]. Each tank was equipped with a feeder adapted to allow fish to self-feed. Self-feeders and occupancy sensors were connected to a computer to allow measurement of feeding and loco motor activity. Baldwin developed an inexpensive, nonelectric, compartmentalized, feed dispenser for live bait, skipjack tuna and tested for 3 years [32]. It operates on the same principle as a clypsydra water clock, does not require electrical power, sophisticated components, or expensive materials, and is reasonably simple to construct and operate. Nirwan *et al.* developed a principle of the working model is based on controlling the amount of food fed in the fish tank unit at different intervals of time [33]. The prototype which is a combination of mechanical and electrical devices uses the concept of step wise rotation of stepper motor for giving precise amount of food output in proper time thus, saving labour time they collected information regarding development of fish feeding system. The research was than bifurcated into software and hardware. In the later stage hardware and software both were fused. The data in the program was processed using Arduino and the output of the Arduino through an interface was given to the stepped motor.

4. Present Need

Modern aquaculture in the whole world emphasizes higher production of fish from limited areas. Depending upon the management practices and yield obtained, aquaculture is divided into three categories, viz.: (i) extensive; (ii) semi-intensive; and (iii) intensive. Extensive culture is more or less the same as that of traditional methods and gives very poor yield. In India no artificial feed is supplied in extensive culture. Nowadays semi-intensive and intensive cultural practices are being adopted on a large scale to get higher production. In these types of farming fish is cultured under a controlled environment and artificial compounded feed with a proper percentage of proteins, carbohydrates, fatty acids, minerals, etc., are required to enhance the survival and yield of fish. Therefore, application of feed to the pond is a very important factor. Different methods are used to supply feed into the pond. In one of the simplest and widely followed methods, feed is broadcasted by aqua farmers in different parts of the pond. The main disadvantage of this method is that a large percentage of feed is lost in the water and not, therefore, available to the fish. The artificial feed may be sprayed to a fixed place on the pond surface during specified hours or fed as a thick paste in small earthen vessels suspended in the water. In this second method refilling is very difficult and as the number of ponds increase labour requirements become very high. Moreover, scheduled feeding of correct quantities, especially during the night, is not practical for many sites.

5. Automatic Feeder

Baldwin developed a low cost, fish feed dispenser specifically for live bait for skipjack tuna and tested it for 3 years [32]. The principle of operation of the dispenser was based on clypsydra water clock, where time of dispensing of feed was measured by means of the flow of water in the container or pond. This type of feeder was economical and no electrical power was required to operate. Moreover, Mal evaluated the performance of Hawaii type automatic fish feed dispenser [11]. The study was carried out by developing a lab scale automated fish feed dispensing unit. It was concluded that the developed dispensing unit will help in feeding times to be better matched to the changing rhythms of the fish cultured, thereby reducing aquaculture waste and pollution. Tytler *et al.* studied the fish feeding behaviours and nutritional aspects of feed on laboratory scale [34]. The study was focused on understanding the physiology of the feeding and digestive process, fish husbandry, diet formulation and extrapolation to natural populations of fish biomass. Lee reported that Commercial aquaculture systems will be benefited by the application of modem process control technology and in-line instrumentation [35]. He also added that performance of any system on economies of scale should be the base for all decisions on automation and instrumentation in aquaculture facilities. Hence, a properly designed and economically viable system will contribute to the profitability of aqua culture operations. Anras analyzed the feeding activity of sea bass and concluded that feeding strategy was correlated to meteorological factors [36]. In the experimental study he used a demand based feeding system. However, this system helped in feeding times to be better matched to the changing rhythms of the fish cultured, thereby reducing waste and pollution. The system was not useful to feed a baby fish in an efficient manner. Hence, there is a requirement to develop and automatic feed dispenser to cater the need of fingerling up to harvesting point. Chang *et al.* worked with timer-controlled automatic feeders with a rotating plate and scrubbers are widely used specifically in the indoor re-circulating eel culturing industry in Taiwan [5]. They developed an intelligent feedback control system to reduce the wastage of feed and minimize the pollution in eel cultured water. Hence, the authors suggest that feeding system designed for the use of floating feed in eel culture also potential for other commercial fish. Soto-Zarazua *et al.* developed the feeder system for intensive tilapia culture unit based on fuzzy logic [37]. It was emphasized that developed feeding system helps to reduce the toxic ammonium components and dissolved solids presents in water, which ultimately determine quality of food at the time of feeding. Hence, it is necessary to develop an automatic fish feeder with high yield rate in aquaculture operations. Yeoh *et al.* developed an automatic fish feeder to be used in aquaculture systems at commercial scale [38]. This device was developed to overcome labour problems in the industry and introduced a semi-automatic process in the aquaculture industry. Emmanuel *et al.* developed the automatic fish feeding system consists of mechanical and electronic sections [39]. The system was adaptable to dispense the feed of about 6-10 mm (feed size) for all aged (fingerlings and adult) fishes. The authors evaluated that the machine is capable to perform 86.9% efficiently with 3% feed loss during feeding process. They also incorporated an Inverter circuit to the electronic system, which helps to keep machine in continuous operation even though power is shutdown. Millot *et al.* described the behaviour of Atlantic cod (*Gadus morhua*), and the fish species learnt to use a dorsally attached external tag to activate a self-feeder [40]. These observations demonstrate a capacity of cod to develop a novel behaviour utilizing an attached tag as a tool to achieve a goal. This may be seen as one of the very few observed innovative approach and tool used in fish. Abdallah and Elmessery developed an automatic fish feeder. The performance evaluation of the developed automatic fish feeder was carried out in Intensive mirror carp production tanks. Two different ways were used to control feed distribution in the study [41]. The water quality parameters were considered to know the pollution in fish cultured water and feeder performance were evaluated based on the minimum pollution. The system was specifically designed for tank culture system not for the pond culture systems. Hence, there is a need to develop a system to be best fitted in tank as well as pond culture systems. Ani *et al.* developed a solar powered automatic feeding system for shrimp culture. The researchers did not use a timer for properly dispensing feed at a definite time interval and the developed feeding system was fixed at one corner of the pond [42]. Hence, there is a need to develop an automatic shrimp feeder along with floatation unit to efficiently dispense feed at each corner of the pond to minimize the loss. Atoum *et al.* developed an automatic fish feeder and studied its performance for intensive fish culture tanks. A Support Vector Machine (SVM)-based refinement classifier was used to suppress the falsely detected feed to minimize the pollution in cultured water [43]. They developed visual signal processing device to detect the feeding process of fish in culture tanks, it controls the amount of fish feed at an optimal rate. Ayub *et al.* developed an automated fish feeding system. A pneumatic computerized fish feed dispensing unit based on the Bernoulli's principle was developed [44].

Therefore, they emphasized that developed mobile robot system is suitable for aquaculture environment that will be technically feasible and economically viable. However, they highlighted that the developed system will be profitable in long term fish food management. Ogunlela and Adebayo developed an automatic fish feeder based on feed conversion ratio (FCR) and feeding efficiency (FE) built-in with recirculatory aquaculture system (RAS) [45]. The authors concluded that automatic feeding system for aquaculture has more potential and profitable, compared with manual feeding system. Nasir Uddin *et al.* developed an automatic fish feeder, a combination of mechanical and electrical system to form a machine instead of manually feeding the fish by hand for pond or aquarium [46]. De Mattos *et al.* developed an automatic feeder and evaluated the daily feeding rhymes for Pirarucu (Arapaima gigas) cultivated in outdoor tanks. It was concluded from the study that the use of an automatic feeder system activated by the fish could allow the animal to feed at their preferred time and hence reduces waste and improve the food intake of Pirarucu raised for aquaculture [31]. Moreover, the optimum feeding strategies, including times, schedules and regimes, should be determined from detailed investigations of feeding rhythms. Nirwan *et al.* developed an automatic fish feeder system using arduino uno [33]. Arduino uno is open source computer hardware and Software Company that designs and manufactures single board microcontroller to build digital devices and interactive objects that can sense and control objects in the physical and digital world.

In the study arduino uno board, combination of mechanical and electrical devices used the concept of step wise rotation of stepper motor for giving precise amount of feed.

5.1 Advantages of Automatic Fish Feeder

A power-free, inexpensive, automatic fish feeder is not available so far in India. However, Baldwin developed an automated feed dispenser at the Hawaii Institute of Marine Biology. It is simple in construction and does not require any electrical power [32]. This automatic fish feeder may become popular in India and other developing countries because of following advantages:

The shortage of man power will not hamper the feed distribution; It may be inexpensive compared to other methods of feed distribution; the fish feed can be applied to the pond system at suitable times by adjusting the feeder properly; It does not require any sophisticated components or expensive materials, and will be reasonably simple to construct and operate.

6. Conclusions

This study provides new strategies for food management in intensive aquaculture systems. Therefore, it can be said that there is an urgent need to develop an automatic feeder, supports aquaculture industry to savings in food (reducing the feed conversion rate) and manpower, and diminishing water pollution, cost effective and user friendly.

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