Preliminary study of acceleration based sensor to record Nile tilapia (Oreochromis niloticus) feeding behavior at water surface

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Abstract. In this preliminary study, the acceleration based sensor was developed to monitor the activity of Nile tilapia (Oreochromis niloticus) feeding behavior at the water surface. This study was conducted for three weeks in a fish pond with 40 m² in size, stocked with 850 fingerlings of Nile tilapia strain Nirwana-2 (average biomass of 13 g, fed four times a day at 8 am, 12 pm, 4 pm, and 8 pm). The acceleration sensor system was installed floating in the pond and was designed in a way so that the xz plane of the sensor will be parallel with water surface, while the y-axis will be pointing downward. By sensing the acceleration caused by the surface wave, the activities of fish near surface water could be monitored. The result showed that there were three distinctive patterns could be observed which was related to the feeding activity of fish. Generally, it can be concluded that this acceleration based sensor system can be integrated with automatic feeder machine, in particular by analyzing the recorded pattern, it is possible to monitor when the fish stop eating, and so the right amount of feed could be given to the fish.

1. Introduction
Aquaculture is known as the fastest-growing food production system with the average level of annual growth between 1970 and 2008 at 8.3%, showed impressive growth as the production of capture fisheries has been static since the late 1980s. Aquaculture has expanded, intensified and diversified to bridge the gap between global supply and demand of food as world human population keeps increasing. As it was projected by United Nations (2013) that human population will reach 9.6 billion by 2050 and 10.9 billion by 2100, the increase in aquaculture production is required [1]. Feeding management is one of the important aspects of aquaculture business as feeding cost contributes to 30-70% of total operating expenses [2, 3]. Feeding management efficiency regarding feeding rate, frequency and timing need to be adjusted to the required level and follows the feeding behavior of reared fish to avoid both over- and underfeeding. Overfeeding, in particular, can give a detrimental effect to the growth of fish due to the overload of stomach and intestines which further leads the decrease of digestive efficiency and feed utilization [4, 5]. Overfeeding can even cause deterioration in water quality and further affect the health of fish by weakening the immune system and increasing susceptibility to infection [6, 7]. Thus, feeding management efficiency prevents these problems from happening.

There are two strategies to increase feeding management efficiency, first by hiring experienced employee (which is harder to find) and second by implementing automatic fish feeder technology. The later can be conducted by integrating it with a sensor system to detect and monitor fish behavior.
during feeding and to determine the amount of feed required in reaching fish satiation. Even though manual feeding is the most used feeding method in aquaculture, the intensification which usually includes a more complex system, a larger production unit and a greater quantity of supplemental feed can be optimized by the use of automatic feeder. In addition to that, automatic feeder supports more frequent feeding as well as night feeding [7].

Nile Tilapia (*Oreochromis niloticus*) has been known as one of commercially important fish species for aquaculture, ranked as the second most important fish species after the carp due to their high growth rates, tolerance to environmental stress, high market demand, etc. [8, 9]. Several factors affect feed requirement of Nile tilapia, including biological factors (size, age, condition, and reproductive state of the fish), environmental factors (temperature, dissolved oxygen, water quality, and photoperiod) as well as feeding management (in term of the amount and frequency of feeding). The important point needs to be understood related to feeding management in Nile tilapia is its natural feeding habit. Tilapia is daytime and surface feeder which means that they eat at the water surface and commonly known eat more during the day [10].

Accelerometer has been used to monitor very small movement such as microtremors [12] and landslide movement direction [13]. The same device could be used to measure wave properties (amplitude, wavelength) at water surface generated by fish movements.

2. Methods

This study was conducted in three weeks, in which 850 animals of mixed-sex Nile Tilapia fingerlings strain Nirwana-2 (average biomass of 13 g) were stocked in one 40 m$^2$ earthen ponds located in Bandung, West Java province. Fish were fed commercial pellets with 30-33% crude protein content four times a day at 8 am, 12 pm, 4 pm, and 8 pm. Feed was applied at 6% of estimated biomass during the study. The pond continuously flowed with freshwater from the river with an average flow rate around 10 liters per minute.

![Figure 1](image1.png)

**Figure 1** (a) The illustration of sensor tube when floating at the water surface. More than 80% of the tube submerged underwater. (b) The illustration of ADXL345 and microcontroller position inside the tube. The direction of each axis is also shown in the picture.

Acceleration sensor ADXL345 was used to record pond ripple. The sensor was placed inside a PVC tube with inner diameter of 28.7 mm, outer diameter of 38.2 mm, and height of 75.5 mm. Some weights were added to the tube to make sure it floated vertically at the water surface with more than 80% of its body submerged as illustrated in Figure 1. At this position, X and Z axis of the sensor would be parallel with water surface, while Y-axis would be pointing downward. Sensor configured at sensitivity of \(3.77 \times 10^{-3} \text{ g}\) with a maximum measurement range of \(\pm 2 \text{ g}\) [11]. Sensor captured data for each axis simultaneously every 100 ms, followed by sending them to the receiver which was placed outside the pond through a communication cable. The communication cable also acted as an anchor so the sensor would not drift to the edge of the pond by wind or water current.
3. Results and Discussion

The results showed that there was no fish mortality during the study period. According to the study, this variety of fish showed well adaptation with the rearing environment. After arrival, several critical points checked were fish movement, oxygen, and water condition in the bag, feeding respond and if there is any abnormality on the body. Water quality parameters were checked prior stocking and were in the average optimum value for grow-out tilapia: 7.0-11.1 mg/L, 7.65-8.96, 25.9-27.7°C and 0 mg/L for dissolved oxygen (DO), pH, temperature, and ammonia respectively. Good water quality parameter supported good feeding respond and intake, thus would be advantageous for gathering data from the sensor.

There were three distinctive patterns of acceleration recorded by the sensor as a function of time. The first pattern was an idle pattern as shown in Figure 2. This pattern occurred because almost no ripple presented at the water surface. This pattern can be interpreted as no significant activity performed by the fish at the surface. The X and Z acceleration recorded by the sensor was not zero because the real sensor axis was slightly tilted from expected axis due to soldering process and center of mass position which was not exactly at the center of the tube. The slow change of acceleration at the X and Z axis can be seen in Figure 2(a), which was caused by the wind. In the Figure 2(b), it is shown there was some little yet fast change acceleration at X and Z axis which was caused by fish activity below the surface, especially the fish activities near the communication cable. Meanwhile, at the Y-axis, the acceleration recorded by the sensor relatively constant at around 1055 mg for both graphs, which is equal to the addition of 1000 mg caused by gravity and 55 mg caused by sensor offset and noises.

The second pattern was spike pattern as shown in Figure 3, which occurred when a very short physical impulse given to the sensor. The source of this impulse was mostly from the fish. This pattern was occasionally shown up. Almost all spike captured by the X and Z axis, which means most of the time the physical impulse from fish given to the sensor horizontally. The Y-axis of the sensor is relatively immune from fish disturbances. Sometimes spike pattern also occurred at night, which is mean that fish activities not completely stopped even after the sun set.

![Figure 2](image)

**Figure 2** (a) Idle pattern recorded by the sensor at 6 September 2016 from 2:09:20 to 02:09:50 local time zone. (b) Idle pattern recorded by the sensor at 6 September 2016 from 2:09:20 to 02:09:50 local time zone.
Figure 3 (a) Two spike patterns recorded by the sensor at 6 September 2016 from 2:05:05 to 02:05:35 local time zone. Each spike caused by a physical impulse that directed to the +X axis and slightly to the –Y axis. (b) Four-spike patterns recorded by the sensor at 6 September 2016 from 12:12:50 to 12:13:20 local time zone.

Figure 4 Feeding pattern recorded by the sensor at 6 September 2016 from 08:03:55 to 08:04:55 local time zone.

The third pattern was feeding pattern as shown in Figure 4, which only showed up when feed is given to the fish. The acceleration recorded by each axis changed rapidly. The change of value was significant enough to be differentiated from noises. This rapid change of acceleration was caused by surface ripple generated by fish movement in their attempt to snatch the floating feed. Over the time, the value of acceleration change became smaller and smaller, as fewer and fewer fish went to the surface. By looking at the Y-axis data, the pattern started around 08:03:58 and ended around 08:04:45. It seemed to be a short duration, but it was normal since the fish only three weeks old. Several spike patterns were also recorded at Z-axis as the fish unintentionally collided with the sensor.
Although the sensor could only record three patterns, and only two patterns have correlation with fish behavior at water surface, this experiment could be considered success. Not only the sensor was able to record surface ripple created by the fish, it was also successfully recorded distinctive pattern which contain information about feeding time duration. This is important information in order to design control system that have capability to give the right amount of feed.

4. Conclusion
With this result, it can be concluded that this design of sensor positively could be integrated with automatic feeding machine. By analyzing the pattern recorded by the Y-axis sensor, it is possible to know when the fish stop eating and send a signal to feeding machine so the feeding process could be stopped immediately.

Acknowledgments
We gratefully thank PT. Multidaya Teknologi Nusantara (eFishery) for providing us with funding, automatic fish feeder machines and fish pond facilities.

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