The effect of feed ingredients on the settling velocity of feces in tilapia (*Oreochromis niloticus* L.)

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Knowledge on the solid waste characteristics is valuable to set up a proper facility in order to increase the removal efficiency and also to understand the factors influencing waste quality. There are two main methods to evaluate removal efficiency of solids generated from a fish farm: feces recovery percentage (Amirkolaie et al., 2005, 2006) and settling velocity of feces (Wong and Piedrahita, 2000).

Both the recovery efficiency and settling velocity of particles generally have a direct relationship to the weight and size of particles (the heavier the particle, the faster the deposit; Han et al., 1996). Manipulation of diet composition alters fecal physical properties improving feces consistency and leading to a higher recovery and a larger particle size (Brinker et al., 2005; Amirkolaie et al., 2006; Brinker, 2007).

However, although a few studies have been done on the stability (Brinker et al., 2005; Brinker, 2007), particle size distribution (Han, 1996), and the settling velocity of aquaculture waste (Wong and Piedrahita, 2000), there is little information on the effect of feed ingredient on the settling characteristics of feces. Because of the direct effect of feed on feces quality, feed composition can play a significant role in the physical properties of feces and may change the settling velocity of feces. Therefore, the main objective of this study is to investigate whether differences in dietary composition caused by six feed ingredients have significant impact on settling velocity of the feces.

In this study six ingredients were tested for tilapia (*Oreochromis niloticus*). The ingredients were fishmeal, soybean meal, soybean protein concentrate, wheat gluten, duckweed (*Lemna minor*), and single cell protein (Brewer's Yeast/ *Lactobacillus*). These six feed ingredients were added to the basal diet in a ratio of 15% weight/weight (Table 1).

Table 1: The percentage of ingredient used in the experimental diet on % dry matter weight basis

Experimental diet	Amount
Test ingredients	15
Fish meal	28.9
Corn	25
Wheat	17
Wheat bran	8.5
Fish oil	2.6
Diamol[a]	2
Premix	1

[a]Diamol GM, Franz Bertram, Hamburg, Germany.

There were 12 aquaria in this experiment, two aquaria for each treatment. Water quality was checked every day after the first feeding and kept within optimal range for tilapia.

The experiment lasted for 8 weeks and feces was collected during the final two weeks using two settling tanks. The fish tanks were directly connected to a sedimentation tank (a 45-L tank, 30 cm in diameter and 70 cm high). The settled feces was emptied by the use of a bottom tap. Based on the dimension and water flow, the hydraulic surface load (HSL) of the outsettling tank was 0.20 Cm. S^{-1}, so any particle with a settling velocity (SV) greater than HSL settled out of suspension.

In the current study, the settling velocity test was conducted by UFT-type settling column. This apparatus consists of a 70-cm high column developed by a German company called Umwelt und Fluid Technik (UFT) (Pisano, 1996). A detailed description of UFT column is available in Wong and Piedrahita, (2000).

For settling velocity measurement, 75 ml of feces sample collected by the settling tanks was poured into the short cylinder. Samples were withdrawn from the bottom of the column with a 15 ml tube at the following intervals: 0, 6, 9, 12, 15, 20, 25, 30, 60, 120, 240, 480, 900, 1800, 3600, 7200 seconds. This produced a total of 16 sub-samples in 120 minutes.

The behavior of the settling velocity curve was studied by non-linear SAS (version 6.12). The independent variables were treatments, tanks and replication, and the dependent variable was the time of sedimentation. The results showed that the settling curves followed an “S” shape model. The median settling velocity for the settleable solids was 2.52 $cm.s^{-1}$ for all treatments. Addition of 15% feed ingredients did not statistically change settling velocity among the feces (Fig. 1). From Figure 1, it can be also inferred that almost 40% of feces did not settle while passing through the UFT column during 120 min of the period.

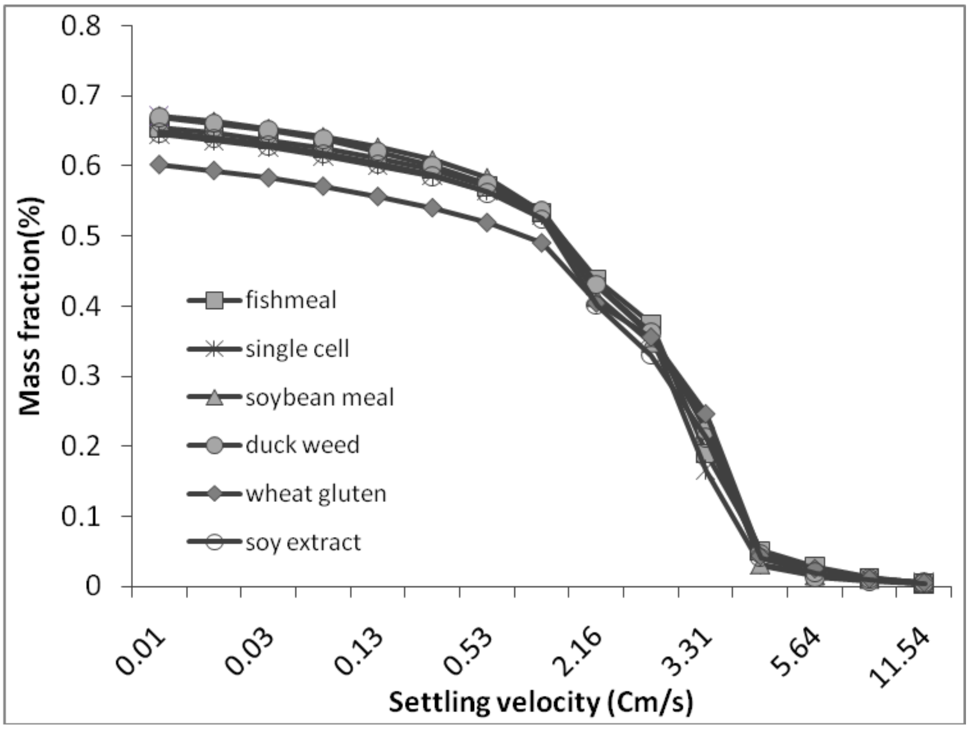

Figure 1: Mass based settling curves adjusted for tilapia fed six different diets. Each symbol represents mean values of the data observed for this particular diet.

One objective of this study was to find a mathematical expression that explains the settling velocity behavior of the solids. The characteristics of the settling curves showed that they always followed a non-linear model being appropriate for all samples:

$$y = \frac{a}{1 + \left(\frac{b}{x}\right)^{c}}$$

where y is the mass fraction and x is the settling time. The estimates for a, b and c did not vary ($P > 0.05$) indicating similar settling behavior for each of the six feeds.

The efficiency of the settling tank for fishmeal diet demonstrated that the settling tank at flow rate of 10 $l.m^{-1}$ can collect around 60% of the solids (Table 2). However, the efficiency does not improve substantially with further decrease in HSL of the collector.

Table 2: The efficiency of the settling tank at different flow rate for fishmeal diet

Flow rate(L/M)	Hydraulic surface load (HSL)(Cm/S)	Removal efficiency	Improvement percentage
100	4.01	10.2	18.3
75	3	28.5	24.8
50	2	53.3	7.5
25	1	60.8	0.7
10	0.4	61.5	0.3
5	0.2	61.8	0.2
2	0.08	62.0	

a. The dimension data was driven from a settling tank with a 23 Cm in diameter

The results revealed that the six tested ingredients did not significantly affect settling velocity of the feces. It appears that the inclusion level (15%) was too low to put a significant effect on settling velocity. Chen et al., (2003) reported no difference in settling velocity between feces generated from a high-energy diet of 30% lipid and a standard diet of 20% lipid. Due to lack of reproducible measurement protocols, a series of combined methods of measurements including shear resistance (Brinker, 2007), particle sized distribution (Han, 1996) and image analysis (Ogunkoya et al., 2006) along with a longer experimental period are necessary to have a clear judgment about variation in feces characteristics caused by feed ingredients.

However, there is evidence showing that particle size and stability of feces are affected by dietary composition. Han et al., (1996) observed that addition of binding materials such as lignin sulfonate and gelatinized starch in fish feed increased particle size distribution of suspended solids. Addition of soybean meal had a significant negative effect on both sinking speed and cohesiveness of feces in rainbow trout (Ogunkoya et al., 2006). A slightly higher digesta viscosity induced by the addition of guar gum or alginate (Brinker et al., 2005) or even a high-starch diet (40%) improved feces stability by increasing elastic resistance in the digesta (Amirkolaie et al., 2006).

Settling velocity curves allow us to design and develop improved purification systems to treat aquaculture waste. A comparison of the HSL with the settling curves establishes the theoretical removal efficiency of the basin. Examination of the settling velocity curves (Fig. 1) shows that small changes in flow rate or dimension of the basin may result in very significant difference in the overall removal efficiency of the sedimentation basin. For instance, halving the HSL from 2 to 1 cm s^{-1} (Table 2) changes the removal efficiency for the settleable tilapia feces fed by fishmeal diet from 53.3 to 60.8 %, an improvement of 7.5%.

In conclusion, the understanding of sedimentation dynamics of solids induced by feed composition allows us to design and develop a proper sedimentation basin. A slower median settling velocity of feces excreted by tilapia demands a larger dimension and/or lower flow rate of settling basin.

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