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Effects of Temperature Variation and Pellet Dimension on Settling Velocity of Fish Feed Pellets

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Abstract. In the present research, investigation was carried out for variation in settling velocity of some pelletized fish pellets in relation to floating time (T_f), diameter of pellets and temperature along with their water absorption properties under defined laboratory conditions. Among two diets of different ingredients DI and DII, it was observed that time for float (T_f) were greater at high range of temperature than lower range of temperature, for all tested pellets dimension (3 mm, 6 mm, 9 mm) of both diets DI and DII, while in case of settling velocity against high temperature range, lower values of settling velocities were recorded which shows an inverse relationship between them. On the other hand percent weight increments for diet DI were noted maximum for pellets size of 3,6 and 9 mm after 10 min of immersion i.e., 33.33, 55.55 and 38.46%, respectively, when compared to dry pellets.

Keywords: artificial fish feed, settling velocity, floating time, water absorption, water dispersion

Introduction

In order to maximize fish production and reduced waste dispersion, selection of ingredients, their composition and palletizing are of considerable importance. Modeling of waste dispersion is a key factor in regulation of rearing ponds. During feeding, significant amount of waste products (uneaten feed, fecal and soluble excretory material) are produced. Among these the primary reason for impairment of pond ecology is the settled uneaten feed pellets.These pellets not only affect over the benthos communities as well as other living biota (Vezzulli *et al.,* 2003; Beveridge *et al.,* 1991). Earlier studies suggested that 25-30% of dry weight of feed consumed is wasted as fecal matter (NCC, 1990; Butz and Vens-cappel, 1982). Decay of food matter could result in an accumulation of organic matter at pond bottom to manipulate the normal ecological conditions (Carroll *et al.,* 2003; Karakassis *at al.,* 2000). Keeping this in view, a number of models have been reviewed for monitoring the effects of temperature variation and pellet dimension on settling velocity and rate of soaking (Doglioli *et al.,* 2004; Cromey *et al.,* 2002; Perez *et al.,* 2002; Dudley *et al.,* 2000). It is true that settling velocity of uneaten feed pellets and soaking time is very useful tool to predict any model in intensive aqua culturing system. Earlier studies related with dimension of fish pellets involved in either sea water (Vassalo *et al.,* 2006; Chen *et al.,* 1999a) or fresh water (Elberizon and Kelly, 1998) have been recorded but in the present research instead of salinity, two temperature regimes are focused.

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Materials and Methods

In the present experiment two diets of different low cast ingredients more given to fish therefore, feed pellets of different length were produced. The proximate compositions of two feeds (D I & D II) are given in Table 1.

Measurement of settling velocity. Three different diameters (3 mm, 6 mm, 9 mm) of two different diets were examined at two ranges of temperature (28-30 °C and 20-22 °C) as described by Vassalo *et al.* (2006). Length was taken by the help of a vernier caliper. Plexiglas tube of 120 cm length with a diameter of 10 cm was used to find out the settling velocities of pellets following the method of Chen *et al.* (1999a). The tube was marked from the top, up to 5 cm for defining floating surface and the time to cover this distance was denoted as floating time (T_f). Then from this point, after every 50 cm, the tube was filled with fresh water and fixed vertically at different temperatures. 10 pellets of each length for each diet were examined. Pellets were gently dropped in water with the help of 0.01s chronometer. Time of pellet fall up to 5 cm (T_f) and beyond 5 cm to each 50 cm apart was noted. Water in the apparatus was changed for each

Table 1. Proximate composition of two feeds

Diet I		Diet II	
Ingredients	Percent values	Ingredients	Percent values
Rice polish	20	Rice protein	35
Rice bran	15	Corn gluten	30
Fish meal	20	Wheat bran	20
Sun flower meal	20	Fish meal	15
Wheat bran	10		
Bone meal	10		
Wheat flour	5		
Proximate values			
Crude protein	29	Crude protein	16.9
Fats	11.3	Fats	9.7
Moisture	5.7	Moisture	6.3

type of pellet and for temperature ranges. Temperature of water was noted by a thermometer and maintained at the required ranges by adding ice cubes.

Determination of water absorption property of pellets. The weight of feed pellet was not affected by change in temperature and salinity (Chen *et al.,* 1999b), so the water absorption property was recorded at room temperature, during the whole experiment. Ten pellets of each type of dimension were taken. After measuring their length and diameter, weight was taken in dried condition. All the selected pellets were soaked in fresh water for 2, 5 and 10 min of immersion time as indicated by Vassalo *et al.* (2006). After passing the immersion period pellets were taken out from water and left on absorbing paper for absorption of excess water. Finally all pellets were measured and weighed again to observe the changes in pellet dimension and weight.

Results and Discussion

Settling velocity. The effects of temperature variation and pellets dimension on T_f and V_{set} are presented in Tables 2-3. Keeping temperature as a controlling factor, it was observed that time for float (T_f) of both diets DI and DII were greater at high range of temperature than lower range of temperature for all tested pellets dimensions (3 mm, 6 mm, 9 mm). On the other hand the settling velocity (V_{set}) did not respond as T_f i.e., against high temperature lower V_{set} recorded when compared to lower range of temperature. Furthermore, it is attributed that there was an inverse relationship between T_f and V_{set} for all dimensions of pellets (Fig. 1- 4).

Statistically it is proven by general linear model (GLM). Analysis of variance for floating time (Tables 4-5) indicated significant differences ($P<0.05$) for pellets dimension within each temperature regime (28-30 °C, 20-22 °C). The interaction between pellets dimension and temperature regimes was significantly affected over time for floating pellets on water surface. Tables 6-7 show response of pellets in terms of settling velocity (V_{set}) (Fig. 5-8). Again a highly significant difference was noted for pellets dimension and temperature regimes ($P< 0.05$), however,

Table 2. Settling velocity (V_{Set}) and floating time (T_f) for three different dimensions of fish feed pellets of DI (3.5 mm, diameter) with reference to two temperature regimes

S.No.	Temperature (28-30 ºC)						Temperature (20-22 ºC)					
	3 mm		6 mm		9 mm		3 mm		6 mm		9 mm	
	T_f (sec)	V_{set} (m/s)	T_f (sec)	V_{set} (m/s)	T_f (sec)	V_{set} (m/s)	T_f (sec)	V_{set} (m/s)	T_f (sec)	V_{set} (m/s)	T_f (sec)	V_{set} (m/s)
1	1.2	0.071	1.1	0.095	0.52	0.098	0.63	0.079	0.75	0.082	0.49	0.113
2	1.68	0.068	1.02	0.085	0.47	0.089	0.61	0.08	0.42	0.107	0.51	0.107
3	1.56	0.077	0.8	0.087	0.4	0.1	0.71	0.078	0.7	0.092	0.35	0.097
4	1.36	0.08	0.6	0.081	0.42	0.094	0.4	0.087	0.73	0.083	0.37	0.092
5	1.52	0.079	0.56	0.094	0.7	0.094	0.45	0.079	0.51	0.097	0.32	0.106
6	1.62	0.081	0.89	0.092	0.46	0.104	0.7	0.087	0.54	0.105	0.27	0.092
7	1.23	0.069	0.92	0.088	0.64	0.095	0.51	0.093	0.43	0.1	0.39	0.094
8	1.38	0.09	1.02	0.087	0.38	0.104	0.77	0.075	0.6	0.102	0.41	0.118
9	1.6	0.071	1.96	0.085	0.59	0.105	0.74	0.082	0.37	0.104	0.53	0.123
10	1.51	0.084	0.72	0.08	0.62	0.096	0.59	0.076	0.36	0.133	0.46	0.098
Mean	1.46 (0.16)	0.077 (0.007)	0.95 (0.39)	0.16 (0.24)	0.52 (0.11)	0.097 (0.005)	0.61 (0.12)	0.087 (0.005)	0.54 (0.14)	0.104 (0.01)	0.41 (0.08)	0.104 (0.01)

Values in subscripts are standard deviations.

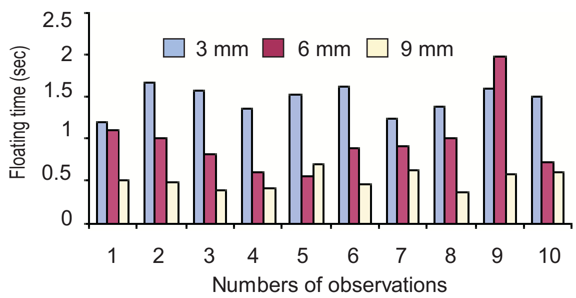

Fig. 1. Floating time of three different dimensions of fish feed pellets of DI at 28-30 ºC.

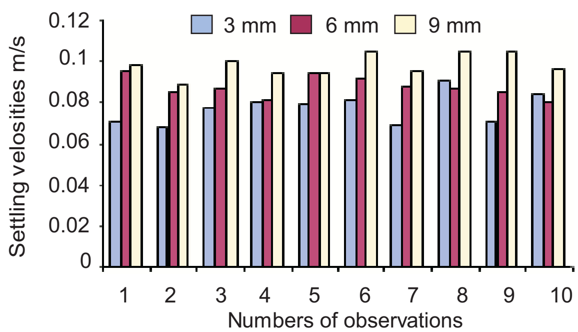

Fig 2. Settling velocitie of three different dimensions of fish feed pellets of DI at 28-30 °C.

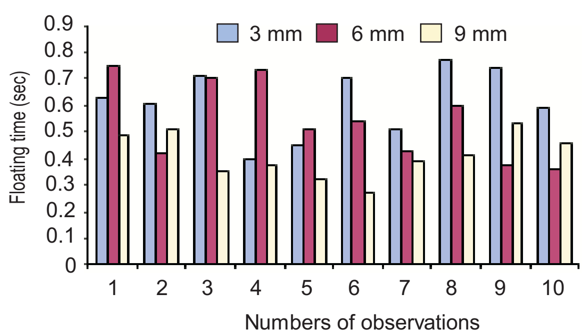

Fig 3. Floating time of three different dimensions of fish feed pellets of DII at 20-22 ºC.

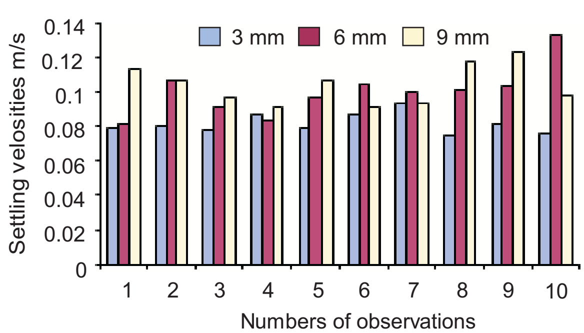

Fig 4. Settling velocities of three different dimensions of fish feed pellets of DII at 20-22 °C.

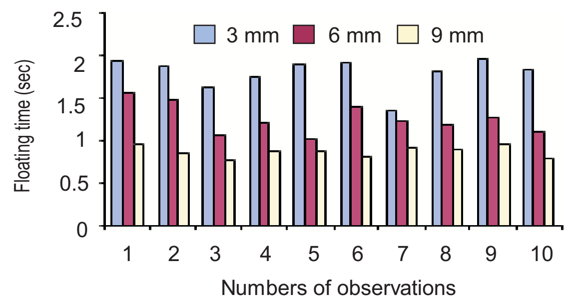

Fig. 5. Floating time of three different dimensions of fish feed pellets of DII at 28-30 ºC.

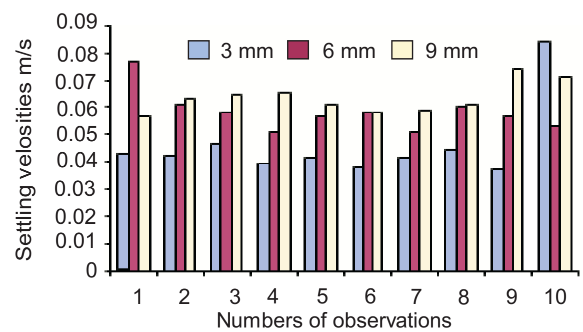

Fig. 6. Settling velocities of three different dimensions of fish feed pellets of DII at 28-30 °C.

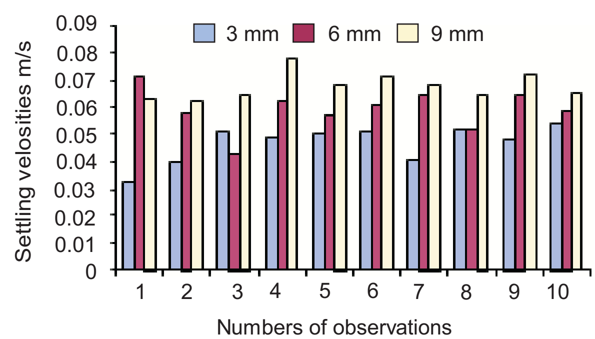

Fig. 7. Settling velocities of three different dimensions of fish feed pellets of DII at 20-22 ºC.

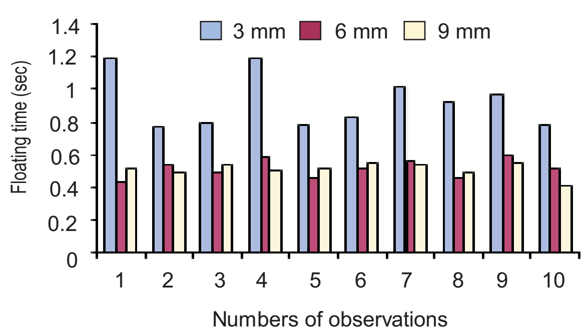

Fig. 8. Floating time of three different dimensions of fish feed pellets of DII at 20-22 °C.

Table 3. Settling velocity (V_{set}) and floating time (T_f) for three different dimensions of fish feed pellets DII (2mm, diameter) with reference to two temperature regimes

S.No	Temperature 28-30 ºC						Temperature 20-22 ºC					
	3 mm		6 mm		9 mm		3 mm		6 mm		9 mm	
	T_f (sec)	V_{set} (m/s)	T_f (sec)	V_{set} (m/s)	T_f (sec)	V_{set} (m/s)	T_f (sec)	V_{set} (m/s)	T_f (sec)	V_{set} (m/s)	T_f (sec)	V_{set} (m/s)
1	1.93	0.043	1.56	0.077	0.96	0.057	1.19	0.032	0.43	0.071	0.51	0.063
2	1.86	0.042	1.48	0.061	0.84	0.063	0.77	0.04	0.54	0.058	0.49	0.062
3	1.63	0.047	1.06	0.058	0.77	0.064	0.8	0.051	0.49	0.043	0.54	0.064
4	1.74	0.039	1.2	0.051	0.86	0.065	1.19	0.049	0.59	0.062	0.5	0.078
5	1.89	0.041	1.02	0.057	0.87	0.061	0.78	0.05	0.46	0.057	0.51	0.068
6	1.91	0.038	1.4	0.058	0.81	0.058	0.83	0.051	0.52	0.061	0.55	0.071
7	1.34	0.041	1.23	0.051	0.92	0.059	1.01	0.041	0.56	0.064	0.54	0.068
8	1.82	0.045	1.19	0.06	0.89	0.061	0.92	0.052	0.46	0.052	0.49	0.064
9	1.96	0.037	1.27	0.057	0.96	0.074	0.96	0.048	0.6	0.064	0.55	0.072
10	1.83	0.084	1.1	0.053	0.79	0.071	0.78	0.054	0.51	0.059	0.41	0.065
Mean	1.79 (0.18)	0.041 (0.01)	1.25 (0.17)	0.058 (0.007)	0.86 (0.06)	0.063 (0.005)	0.92 (0.16)	0.046 (0.006)	0.51 (0.05)	0.059 (0.007)	0.50 (0.04)	0.067 (0.004)

Values in subscripts are standard deviations.

Table 4. Two way analysis of variance for floating time of diet DI

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Pellets	2	3.2891	3.2891	1.6445	40.93	0.000
Temperature	1	3.1878	3.1878	3.1878	79.33	0.000
Pellets × Temperature	2	1.4014	1.4014	0.7007	17.44	0.000
Error	54	2.1699	2.1699	0.0402	-	54
Total	59	10.0482	-	59	-	-

DF = degree of freedom; Seq SS = sequential sum of square; Adj SS = adjusted sum of square; MS = means of square; F = F ratio; P = probability ratio.

Table 5. Two way analysis of variance for settling velocity of diet DI

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Pellets	2	0.0048632	0.0048632	0.0024316	31.09	0.000
Temperature	1	0.0009362	0.0009362	0.0009362	11.97	0.001
Pellets × Temperature	2	0.0002077	0.0002077	0.0001039	1.33	0.274
Error	54	0.0042231	0.0042231	0.0000782	-	-
Total	59	0.0102302	-	-	-	-

DF = degree of freedom; Seq SS = sequential sum of square; Adj SS = adjusted sum of square; MS = means of square; F = F ratio; P = probability ratio.

the interaction between pellet size and temperature regimes did not significantly affect over V_{set}.

Water absorption property of pellets. Table 8 shows immersed pellets weight increment with reference to time of immersion i.e., 2, 5 and 10 min. None of the pellets of diet DI exhibit any change in dimension after three different times of immersion. However, in case of diet DII 3 mm size pellets were dissolved or loosed their dimension when immersed for 5 and 10 min due to having small diameter than diet DI. On the other hand percent weight increments for diet DI were noted maximum for pellets size of 3,6 and 9 mm after 10 min of immersion i.e., 33.33, 55.55 and 38.46%, respectively, when compared to dry pellets and 2 and 5 min of immersion time. Totally different trends were observed for diet DII in this context. With comparison to dry pellets weight increment of 100%, 50% and 66.66% were recorded for 3, 6 and 9 mm of pellets size, respectively, after 2 min of immersion.

The same increasing pattern of weight enhancement was noted for DII pellets having the same pellet size i.e., 100% after 5 min and 150% after 10 min. The differences between the weight increment values of DI and DII showed that as the diameter of pellets increases, their water absorption property decreases (Chen *et al.,* 1999a). It was also noted that more or

Table 6. Two way analysis of variance for floating time of diet DII

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Pellets	2	4.0049	4.0049	2.0024	66.43	0.000
Temperature	1	5.7722	5.7722	5.7722	191.49	0.000
Pellets × Temperature	2	0.5189	0.5189	0.2594	8.61	0.001
Error	54	1.6277	1.6277	0.0301	-	-
Total	59	11.9237	-	-	-	-

DF = degree of freedom; Seq SS = sequential sum of square; Adj SS = adjusted sum of square; MS = means of square; F = F ratio; P = Probability ratio.

Table 7. Two way analysis of variance for settling velocity of diet DII

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Pellets	2	0.00476	0.0047	0.0023805	61.01	0.000
Temperature	1	0.0001908	0.0001908	0.0001908	4.89	0.031
Pellets × Temperature	2	0.0000492	0.0000492	0.0000246	0.63	0.536
Error	54	0.0021071	0.0021071	0.0000390	-	-
Total	59	0.0071082	-	-	-	-

DF = degree of freedom; Seq SS = sequential sum of square; Adj SS = adjusted sum of square; MS = means of square; F = F ratio; P = probability ratio.

Table 8. Mean weight increase (%) of pellets of DI and DII as a function of different immersion times (2, 5 and 10 minutes)

Before immersion

Diet I		Diet II	
L(mm)	W(gm)	L(mm)	W (gm)
3	0.6	3	0.1
6	0.9	6	0.2
9	1.3	9	0.3

After immersion

Time in minutes

2			5			10			2			5			10		
L	W	MWI	L	W	MWI	L	W	MWI	L	W	MWI	L	W	MWI	L	W	MWI
3	0.7	16.66	3	0.8	25	3	0.8	33.33	3	0.2	100	3	0.2	100	3	0.1	**
6	1.2	33.33	6	1.3	44.44	6	1.4	55.55	6	0.3	50	6	0.4	100	6	0.5	150
9	1.4	7.69	9	1.7	30.76	9	1.8	38.46	9	0.5	66.66	9	0.6	100	9	0.6	100

L, length; W = weight; MWI = mean weight increase (%), ** = dissolved completely.

less all under observed pellets of diet DII were dissolved or disintegrated into its constituents revealing greater absorption properties as compared to diet DI. The role of formulated diets definitely contributes in rate of production. Feed manufacturers have diverted their efforts towards the physical qualities including settling velocity and soaking or immersion time. According to linear law of stokes, a particle falls in water with its settling velocity with respect to its dimension, density and viscosity. Among these, the viscosity is highly influenced by temperature, solute concentration and hydrostatic pressure. In present feed trial smaller pellets size of diet DII (3 mm) were dissolved or loosed their dimension when immersed for 5 and 10 min while more pellets of diet DI show any change in dimension after three different times of immersion. These results were in line with the findings of Thomas and Vander Poel (1996), who claimed that small diameter pellets (3 mm) were found to be more susceptible to breakage than larger diameter pellets (6 mm). The differences between diet DI and DII can be attributed to variations in formulation because of the water soaking ability of different ingredients. It shows that the diet DII is more friable than diet DI. Doglioli *et al.* (2004) focused on behaviour of pallets made for salmon aquaculture and potentially applied and described a model.

In present research, a comparison was undertaken between two diets DI and DII to investigate the settling velocity and time for immersion. The findings were indicated that an inverse relationship exist between T_f and V_{set} for all dimensions of pellets. As far as immersion time is concerned (2, 5 and 10 min) none of the pellets of diet DI exhibit any change in dimension after three different times of immersion. However, for diet DII 3 mm sized pellets were dissolved when immersed for 5-10 mins due to smaller in size. These results conclude that two diets have no similar pattern of T_f and V_{set}, although Wood (1987) found a relationship between pellet hardness and friability. Relationship between the under observed parameters are generally only found where the feed ingredients and pellet producer are same as suggested by Thomas and Vander Poel (1996).

The outcome from Tables mean velocities to sink for diet DI (3 mm) were 0.077 m/s in water having two temperature ranges followed by 0.087 m/s. 0.16 m/s and 0.100 m/s for 6 mm and 0.097 m/s and 0.104 m/s for 9 mm respectively. For pellets size of 3 mm of diet DII 0.041 m/s, 0.046 m/s were calculated with the increasing trend for 6 mm, 9 mm i.e., 0.058 m/s, 0.059 m/s and 0.063 m/s,0.067 m/s, respectively. When comparing these results with the results of earlier studies the similar attributions are found.

Gowen *et al.* (1989) quoted results from unpublished data of velocities of 0.09 to 0.15m/s and used a settling velocity equal to 0.12 m/s in developing waste dispersion models. Findlay and watling (1994) provided data on several North America pellet types or sizes and quoted settling rates of 0.055 m/s and 0.155 m/s for 3 mm and 10 mm dry pellets, respectively. Elberizon and Kelly (1998) showed settling velocities of freshwater salmonid pellet diets ranging from 0.05 to 0.12 m/s for 2 mm and 8 mm pellet sizes, respectively.

The floating time since the ANOVA test showed that it significantly affects settling velocity. The reason for this fact may be because of the observed weight increment of pellets immersed in the water at the surface before they start to fall. The soaking experiment provides a quantitative estimate of this process, pointing out that the phenomenon is greater for smaller particles. Thus, it could be said that the influence of temperature and salinity on the settling velocity is indirect via T_f the lesser the percentage of uneaten feed. However, a quantitative calculation of this link is very hard to achieve but knowing the T_f value provides a valuable piece of information for model calibration and validation processes.

Finally, the present study provides important information for aquaculture wastes dispersion modeling. A realistic dispersion model would then have to consider: (a) the diameter of the actual feed distributed to fishes: (b) the seasonal variation of temperature. Collaboration with farmers, nutritional data collection and hydrological measurements will be useful to improve aquaculture impact predictions. Two temperature ranges show the seasonal temperature variations which have a significant influence or the settling velocity and floating time.

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