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Effect of pelletizing machines on floatation and water stability of farm-made fish feeds

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Abstract
The effect of two different fish feed pelletizing machines (Powdery Feed Machine/Dry Pelletizer and Feed Mincer) on the physical qualities, floatation and water stability of pellets was tested on two sets of 40% crude protein diets produced using rice bran and wheat offal as binders, and yeast as water stability enhancer. The results obtained revealed that the feed mincer produced pellets with significantly higher ($P<0.05$) expansion ratio (33.33±14.43 and 50.00±33.33) and lower bulk density (0.69±0.02 and 0.57±0.03) that enabled them to float within duration of the experiment. Water stability was also significantly higher for pellets of both set of diets produced from the feed mincer (75.84±3.63 and 70.27±1.51). On the other hand, pellets of both set of diets from the dry pelletizer had no expansion nor floatation, and were significantly lower in water stability (58.21±1.15 and 59.44±0.49) when compared with feed mincer. Although the pellets from the dry pelletizer had a more appealing physical appearance, they were not as hard and durable as those from the feed mincer. It was therefore recommended that feed mincers should be used rather than dry pelletizers for the production of more durable and water-stable on farm fish feed pellets.

Keywords: pelletizing machines, floatation, water stability

1. Introduction

The procedure for the manufacture of aquaculture diets after formulation generally includes the grinding of feed ingredients to reduce particle size, mixing, subjecting them to moisture (water or steam), and applying heat and pressure to produce a particular product physical form (Tidwell and Allan, 2001) [1]. The most common physical forms include finely ground meals (granules), crumbles, pellets, balls and flakes of various sizes and density (Hardy and Barrow, 2002) [2], although the choice of physical form may depend on the species of fish, nature of culture system and stage of maturity of fish (Falayi and Sadiku, 2013) [3]. Also different ingredients combinations produce different levels of pellet buoyancy or spatial characteristic within the water column (Strahm and Plattner, 2001) [4]. However some fish prefer floating pellets while others prefer sinking types, although most cultured fish can be trained to accept floating pellets (Craig and Helfrich, 2009) [5]. Floating pellets produced from Feed Extruders are in greater demand than sinking pellets produced from Pelletizers because they enable the farmer to observe the feeding activity of the fish, thus prevent wastage of feed. They also exhibit superior physical characters such as greater water stability, digestibility, water protection, zero water pollution and zero wastage of raw materials (Almaraaj, 2010) [6], and in addition supply higher energy than sinking pelleted feed (Johnson and Wandsvick, 1991) [7]. Sinking pellets are often characterized by poor water stability thus are easily dissociated in water (Effiong *et al*, 2009) [8]. Uneaten feeds that sink to the bottom of the pond usually end up as fertilizers causing high algal bloom and related water pollution problems (Bolorunduro, 2002) [9], such as eutrophication and depletion of oxygen from the culture medium. The use of sinking feeds may also result in impaired growth of fish since it involves a high feed conversion ratio (Johnson and Wandsvick, 1991) [10]. Furthermore, the economic implication of using sinking pellets is another challenge for the small scale fish farmer. The direct implication is that most of the feed end up uneaten resulting in waste of resources while additional cost and labor incurred in maintaining healthy water conditions are secondary consequences (Falayi *et al.*, 2006) [11]. Despite all the superior qualities of floating feeds, their relatively high cost (≥ N4,500/15kg) increases the overhead cost of fish production, while the cost of procuring the Feed Extruders – about 40 million Naira, (Jauncey *et al*, 2007) [12] –

discourages the popularity of such technology among Nigerian fish farmers, who mostly operate on low to medium scale. Also overheating of ingredients during the extrusion proscess may result in the production of pellets of inferior nutritive quality as some thermo labile vitamins (especially vitamin A and C) and other nutrients may be lost (Obi *et al*, 2011[13]; Falayi *et al*, 2006 [11]).

In recent times, several researchers (Falayi and Sadiku, 2013[3]; Adekunle *et al*., 2012 [14]; Adeparusi and Famurewa, 2011[15]; Solomon *et al*., 2011[16]) have focused mainly on the use of certain ingredients as binders and floating additives to support water stability and floatation in pellets. However even with the correct ingredient combination, different machine types could produce physically different products as a result of the differences in production conditions such as moisture, heat and pressure employed (Hardy and Barrows, 2002) [2]. In Nigeria, the most common types of machine used are the locally fabricated mincers and the imported Chinese dry pelletizers. This experiment therefore aims to compare the physical characteristics of pellets produced from the same combination of ingredients, using each of these machines.

2. Materials and Methods

2.1 Experimental Location

The present tudy was carried out within the main campus of Usmanu Danfodiyo University, Sokoto, Sokoto State. Sokoto state is located in the northwest geographical zone of Nigeria within longitude 13° 05’ N and latitude 05° 15’ E, covering an area of 25,973 km^2. Its annual average temperature is 28.3 °C (82.9°F) with maximum daytime temperature for most of the year at 40 °C (104.0°F). The warmest months are between March and June when daytime temperature can exceed 45 °C (113°F), the rainy season is from June to October while the other times of the year are characterized by Harmattan (Mamman *et al.,* 2014) [17].

2.2 Selection of Ingredients

The feed ingredients were sourced from Ibadan and Sokoto – yellow maize, fishmeal, wheat offal, lysine, methionine and premixes were bought from a feedstuff store in Ibadan. The others were obtained in Sokoto – Soybean meal and bone meal were bought already toasted at Kofar Doya market while rice bran was obtained as the byproduct of the second milling of rice to produce edible rice, from local rice processors in Kalambaina area, Sokoto.

2.3 Proximate Analysis

Samples of all the ingredients used were subjected to proximate analysis to determine their nutrient composition on dry matter basis, according to method described by AOAC (2000) [18]. Crude protein content was determined using Kjeldahl method, crude fiber content using acid-alkaline digestion method, ash content by burning the dried residue for 24hrs in a Galle Kamp Hot spot furnace at 450^0 C, moisture content by oven drying of sample at 105^0 C until a steady weight was achieved, and crude lipid content by extraction using N-Hexane.

2.4 Experimental Diets

Two sets of isoproteic (40% crude protein) diets were formulated using wheat offal and rice bran respectively. Maize was fixed at 10% for each of the diets, while fish meal, soybean meal and baker’s yeast (*Saccharomyces cerevisiae*) were added as protein supplements.

2.5 Preparation of Diets

All ingredients except the premixes and Bakers’ yeast were severally milled until very fine particles were produced. The milled ingredients were further sieved using 0.5mm mesh size sieve to ensure a homogenous particle size for proper mixing and adequate compaction of the diets (Houlihan, 2008 [19]; Jauncey *et al*., 2007 [12]; Hardy, 1989 [20]).

Table 1: Proximate Composition of Ingredients

Ingredient	Moisture (%)	Crude Protein (%)	Crude Lipid (%)	Crude Fiber (%)	Ash (%)	NFE (%)	M.E (Kcal/Kg)
Rice Bran	1.5	13.30	1.0	11.4	2.0	72.30	2921
Wheat Offal	2.5	18.60	2.0	10.5	2.0	66.90	2093
Maize	9.5	10.34	4.0	6.5	3.0	76.16	3554
Fish meal	3.5	68.50	10.2	2.5	8.0	10.9	2860
SBM	1.0	44.90	8.5	7.8	6.0	32.8	2868
Yeast	7.0	45.20	1.0	2.7	4.2	46.9	2842

The ingredients including premixes were then measured using a digital weighing balance according to the percentage composition in the formulation, after which they were mixed using an electronic mixer until a homogenous blend was obtained. Hot water was used to prepare the ingredients into a consistent dough that can pass through the dies of the machine used.

2.6 Experimental Design

One kilogram of each diet was pelletized using an electric dry pelletizer designated as “Machine A” and another one kilogram using a petrol powered mincer designated as “Machine B”. Diets 1 and 2 produced from machine A were recorded as A1 and A2 respectively, while Diets 1 and 2 from machine B were recorded as B1 and B2 respectively. To test the effect of two different types of pelletizing machines on the quality of diets produced.

2.7 Pellet Production

The compounded dough for each diet was pelleted by passing it through a 4mm die plate for both machines. The wet pellets were automatically cut into fairly uniform sizes of about 1cm for the electric dry pelletizer and manually into about 2cm for the mincer, before they were spread evenly on trays and kept under the sun for 3 days to ensure adequate drying.

Table 2: Gross Composition of Diets

Ingredients	Diet 1 (Rice Bran)	Diet 2 (Wheat offal)
Rice Bran	15.17	-
Wheat Offal	-	17.28
Yeast	16.27	15.74
Fish Meal	32.54	31.49
Soybean Meal	16.27	15.74
Maize	10	10
Lysine	1	1
Methionine	1	1
Vit. Premix	1	1
Bone meal	2.5	2.5
Vegetable Oil	4	4
Salt	0.25	0.25
Total (%)	100	100
Calc. CP (%)	40	39.99
Metabolizable Energy (KCal/Kg)	2986.05	2886.13
Price/Kg (N)	347	339

Plate 3.2: Powdery Feed Machine (Dry Pelletizer) (Machine A)

Plate 3.3: Feed Mincer (Machine B)

2.8 Experimental Tests

2.8.1 Bulk Density (g cm^{-3})

Bulk density was calculated as follows

$$\text{Bulk density} = \frac{M}{AL}$$

Where M = Mass (g) of the pellet
L = Length (cm) of the pellet
A = Cross-sectional area of the pellet

2.8.2 Expansion Ratio

Expansion ratio was calculated as described by Misra *et al* (2002) [21]. The average pellet diameter for each diet treatment was measured using a vernier caliper. The expansion ratio which is the increase in the pellet cross-sectional area compared to the die cross-sectional area was then calculated as follows:

$$\text{Expansion ratio (\%)} = \left[\left(\frac{D_p}{D_d}\right) - 1\right] * 100$$

Where D_p = Pellet diameter
D_d = Die dimeter

2.8.3 Floatation test

The buoyancy of the test diets was determined by placing samples containing 10 pellets from both machines, replicated 3 times into 2litres bowls filled to about 75% with water. The number of pellets from each sample remaining afloat after every 60seconds interval was recorded for a period of 30 minutes. Percentage floatation at any time interval was determined as follows:

$$\text{\% Floatation} = \frac{\text{Number of pellets afloat}}{\text{Number of pellets in sample}} \times 100\%$$

(Misra *et al.*, 2002) [21].

2.8.4 Water Stability

Water stability of the diets was measured for each test duration by placing 10 pellets from each machine replicated 3 times into a nylon sieve, tied with a string, and inserted into a bowl containing water and observed for a period of 30 minutes and 60 minutes. After the duration elapsed, the portion of the feed left whole were sun-dried for 3 days and the weight were recorded as M_{30} and M_{60} representing final dry weights after 30 minutes and 60 minutes immersion respectively. Water stability was then calculated as follows

$$\text{Water Stability} = \left(\frac{M_{30}}{M_1}\right) * 100\% \text{ (for 30 minutes)}$$

and

$$\left(\frac{M_{60}}{M_1}\right) * 100\% \text{ (for 60 minutes)}$$

Where M_{30} = Weight of pellet after 30 minutes immersion and drying
M_{60} = Weight of pellet after 60 minutes immersion and drying
M_1 = Initial dry weight of pellets (Fagbenro and Jauncey, 1995) [22].

2.8.5 Relative absorption rate (RAR)

RAR which is the measure of the volume of water absorbed in relation to the initial weight of the pellets was calculated as follows:

$$\text{RAR} = \left(\frac{M_2 - M_1}{M_1}\right) * 100\%$$

Where M_2 = Mass of wet pellets
M_1 = Initial mass of dry pellets
$M_2 - M_1$ = Weight gain after immersion in water

(Fagbenro and Jauncey, 1995) [22].

2.9 Data Analysis

All recorded data on the physical properties of the various diets were analyzed by one way ANOVA to test for significance difference in the mean recorded for each parameter. Regression analysis was done to describe the relationships between different parameters where necessary. All Analysis were done using SPSS statistical data analysis package and the charts were designed using Microsoft excel 2013 package.

3. Results

3.1 Physical Characteristics of Pellets

The present study shows that pellets from machine B had the best expansion and were significantly different (*P*<0.05) from those from Machine a (Table 3). There was no expansion recorded in the pellets of both diets produced from machine A while the pellets from Machine B had varying level of expansion 50.00 ± 33.33 for Diet B2 and 33.33 ± 14.3 for Diet B1 (Table 3). In terms of bulk density, there was significant difference between pellets from both machines. Pellets from machine B had significantly lower bulk densities than those from machine A. Also, there was no significant difference in bulk density of both set of pellets from machine A, mean bulk density was 1.06 ± 0.06 for Diet A1, and 1.12 ± 0.05 for Diet A2. However pellets made with machine B had significantly different bulk densities based on ingredient composition. Relative absorption rate was significantly different between both machines. Diet A2 from machine A had the least water absorption (38.83 ± 2.67), and Diet A1 also from machine A had the greatest water absorption (61.83 ± 7.1) in relation to their initial mass. There was no significant difference between the pellets produced from machine B in terms of relative absorption rate, although Diet B1 from machine B was also significantly similar to Diet A1 from machine A.

Table 3: Physical Characteristics of Pellets

Parameter	A1	A2	B1	B2
Expansion Ratio	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	33.33 ± 14.43^{b}	50.00 ± 33.33^{a}
Bulk Density	1.06 ± 0.06^{c}	1.12 ± 0.05^{c}	0.69 ± 0.02^{b}	0.57 ± 0.03^{a}
RAR	61.83 ± 7.1^{c}	38.83 ± 2.67^{a}	54.94 ± 1.67^{bc}	52.67 ± 1.02^{b}

Table 4: Floatation and water stability of pellets

Parameter	A1	A2	B1	B2
Floatation (1-5minutes)	$0.00^{b} \pm 0.00$	$0.00^{b} \pm 0.00$	$96.67^{a} \pm 5.77$	$100.00^{a} \pm 0.00$
Floatation (6-10minutes)	$0.00^{c} \pm 0.00$	$0.00^{c} \pm 0.00$	$13.33^{b} \pm 5.77$	$76.67^{a} \pm 5.77$
Floatation (11-15minutes)	$0.00^{b} \pm 0.00$	$0.00^{b} \pm 0.00$	$0.00^{b} \pm 0.00$	$73.33^{a} \pm 5.77$
Floatation (16-20minutes)	$0.00^{b} \pm 0.00$	$0.00^{b} \pm 0.00$	$0.00^{b} \pm 0.00$	$33.33^{a} \pm 11.55$
Floatation (> 20 minutes)	$0.00^{b} \pm 0.00$	$0.00^{b} \pm 0.00$	$0.00^{b} \pm 0.00$	$16.67^{a} \pm 5.77$
Water Stability (30 minutes)	$58.21^{c} \pm 1.15$	$59.44^{c} \pm 0.49$	$75.84^{a} \pm 3.63$	$70.27^{b} \pm 1.51$
Water Stability (60 minutes)	$44.67^{d} \pm 0.58$	$46.98^{c} \pm 1.18$	$58.24^{a} \pm 1.67$	$52.67^{b} \pm 1.02$

3.2 Floatation and Water Stability

There was significant difference (*P*<0.05) in floatation between the pellets subjected to both of the machines. There was absolutely no floatation in the pellets of both diets produced from Machine A, however among the pellets produced from Machine B the different diet combinations produced different percentages of floatation at different time intervals. In the first five minutes, both sets of pellets from machine B floated at different proportions. 100% of the pellets of Diet B2 (Wheat Offal) floated, while 96.67% of Diet B1 (Rice Bran) floated, but both diets were not significantly different (*P*>0.05) from each other.

Within the second time interval (6 – 10 minutes), Diet B1 (Rice Bran) had 13.33% floatation, while Diet B2 (Wheat Offal) had 76.67% floatation, and both diets were significantly different from each other. Subsequently only Diet 2 (Wheat Offal) continued to float, although with decreasing percentage floatation with increase in time, and at the end of the 20 minutes duration of the test, 16.67% of Diet B2 continued to float.

Water stability of pellets from machine B was significantly higher than those from machine A for both durations of the test. In the first 30 minutes, Diet B1 had the highest water stability (75.84±3.63) while Diet A1 had the least (58.21±1.15). There was however no significant difference between both set of diets from Machine A, whereas Diet B1 had significantly higher water stability than Diet B2. Water stability after 60 minutes was generally less than that recorded after 30 minutes. Diet B1 still had the best water stability, while Diet A1 remained the least water stable.

4. Discussion

4.1 Physical Characteristics of Pellets

The physical characteristics of pellets of the two sets of diets produced from both machines are presented on table 3. They include expansion ratio, bulk density, relative absorption rate, and absorption efficiency ratio. It was observed during the course of this experiment that most of these physical factors are highly related and the factors that may cause changes in one often result in a similar or opposite change in another.

4.2 Expansion Ratio

There was no expansion in the set of pellets produced using machine A. However the same set of diets produced expansion when they were pelletized with machine B. The complete absence of expansion in the pellets produced with Machine A could be attributed to a number of factors. Although hot water was used to mix the dough, it could not be added in adequate amount that will result in gelatinization of the starches present in the ingredients. This is because excess moisture causes the die of this machine to get clogged, such that even after the pellets are eventually forced out they come out poorly binded with lots of powdery residue. According to Hardy (1989) [17], expansion in pellets is as a result of extrusion or cooking of the pellets which causes them to expand as they are forcefully ejected out of the machine die, while extrusion itself is influenced by the quantity of moisture and heat applied during pellet production usually about 20 – 24% and 120 – 125 °C respectively. The limitation on moisture when using this machine makes it impossible to expose the pellets to these essential physical factors during their production.

Contrastingly, the second set of pellets produced with machine B experienced appreciable expansion since adequate hot water was used in preparing the dough, therefore increasing the heat of the dough and gelatinization of the starches present in the ingredients. It was also observed that the pellets are usually hotter when coming out of machine B than when they are being ejected from machine A. This could be as a result of the screw nature of the machine part, of which its movement increases the friction between particles of the dough and machine, hence creates greater amount of heat than machine A.

4.3 Bulk Density

All the pellets produced from machine B had lower bulk densities than those from machine A, and the lower the bulk density of a body, the greater its potential to float. Specifically objects that float on water have to be less than 1g/cm^3 (density of water) in bulk density (Riaz, 2009) [23]. The better performance of the set of pellets produced from machine B can be attributed to the expansion of the pellets, this agrees with Jauncey *et* al., (2007) [12] who stated that the greater the expansion of the pellets the less its bulk density. This is because as pellets expand, their volumes increase disproportionately with their masses, leading to reduction in bulk density. The forceful ejection of the pellets out of the die in Machine B seems to have caused the entrapment of air bubbles within the complex of the pellets which makes them lighter in weight, unlike in Machine A where the particles of the dough were compacted such that the volume to mass ratio is reduced.

4.4 Relative Absorption Rate

Table 3 shows that the difference in water absorption was more related to ingredient composition rather than machine type. This is because the least water absorption for a pellet was recorded for Diet A2, while the poorest diet with the highest water absorption was Diet A1, both from machine A. More so there was no significant difference in RAR among the feeds pelleted on the different machines.

4.5 Water Stability

After the first 30 minutes, water stability was higher for the pellets of both diets from machine B than it was from machine A. This is probably because the pellets from machine B had better adhesion as a result of the gelatinization of starches caused by the relatively high moisture and heat employed during the preparation of the dough. Also there was no significant difference in water stability of both diets from Machine A, while those Machine B were significantly different from each other. This indicates that machine B portrays the variation and influence of ingredient composition on water stability of both diets. Water stability after 60 minutes was generally lower for both diets, and on both machines. However diets from machine B still had higher stability than those from machine A.

4.6 Floatability

No floatation was observed in any of the diets produced with machine A while percentage floatation differed significantly among the pellets of both diets produced with machine B. The absence of floatation in diets produced with machine A could be as a result of the lack of adequate heat and moisture during pelletization which led to the lack of expansion in the pellets, and subsequently their relatively higher bulk densities (Table 3). This supports the claim by Riaz (2009) [23] that objects must have bulk densities less than that of water (1g/cm^3) to float. It also agrees with the findings of Rokey and Plattner (2006) [24] which suggests that pellets will sink very fast when immersed in water if their bulk density is greater than 640g/cm^3.

However pellets produced with machine B had different ranges of percentage floatation based on the composition of the ingredients in the diets. In the first 5 minutes of the test, both set of diets floated without significant difference. This could also be as a result of the uniform particle size (< 0.5mm) of ingredients that were used in their production (Hardy, 1989) [17]. Within the second time interval (6 – 10 minutes), Diet B2 had significantly higher percentage floatation than B1, and subsequently only Diet B2 had percentage floatation (although decreasing with increase in time) till the end of the experiment. This is probably as a result of the chemical properties of wheat that enables it to swell better than other ingredients and trap air within the pellets (Falayi and Sadiku, 2013) [3].

4.7 Physical Appearance and Durability of Pellets

Plates 3 and 4 shows the appearance of pellets produced from machine A and Machine B respectively. It was observed that pellets from machine A had a more appealing look, they were automatically cut into fairly uniform sizes by the machine and appeared rather smooth and glossy on the surface. This was probably as a result of the pressure applied during pelletizing, aided by the polished holes of the die of the machine (Jauncey *et al*., 2007) [12]. On the other hand the pellets from Machine B looked coarser and were irregularly sized which may be as a result of the high force exerted in pushing the wet pellets out of the die.

It was however observed that after drying, the pellets from machine A crumbled easily from touch while those from machine B were harder. The lack of mechanical strength in the pellets produced from machine A could have resulted from absence of gelatinization of starches in the ingredients as a result of the limited use of water in preparing the dough of the diets. This also agrees with Jauncey *et al*., (2007) [12] that added that even when binders are added to the diet to compensate for the poor physical strength, since there was no significant addition of water before pelletizing, these binders would have absolutely no effect.

Plate 3: 4mm Pellets Produced with Machine A

Plate 4: 4mm Pellets Produced with Machine

5. Conclusion and Recommendation

The experiment showed that the Feed Mincer (Machine B) produces better pellets than the Powdery Feed Machine. Expansion ratio was significantly higher in pellets of machine B than those from machine A, and bulk density of pellets from machine B were significantly less than those from machine A, which enabled the former to float substantially in water. Also Water stability of pellets produced from machine B were significantly better than those of the pellets from machine A. This significantly better performance has been tied to the ability of machine B to accept dough with greater quantity of moisture than machine A. Thus the present results indicate that the Feed Mincer provides the small scale fish farmer a better option for the on-farm production of floating feeds with better water stability and other physical characteristics than the powdery feed machine. It is therefore recommended that the Feed mincer should be adopted for the production of pelletized floating fish feeds.

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