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Effect of Drying Parameters on the Physical Properties of Extruded Fish Feed

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Abstract. Commercial catfish feed is sometimes manufactured through extrusion, usually are of high moisture content which cannot be stored or transported without it being damaged, hence, the need for effective drying of fish feed. Fish feed was formulated, mixed, extruded (single screw extruder), dried (mechanical convective dryer) and evaluated upon to examine the impact of the drying parameters (air drying temperature and air-drying velocity) and some physical properties of the fish feed. Five levels of drying air temperature (40 °C, 50 °C, 60 °C, 70 °C and 80 °C) and three levels of drying air velocity (1.0 m/s, 1.5 m/s and 2.0 m/s) were used during the drying experiments. The final moisture content reduces with increase in drying air temperature and drying air velocities. The drying temperature does not significantly affect the unit density and porosity. Bulk density reduces with increased drying air temperature and drying air velocity. The extrudate porosity increases with drying air temperature. The drying air velocities does not significantly affect the sinking velocity and porosity. The optimum floatation time is from the feed dried at 1.5 m/s drying air velocity and 80oC drying air temperature.

1. Introduction

Feed is the most cost-intensive and semi-intensive production in aquaculture It is essential to guarantee that the feed is well used, offering a high rate of development, excellent health to the fishes and, lastly, a high-quality product. Effective drying of extruded fish feed must be properly carried out to enhance the shelf life of the feed and its quality. The extent to which the feed affects the fish's water quality and usage rates is determined by the feed's physical characteristics. The drying method is recognized as having an impact on the technical quality of feed pellets [1].

Extruded fish feed usually are of high moisture content which cannot be stored or transported without being damaged hence the need for effective drying. The extruded fish feed is usually with high moisture content, hence the need for effective drying. The safe moisture content for fish feed for storage is usually 8% to 12% [2]. If feed is not properly dried, the shelf life will be shortened and it can lead to deterioration of feed. Fish feed drying contributes to its buoyancy hence; it helps in the floatability of the fish feed. The existing fish feed dryer are majorly imported from China. Most of the imported dryers roast the feed into the inner core.

The design of this imported dryers do not support air flow which has a major contribution in any drying operation. Most of the imported dryers are operating at a very high temperature thus, which destroys the important nutrient that are essential for the fish growth. Therefore, it is very important to study the drying kinetics of extruded fish feed. This will help in developing an effective and efficient drying system for floating fish feed. The aim of this study is to evaluate the influence of drying parameters on some physical properties of extruded fish feed.

2. Materials and Method

2.1. Description of dryer.

The convective dryer used was fabricated and assembled at the Agricultural and Environmental workshop of the Federal University of Technology, Akure, Nigeria. The mechanical dryer consists of heating coil, axial blower, drying chamber, speed regulator, air outlet openings and thermostat. The dryer was powered by an electric current of 220 V while the power of the motor was 0.75 kW. The heat for drying was supplied by a heating element of 1.2 kW. The dryer which is cylindrical in shape with the dimension of 1.5 m by 0.9 m by 1 m, length, width and height respectively. The material is made of steel. The heating element (heater) is located at the combustion chamber just beside the axial fan. The blower which was an axial type was operated by an electric motor of 0.75kW capacity at a maximum speed of 1400 rev/min (with speed regulator) [3]. The blades of the fan sucked fresh air from the surrounding and blew it across the heating element to the drying chamber. The speed of the fan was regulated with an electric voltage regulator.

2.2. Sample preparation

The composition of the feed used was based from the literature that contains: fish meal (65% cp), soy bean meal (45% cp), maize, blood meal (85% cp), fish oil, vegetable oil, vitamins/mineral premix and binder [4]. Fish feed raw materials were sourced locally from dealers in fish feed within Akure metropolis, and were mixed manually with a standard mix ratio based on literatures [5]. The mixing was carried out at the Processing and Storage Engineering laboratory in the Agricultural and Environmental Engineering department, of the Federal University of Technology, Akure, Ondo state Nigeria. The mixing was done in batches ready for extrusion during which a determined mass of 2.5 kg of dried mixture were weighed using an electronic weighing balance, recorded and placed in a mixing bowl. Added to this mixture was 1,500 ml of boiled water for quick dissolution in order to further the mixing consequently forming a dough.

Extrusion was later done using an extruder designed and fabricated at the departmental workshop by pouring the feed ingredient dough into it via its hopper. The extruder was allowed to run for fifteen to thirty minutes to allow proper heating of the trough since it is a single screw self-heat generated extruder with various die sizes before pouring in the feed mixtures. For the purpose of this experiment, a single die size of 4 mm was used [6].

2.3. Drying procedure

The drying methods described by [7] was used. Based on literatures amongst which was [8], five levels of air temperatures were selected alongside three levels of air velocities were equally carefully chosen. The levels of air temperatures comprise; 40 °C, 50 °C, 60 °C, 70 °C and 80 °C. On the other hand, the three levels of air velocities are; 1 m/s, 1.5 m/s, and 2 m/s respectively. The method has been followed in three replicates for each run. The use of a mechanical convective dryer was employed during the experiment.

2.4. Determination of dried extrudate physical properties

The dried extrudes were extensively analysed for the following physical property: moisture content (% db), unit density (g/cm^3), bulk density (g/cm^3), water stability, floatability and sinking velocity.

2.4.1. Moisture content. The moisture content of the extrudates for each of the feed formula was measured by recording the weight of mix initially before oven drying for 24 hours at 105° C and measuring the same after drying. Moisture content wet basis of the sample was calculated using the following equation:

$$M_c = \frac{w_w - w_d}{w_w} \times 100 \quad (1)$$

Where; Mc = Moisture content (wet basis) %; w_w = initial weight (kg); w_d = final weight (kg)

2.4.2. Unit density. The extrudates were cut into pieces about 2 cm long using a razor blade. Each extrudate was then measured with a digital weighing equilibrium with a precision of ± 0.01 grams using an analogue Vernier calliper [9]. The unit density was calculated using the formulae below:

$$\text{Unit density} = \frac{\text{Mass of the extrudants}}{\text{Volume of the extrudants}} \quad (2)$$

2.4.3. Bulk density. The feed was loosely poured in a 250 ml beaker till was full, so as to get the bulk volume, then the feed inside the beaker was weighed to get the mass [10]. The bulk density be calculated using the formulae below.

$$\text{Bulk density} = \frac{\text{Bulk Mass of the extrudants}}{\text{Bulk Volume of the extrudants}} \quad (3)$$

2.4.4. Sinking velocity. The sinking velocity was performed using a measuring cylinder of 200 ml filled with water. A specific amount of dried feed was immersed in water and at the end of every observation the time taken for the feed to sink were recorded [5]. The distance travelled for the time taken will give the sinking velocity (m s^{-1}).

2.4.5. Floatability. The floatation test was performed using a transparent conical flask for each treatment. A specific amount of dried feed was immersed in water and at the end of every observation the number of dried feed afloat was recorded. After this time, the total number of feed floating over the surface of the water were expressed as percentage of the initial number.

$$\%\ balls\ afloat = \frac{Final\ number\ of\ balls\ afloat}{Initial\ number\ of\ balls\ afloat} \times 100 \quad (4)$$

2.5. Data Analysis

The obtained data from the drying experiment were analysed using descriptive statistics (Microsoft Excel 2013 and IBM SPSS version 19). Using the IBM SPSS, the data was analysed by comparing the means using ANOVA (Analysis of Variance) and post hoc tests were performed using Duncan multiple range test.

3. Results and Discussion

3.1. Results

The results of effect of drying air temperature (40ºC, 50ºC, 60ºC,70ºC and 80ºC) on the physical properties of extruded fish feed at drying air velocity of 1.5 m/s is shown in Table 1. The variation of Floatability (%) against Time (secs) for 40ºC, 50ºC, 60ºC,70ºC and 80ºC air temperature at different drying air velocities of 1m/s, 1.5 m/s and 2.0 m/s is shown in Figures 1 - 3. The results of effect of drying air velocity (1.0 m/s, 1.5 m/s, 2.0 m/s) on the physical properties of the extruded fish feed at drying air temperature of 60ºC is shown in Table 2. The variation of Floatability (%) against Time (secs) for drying air velocities of 1m/s, 1.5 m/s and 2.0 m/s at drying air temperatures of 40ºC, 50ºC, 60º C,70ºC and 80ºC is shown in Figures 4 – 8.

Table 1. Effect of drying air temperature on the physical properties of extruded fish feed

Drying Temperature ºC	**Physical Property**				
	Moisture Content	Unit Density	Bulk Density	Sinking Velocity	Porosity
40	13.27±0.2[d]	530.90±1.31[a]	267.36±1.84[e]	0.11±0.01[a]	49.64±0.34[a]
50	12.43±0.2[c]	527.90±32.16[a]	255.51±1.77[d]	0.11±0.02[a]	51.48±2.94[ab]
60	11.6±0.1[b]	530.95±31.03[a]	243.28±1.36[c]	0.107±0.06[a]	54.09±2.14[ab]
70	11.24±0.09[ab]	485.1±34.31[a]	223.76±1.72[b]	0.10±0.01[a]	53.73±3.03[ab]
80	11.4±0.01[a]	502.17±22.3[a]	215.18±3.96[a]	0.08±0.01[a]	57.07±2.73[b]

Table 2. Effect of drying air velocity on the physical properties of the extruded fish feed at temperature 60ºC

Drying Air Velocity (m/s)	**Physical Property**				
	Moisture Content	Unit Density	Bulk Density	Sinking Velocity	Porosity
1.0	12.32±0.1[c]	570.50±10.06[b]	269.36±4.61[c]	0.11±0.01[a]	52.76±0.95[a]
1.5	11.6±0.1[b]	530.95±31.03[ab]	243.28±1.36[b]	0.11±0.06[a]	54.09±2.14[a]
2.0	11.33±0.03[a]	482.06±7.72[a]	219.22±1.14[a]	0.11±0.01[a]	54.52±0.62[a]

3.2. Effect of Drying Temperature on the Physical Properties of the Fish Feed

The summary from the data analysis presented in table 1 reveals that the drying air temperature has a significant effect on the physical properties (final moisture content, unit density, bulk density, sinking velocity, porosity, floatability) of the extruded fish feed. For unit density and porosity, there exist no significant difference between temperatures but for final moisture content, 80ºC was ranked the best temperature to yield the least final moisture content of 11.4±0.01% (wb). This does not differ significantly with 70º C drying air temperature as it yielded a final moisture content of 11.24±0.09% (wb). Generally, the moisture content has an inverse proportional relationship with the drying air temperature that is as the drying air temperature increases, the final moisture content reduces and vice versa. 40ºC drying air temperature had the highest bulk density (267.36 kg/ml) while 80ºC had the lowest (215.18kg/ml) amongst the air-drying temperatures.

For porosity, table 1 shows that at lower temperatures we obtained the least porosity while at higher temperatures there was higher porosity. This could have been as a result of shrinkage that could have resulted from a very low final moisture content causing more pores to be formed as the drying air temperature increases. From the research carried, as drying air temperature increases, the porosity of the extruded fish feed increase [10].

Figure 1 reveals the floatability test of dried extrudates at 1.0 m/s drying air velocity. The graph reveals extrudates from drying air temperature of 80ºC to have the highest number of floated extrudate for the first ten seconds to be over taken by that of 70ºC for five more seconds, before that of 60º C took the lead floatation until the twentieth seconds. From the first 25 to 30 seconds, extrudates from drying air temperature 50ºC has more feed still floating, but 70ºC had more floating as from the 35th second before they all finally sank. Here, more extrudates from the 70ºC drying air temperature floated for a longer time than the rest.

Figure 2 reveals the floatability test of dried extrudates at 1.5 m/s drying air velocity. The graph reveals extrudates from drying air temperature of 80ºC to have the highest number of floated feed for the first ten seconds to be over taken by that of 60ºC for twenty more seconds, before that of 80ºC took the lead until the 35th second before they all finally sank. Here, more extrudates from the 60ºC drying air temperature floated for a longer time than the rest.

Figure 3 reveals the floatability test of dried extrudates at 2.0 m/s drying air velocity. The graph reveals extrudates from drying air temperature of 80ºC to have the highest number of floated extrudate for the first ten seconds to be over taken by that of 60ºC for five more seconds, before that of 50ºC took the lead floatation until the 25^{th} seconds. Between 25 to 30 seconds, extrudates from drying air temperature 60ºC took the lead until the 35^{th} second before they all finally sank. Here, more extrudates from the 60ºC drying air temperature floated for a longer time than the rest.

3.3. Effect of Drying Air Velocity on the Physical Properties of Fish feed

Data analysis presented in table 2 reveals that the drying air velocity has little effect on the physical properties (final moisture content, unit density, bulk density, sinking velocity, porosity and floatability presented in Figures 4 – 8) of the extruded fish feed. For sinking velocity and porosity, there exist no significant difference between drying air velocities but for final moisture content, 2.0 m/s was ranked the best drying air velocity to yield the least final moisture content of 11.33±0.03% (wb). This differ significantly with 1.5 m/s drying air velocity as it yielded a final moisture content of 11.6±0.1% (wb). The 70ºC drying air temperature also differ significantly as the 1.0 m/s drying air velocity with a final moisture content of 12.32±0.1% (wb). Therefore, the moisture content has an inverse proportional relationship with the drying air velocity; as the drying air velocity increases, the final moisture content reduces and vice versa. The velocity that yielded the best unit density which happened to be the least of them all was 2.0 m/s, while the most of the unit density was recorded at 1.0 m/s. From Table 2, it can be observed that the unit density reduces with increased drying air velocity. For the velocity that yielded the best bulk density which happened to be the least of them all was 2.0 m/s, while the most of the unit density was recorded at 1.0 m/s (11). It can be observed also that the bulk density reduces with increased drying air velocity.

From figure 4, it reveals extrudates from drying air velocity of 1.0 m/s to have the highest number of floated feeds for the first ten seconds to be over taken by that of 2.0 for ten more seconds, before that of 1.5 m/s took the lead floatation until the 25^{th} seconds. Between 25 to 30 seconds, extrudates from drying air velocity 2.0 m/s floated the most and finally 1.5 m/s took the lead until the 35^{th} second before they all finally sank. Here, more extrudates from the 2.0 m/s drying air velocity floated for a longer time than the rest. From Figure 5, it reveals extrudates from drying air velocity of 2.0 m/s to have the highest number of floated feeds for the first ten seconds to be over taken by that of 1.0 for ten more seconds, before that of 1.5 m/s took the lead floatation until the 20^{th} seconds. Between 20 to 35 seconds, extrudates from drying air velocity 1.0 m/s floated the most before they all finally sank. Here extrudates from the 1.0 m/s drying air velocity floated for a longer time than extrudates from other drying air velocities.

From figure 6, it was revealed that extrudates from drying air velocity of 2.0 m/s have the highest number of floated feed for the first ten seconds to be over taken by that of 1.0 for 5 more seconds, before that of 1.5 m/s took the lead floatation until the 25^{th} seconds. Between 25 to 35 seconds, extrudates from drying air velocity 1.0 m/s floated the most and finally 1.5 m/s took the lead until the 35th second before they all finally sank. Here extrudates from the 1.5 m/s drying air velocity floated for a longer time than extrudates from other drying air velocities

Figure 7 reveals extrudates from drying air velocity of 1.0 m/s to have the highest number of floated feeds for the first five seconds to be over taken by that of 2.0 for 15 more seconds, before that of 1.5 m/s took the lead floatation until the 25^{th} seconds. Between 25 to 30 seconds, extrudates from drying air velocity 2.0 m/s floated the most and finally 1.5 m/s took the lead until the 35^{th} second before they all finally sank. Here extrudates from the 2.0 m/s drying air velocity floated for a longer time than extrudates from other drying air velocities

Figure 5 reveals extrudates from drying air velocity of 1.0 m/s to have the highest number of floated feeds for the first 15 seconds to be over taken by that of 2.0 for 10 more seconds, before that of 1.5 m/s took the lead floatation until the 25^{th} seconds. Between 25 to 30 seconds, extrudates from drying air velocity 2.0 m/s floated the most and finally 1.5 m/s took the lead until the 35th second before they all finally sank. From the figure extrudates from the 1.0 m/s drying air velocity floated for a longer time than extrudates from other drying air velocities.

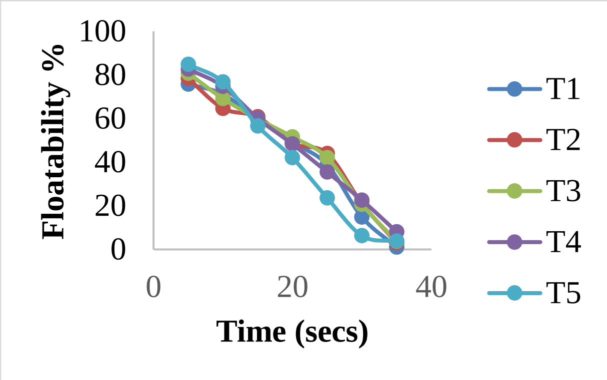

Figure 1. Variation of Floatability (%) against Time (secs) for 40ºC, 50ºC, 60ºC,70ºC and 80ºC air temperature at air velocity of 1m/s

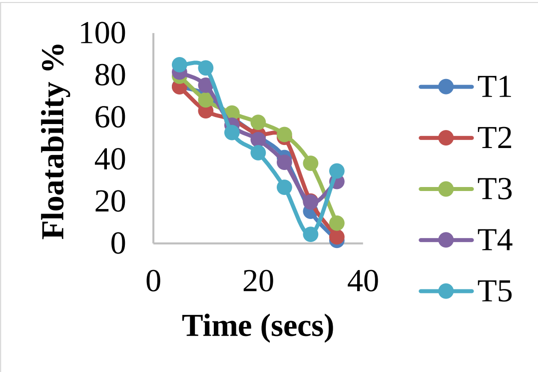

Figure 2. Variation of Floatability (%) against Time (secs) for 40ºC, 50ºC, 60ºC,70ºC and 80ºC air temperature at air velocity of 1.5m/s

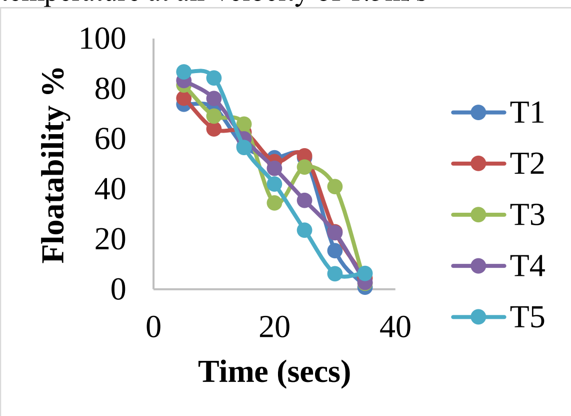

Figure 3. Variation of Floatability (%) against Time (secs) for 40ºC, 50ºC, 60ºC,70ºC and 80ºC air temperature at air velocity of 2m/s

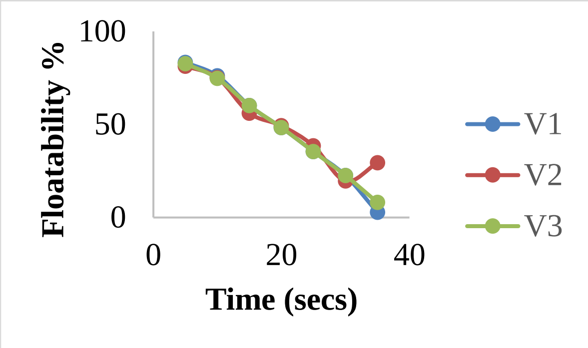

Figure 4. Variation of Floatability (%) against Time (secs) for air velocity of 1m/s, 1.5m/s, 2m/s at air temperature of 40ºC

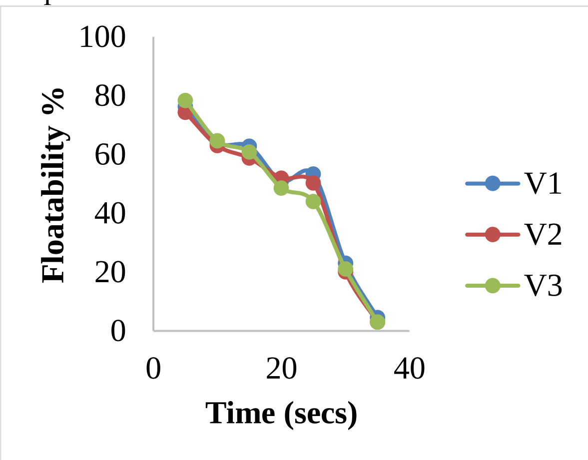

Figure 5. Variation of Floatability (%) against Time (secs) for air velocity of 1m/s, 1.5m/s, 2m/s at air temperature of 50ºC

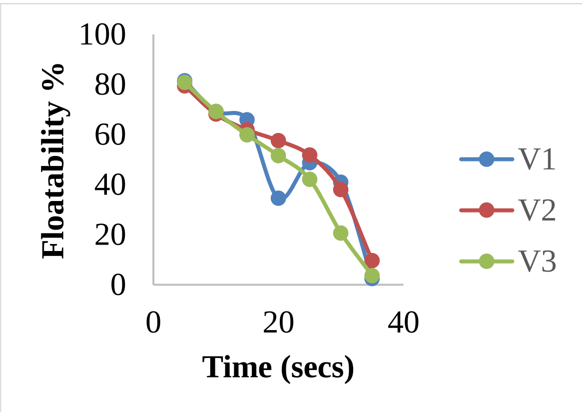

Figure 6. Variation of Floatability (%) against Time (secs) for air velocity of 1m/s, 1.5m/s, 2m/s at air temperature of 60ºC

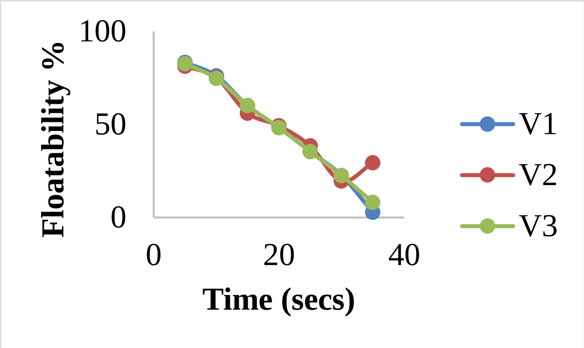

Figure 7. Variation of Floatability (%) against Time (secs) for air velocity of 1m/s, 1.5m/s, 2m/s at air temperature of 70^{0}C

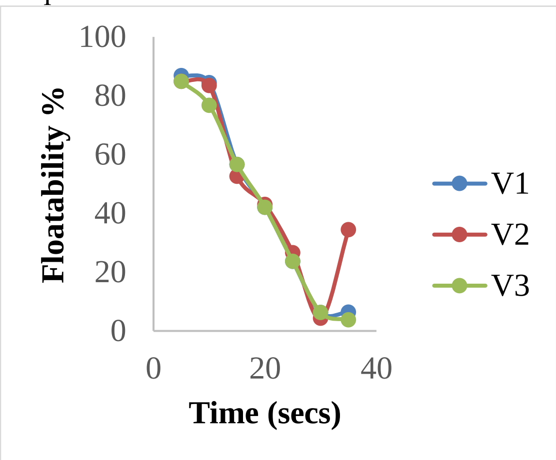

Figure 8. Variation of Floatability (%) against Time (secs) for air velocity of 1m/s, 1.5m/s, 2m/s at air temperature of 80^{o}C

4. Conclusion

Analysis on experimental data produced results which are reported within the pages of this report and consequently leading to the following conclusions the final moisture content reduces with increase in drying air temperature and drying air velocities. For unit density and porosity, there exist no significant difference between temperatures. Bulk density reduces with increased drying air temperature and drying air velocity. The extrudate porosity increases with drying air temperature. For sinking velocity and porosity, there exist no significant difference between drying air velocities. The unit density reduces with increased drying air velocity. Floatability results wasn't really following a regular pattern however, in all, it was observed that the feed with the optimum floatation time remains feed from 1.5 m/s drying air velocity and temperature 80^o C drying air temperature.

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