Turkish Journal of Agricultural Engineering Research

https://dergipark.org.tr/en/pub/turkager
https://doi.org/10.46592/turkager.1356210

Turk J Agr Eng Res
(TURKAGER)

ISSN: 2717-8420
2023, 4(2), 178-190

Research Article

Responce Surface of Drying Parameters on Some Physical Properties Related to Floatability of Extruded Fish Feeds

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Article Info

Received: 06.09.2023 **Accepted:** 27.10.2023 **Published:** 31.12.2023

ABSTRACT

Fish feeds drying plays a major role in the aquaculture industry by ensuring preservation and quality of feed for effective growth and development of farmed fish. Optimization the drying parameters such as drying temperature, drying air velocity and relative humidity plays a crucial role in achieving Response Surface Methodology is a useful to optimized variables/factors more practically as compared to just the statistically significant test for a particular point. The aim of this research to optimize the drying process of an extruded fish feeds which affect the floatability of the feeds. 2000 g of the extruded feeds was dried in a continuous flow belt dryer. The experiments were performed at air temperature of 60, 70, 80, 90 and 100°C, air velocities of 0.7, 0.8, 0.9, 1.0 and 1.2 m s^{-1} and drying belt linear speeds of 50, 55, 60, 65 and 70 rpm. The dried extruded fish feed was subjected to extensive physical properties which are: unit density (kg m^{-3}), water stability (%), sinking velocity and relative absorption ratio. The surface response of each of this physical property of the dried extrudates' were determined. The result shows that the operational parameter can optimally explain about 90.45%, 93.72%, 95.98% and 70.77% change in the density, water stability, sinking velocity and the relative absorption ratio respectively of the extrudate via quadratic function. The optimum predicted values for air temperature of 97.49°C, conveyor belt speed of 50 rpm and air velocity of 1.10 m s^{-1} were obtained for the dryer within the range of the input parameters.

Keywords: *Fish feeds drying, Rejoinder surface, Ropiness, Water stableness, Relative feed-water intake, Sinking speed*

To cite: Ogunnaike F (2023). Responce Surface of Drying Parameters on Some Physical Properties Related to Floatability of Extruded Fish Feeds. *Turkish Journal of Agricultural Engineering Research (TURKAGER), 4(2), 178-190. https://doi.org/10.46592/turkager.1356210*

INTRODUCTION

The demand for seafood continues to rise throughout the continent of the world and a aquaculture has emerged as a sustainable solution to meet this growing needs. The success of aquaculture operations had been reported to rely heavily on the quality and composition of fish feeds (Hasan and Halder, 2019). Nigeria is the largest fish consumer in Africa and among the largest fish consumers in the World with over 1.5 million tons of fish consumed annually (Emmanuel *et al.*, 2014). Commercially, fish feeds are manufactured either as extruded floating or pelletized sinking feeds. Most fish farmers preferred extruded feeds to sink feeds because, extruded feed is buoyant and almost hydrophobic as such leaching is low compared to sinking feeds (Ighwela *et al.*, 2013). In the production of the extruded fish feeds, the most important factors that influence the quality and the capacity production is: the raw materials of fish feed, ingredients of raw material, feed formulation design, drying process and feed producing machines. Also, the drying process is very important in the production of quality dried extruded fish feeds (Heras *et al.*, 2019). Jaescgke and Senge (2018), reported that in understanding the effects of drying on the physical properties of dried extruded fish feeds is vital for optimizing feed production and ensuring the delivery of nutritious and palatable feeds to farmed feeds. Jafaryan *et al.* (2020) reported that the physical properties of fish feeds plays an importance role in the determining the floatability which in turn affects the growth performance of the fish. The buoyancy of fish feed is majorly affected by its density. The density of fish feeds is determined by various factors such as ingredients used in formulating the feed, moisture content and processing technique (Duru *et al.*, 2019). Furthermore, the physical and mechanical properties of fish feed pellets are important to understand its behavior during processing, drying, transporting, packaging and floatability during fish feeding (Khater *et al.*, 2014). Aydar (2018) opined that one of the most commonly used experimental designs for optimization is the response surface methodology because it allows evaluation of multiple factors and their interactions on one or more response variables. Literature is full of effects of physical properties of extruded fish feeds but few research had been reported on the evaluation of drying parameters which affect floatability of fish feeds using surface response method. The objective of this research is to optimize the drying parameters on some physical properties related to floatability of extruded fish feeds.

MATERIALS and METHODS

Feed constituents were purchased from a local Akure, Ondo State, Nigeria market. The feed constituents were formulated as proposed by Liu *et al.* (2020). The formulated feeds were extruded using a screw extruder. 2500 g of the extruded fish feeds were weighed using a digital weighing balance (Model BLC3002, precision of 0.0001 g), The weighed extruded feeds were dried by using a continuous flow dryer which was developed at the University of Technology, Akure. Five drying temperatures of 60 to 100°C at 10°C intervals (Kurt, 2012), air drying velocity of 0.7 to 1.2 m s^{-1} at an interval of 0.1 m s^{-1} as proposed by Torres and Dincer (2011) for drying of fish feeds and belt speed of 50 to 70 rpm at an interval of 5rpm was used in drying the extruded feeds. The dried extruded feeds were made liable to comprehensive physical properties which are density, water stability, sinking velocity and relative absorption ratio.

Measurement of the Dried Extrudate Physical Properties

Density of the dried extruded fish feeds

The dried extrudates were cut into 25.4 mm using a razor blade. A kerro electronic balance (Model BLC3002) was used to determine the mass and the length of the sectional dried extrudate was determined using a digital caliper (Mitutoyo Inc, Japan). The density of the extrudates was determined using Equation 1.

$$p = \frac{M_z}{V_z} \quad (1)$$

Where

p is the density of the extrudates (kg m^{-3}), Mz is the mass of the dried extrudates (kg) and Vz is the volume of the dried extrudates (m^3)

The sinking velocity of the extrudate

The time taken for 10 dried extrudates of length 25.4 mm each to reach the bottom of a 200 ml measuring cylinder filled with distilled water was monitored. This was replicated five times. The sinking velocity (Equation 2) was calculated according to Chevenana *et al.* (2007b).

$$S_v = \frac{D_c}{T_m} \quad (2)$$

Where

Sv is the sinking velocity (m s^{-1}), *Dc* is the distance travelled by the dried extrudates (m) and *Tm* is the time taken (s)

Water stability of the extrudate

10 pieces of the dried extrudates were weighed using a kerro electronic balance (Model BLC3002). This was later placed inside a nylon sieve which is tied with a string and inserted into a bowl containing pond water for 30 minutes. After 30 minutes of immersion, the feeds were sun-dried for 3 days and the weight was recorded as M30 representing the final weight after 30 minutes of immersion. Water stability was calculated using Equation (3) as reported by Fagbenro and Jauncy (1995).

$$Water\ stability = \left(\frac{M_{30}}{M_1}\right) X\ 100 \quad (3)$$

Where M_{30} is the weight of the extrudates after 30 minutes immersion and drying and M_1 is the initial dry weight of the extrudates.

Relative absorption rate of the extrudate

The relative absorption ratio is the measure of the volume of water absorbed in relation to the initial weight of the dried extrudates. This was calculated using Equation (4) has reported by NRC (2011).

$$RAR = \left(\frac{M_2 - M_1}{M_1}\right) x\ 100 \quad (4)$$

Where M_2 is the mass of the wet extrudates (kg) M_1 is the initial mass of the dry extrudates (kg) and $M_2 - M_1$ is the weight gain after immersion in water (kg).

Data Analysis

Microsoft Excel (Microsoft Cooperation 2010) was used for graphical descriptions of the data. Optimization of the relationship between the factors was conducted using Design Expert (9).

RESULTS AND DISCUSSION

Figure 1a, 2a and 3a shows the optimal surface plot of the density, sinking velocity, water stability and the relative absorption rate as affected by the drying temperature and conveyor speed of the continuous flow belt dryer respectively. Figure 1b, 2b and 3b shows the optimal surface plot of the density, sinking velocity, water stability and relative absorption rate as affected by the conveyor speed and air velocity of the continuous flow belt dryer respectively while Figure 1c, 2c and 3c shows the optimal surface plot of the density, sinking velocity, water stability and relative absorption rate as affected by the air velocity and drying temperature of the continuous flow belt dryer respectively. Table 1 shows the optimal goal and range of optimality while Table 2 depicts the optimal solution of the dried extrudate.

Table 1. *Optimal goal and range of optimality of the dried extrudates.*

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A: Conveyor speed	is in range	50.00	75.00	1	1	3
B: Temperature	is in range	60.00	100.00	1	1	3
C: The air velocity	is in range	0.80	1.20	1	1	3
Floatability	maximize	20.000	99.997	1	1	3
Water stability	maximize	6.448	65.856	1	1	3
Expansion ratio	maximize	0.988	1.080	1	1	3
Relative absorption ratio	minimize	13.021	54.817	1	1	3
Sinking velocity	minimize	0.581	5.292	1	1	3
Density	minimize	545.604	854.545	1	1	3

Table 2. Optimal solution of the dried extrudate.

s/n	Conveyor speed	Temperature	Air velocity	Floatability	Water stability	Expansion ratio	Relative absorption ratio	Sinking velocity	Density	Desirability	
1	50.00	97.50	1.10	87.4728	58.0959	1.0260	38.0781	1.2507	586.4950	0.6707	Selected
10	50.00	97.16	1.10	87.0924	57.9071	1.0262	37.6189	1.3192	587.9754	0.6707	
11	50.00	97.36	1.11	87.4423	58.6180	1.0261	38.3176	1.2510	586.1012	0.6706	
12	50.00	96.96	1.11	87.0342	58.5571	1.0263	37.8971	1.3234	587.5674	0.6706	
13	50.00	98.22	1.10	88.1321	57.7763	1.0256	38.5704	1.1361	584.5508	0.6705	
14	50.00	96.14	1.11	86.2367	58.5996	1.0267	37.1906	1.4603	590.2833	0.6701	
15	50.00	98.75	1.09	88.5270	57.1006	1.0252	38.6481	1.0712	583.8783	0.6700	
16	50.00	99.31	1.09	89.1585	57.3882	1.0250	39.4496	0.9517	581.4435	0.6694	
17	50.00	99.23	1.06	88.6902	55.4759	1.0244	38.0961	1.0563	584.9507	0.6679	
18	50.00	95.23	1.14	85.7220	60.3094	1.0269	37.7128	1.5319	590.5703	0.6677	
19	50.00	95.85	1.17	86.7377	62.5480	1.0256	40.0180	1.3292	584.8455	0.6624	
20	50.00	100.00	1.03	88.9854	53.1115	1.0226	37.5049	1.0202	586.3408	0.6615	
21	50.00	91.78	1.19	82.9624	62.1844	1.0271	36.9902	1.9590	599.1380	0.6549	
22	74.69	93.82	1.05	71.5636	52.8656	1.0796	43.4311	2.0329	645.3319	0.6329	
23	74.69	93.84	1.05	71.5627	52.8123	1.0796	43.4098	2.0333	645.4550	0.6329	
24	74.67	93.76	1.05	71.5315	52.9705	1.0796	43.4401	2.0379	645.1940	0.6329	
25	74.73	94.02	1.05	71.6603	52.5933	1.0796	43.4282	2.0170	645.6374	0.6329	
26	74.72	94.12	1.06	71.9259	53.1843	1.0796	43.8975	1.9734	643.5260	0.6328	
27	74.80	94.26	1.04	71.7171	52.0715	1.0796	43.3216	2.0051	646.5831	0.6327	

Estimate the response surface of the dried extrudate density

Figure 1a- c depicts the optimal surface plot of extrudate density versus operational parameters of the machine. The optimal solution shows that the density of the extrudate exhibit a quadratic relationship with the operational parameter with coefficient of determination value of 0.90 which shows that the operational parameter can optimally explain about 90.45% change in the density of the extrudate via quadratic function. Furthermore, the maximum fish feed extrudate density of 854.55 kg m^{-3} was recorded when the machine was operated at the lowest air temperature of 60°C, the lowest air velocity of 0.8 m s^{-1} and 70 rpm of the conveyor speed while the minimum value of the density of 545.60 kg m^{-3} of dry sample was recorded when the wet sample was dried at the highest temperature of 100°C and 1.0 m s^{-1} air velocity with the lowest conveyor speed of 50 rpm. The result of this study was in a close range with the value of 344±3.11 - 537±1.8 reported by Obirikorang *et al.* (2015) while studying the effects of dietary inclusions of oilseed meals on physical characteristics and feed intake of diets for the Nile Tilapia (Oreochromisniloticus). Considering the experimental range of 60°C-100°C drying temperature, 0.8 m s^{-1} - 1.2 m s^{-1}, air velocity and 50 rpm – 75 rpm conveyor speed as operational range of optimality and taking the experimental output range of 545.60 kg m^{-3} to 854.55 kg m^{-3} as the range of optimality and the optimal density of the extrudate was obtained by minimizing (Table 1) the quadratic function which resulted to 586.59 kg m^{-3} (Table 2) and this will be obtained when the continuous flow belt dryer was operated at the drying temperature temperature of 97.49°C, conveyor speed of 50 rpm, and air velocity of 1.102 m s^{-1} with high value of desirability of 0.86 which shows that over 86% of the optimal goal will be attained if the machine was operated at the optimal operational condition.

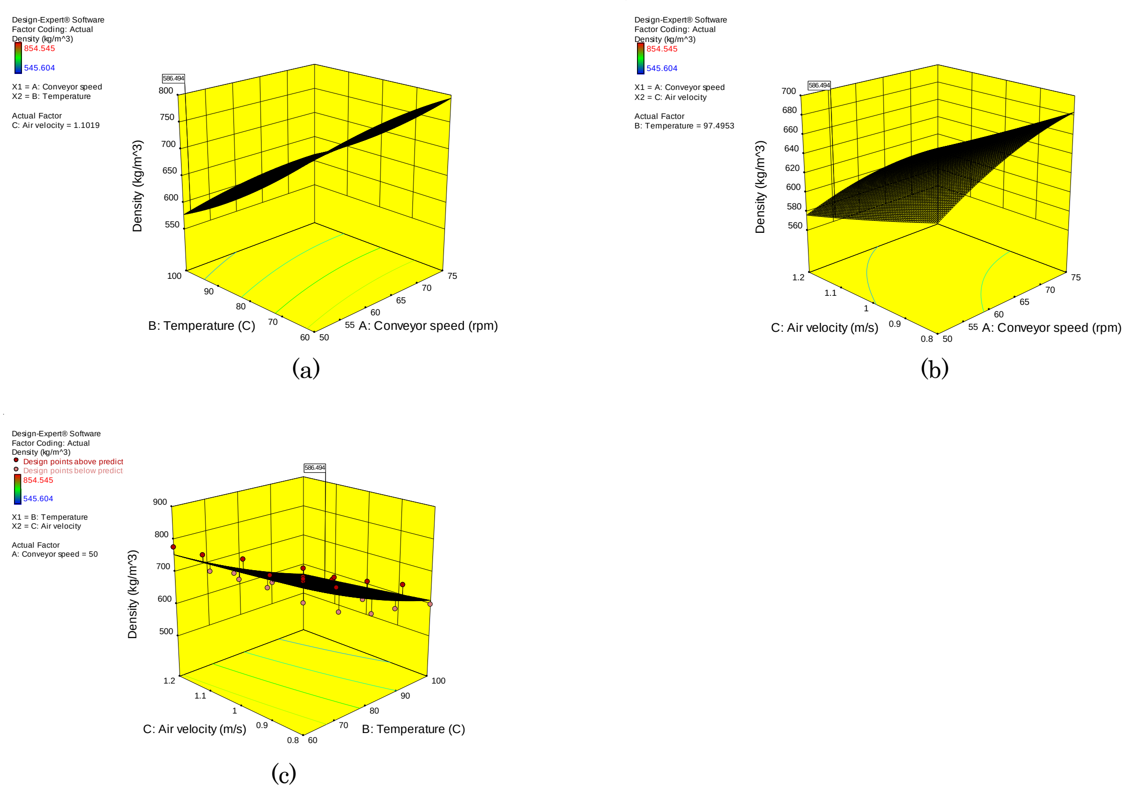
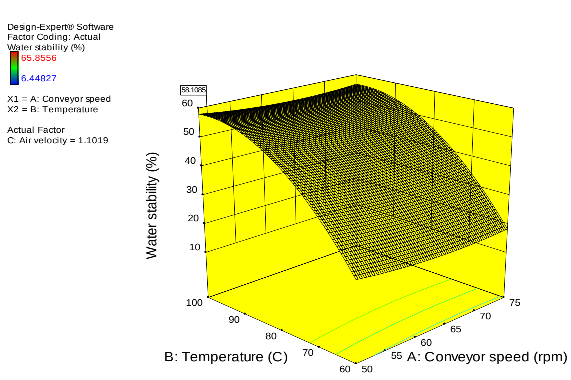


Figure 1(a–c). *Optimal surface plot of extrudate density versus operational parameters of the machine.*

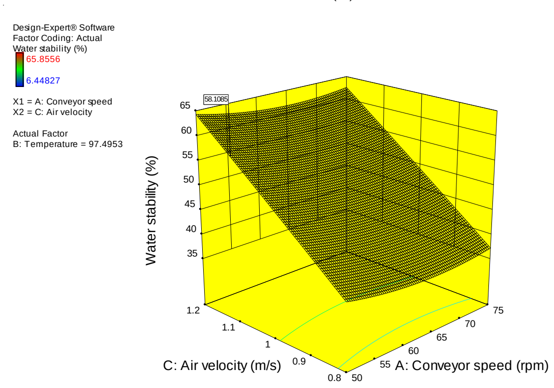
Estimate response surface of the dried extrudate water stability

The water stability of the dried fish feed extrudate under different machine operational conditions shows that the maximum water stability of 65.86% of the fish feed extrudate was recorded when the machine was operated at the highest air temperature of 100°C, the highest air velocity of 1.2 m s^{-1} and the lowest conveyor speed of 50 rpm while the minimum value of the water stability of 6.45% of the dry sample was recorded when the wet sample was dried at the lowest temperature of 60°C and lowest air velocity of 0.8 m s^{-1} with 60 rpm conveyor speed.

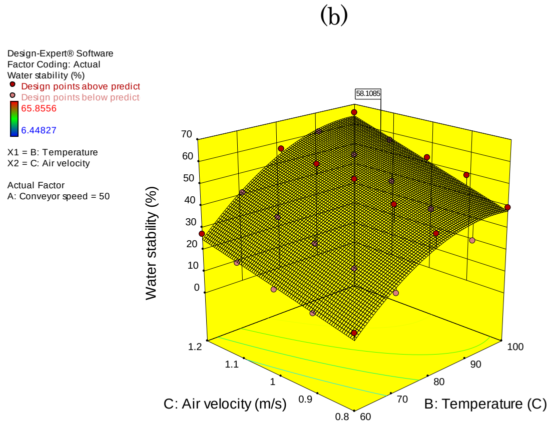
The result of this study is lower than the range of value (84.50±0.19-93.96±0.45%) reported for water stability of fish feed by Obirikorang *et al.* (2015) while studying the effects of dietary inclusions of oilseed meals on physical characteristics and feed intake of diets for the Nile Tilapia (Oreochromisniloticus) and De-Cruz *et al.* (2015) reported 11.47-17.67% as the range of water stability of fish feed during the study of the influence of processing parameters on the extrusion behaviour and quality properties of the feed pellets and this result fall within the range of value obtained in this study. The optimal solution (Figures 2 a-c) shows that the water stability exhibits a quadratic relationship with the operational parameter with the coefficient of determination value of 0.93 which shows that the operational parameter can optimally explain about 93.72% change in the water stability via quadratic function. Considering the experimental range of 60°C -100°C drying temperature, 0.8 m s^{-1} – 1.2 m s^{-1}, air velocity and 50 rpm – 75 rpm conveyor speed as operational range of optimality, Also, taking the experimental output range of 6.43% - 65.85% as the range of optimality and the optimal water stability was obtained by maximizing (Table 1) the quadratic function which resulted to 58.11% (Table 2) and this will be obtained when the continuous flow belt dryer was operated at the drying temperature of 97.495°C, conveyor speed of 50 rpm, and air velocity of 1.102 m s^{-1} with high value of desirability of 0.8695 which shows that over 86% of the optimal goal will be attained if the machine was operated at the optimal operational condition.



(a)



(b)



(c)

Figure 2 (a – c). Optimal surface plot of water stability versus operational parameters of the machine.

Estimate response surface of the dried extrudate sinking velocity

Figure 3a shows the optimal surface plot of the sinking velocity as affected by the drying temperature and conveyor speed of the continuous flow belt dryer and Figure 3b shows the optimal surface plot of the sinking velocity as affected by the conveyor speed and air velocity of the continuous flow belt dryer while Figure 3c shows the optimal surface plot of the sinking velocity as affected by the air velocity and drying temperature of the continuous flow belt dryer. The maximum sinking velocity of 5.2×10^{-4} m s^{-1} of the fish feed extrudate was recorded when the machine was operated at the lower air temperature of 60°C, the lowest air velocity of 0.8 m s^{-1} and 65 rpm conveyor speed while the minimum value of the sinking velocity of 5.8×10^{-5} m s^{-1} of dry sample was recorded when the wet sample was dried at the highest temperature of 100°C, and air velocity of 1.2 m s^{-1} with conveyor speed ranging between 60 and 65 rpm. A similar value of 0.02 - 0.05 m s^{-1} was reported by

Umar *et al.* (2013) for the sinking velocity during the study of the influence of processing parameters on the extrusion behavior and quality properties of the feed pellets. However Tyapkova *et al.* (2016) also reported 10.1 to 7.4 cm s^{-1} as the range of expansion ratio of feed while studying the physical properties of extruded aqua feed with a combination of sago and tapioca starches at different moisture contents and the value of 11.47-17.67 cm s^{-1} reported by Kraugerud and Svihus (2011) is higher than the value obtained in this study. The optimal solution shows that the sinking velocity exhibits a quadratic relationship with the operational parameter with the coefficient of determination value of 0.95 which shows that the operational parameter can optimally explain about 95.98% change in the sinking velocity via quadratic function. Considering the experimental range of 60°C-100°C drying temperature, 0.8 m s^{-1} - 1.2 m s^{-1}, air velocity and 50 rpm-70 rpm conveyor speed as operational range of optimality, Also, taking the experimental output range of 5.8 x 10-5 mm s^{-1} – 3.29 x 10^{-4} mm s^{-1} as the range of optimality and the optimal sinking velocity of the extrudate was obtained by maximizing the quadratic function which resulted to 1.25 x 10^{-4} mm s^{-1} and this will be obtained when the continuous flow belt dryer was operated at the drying temperature of 97.49°C, conveyor speed of 50 rpm, and air velocity of 1.102 cm s^{-1} with high value of desirability of 0.85 which shows that over 85% of the optimal goal will be attained if the machine was operated at the optimal operational condition.

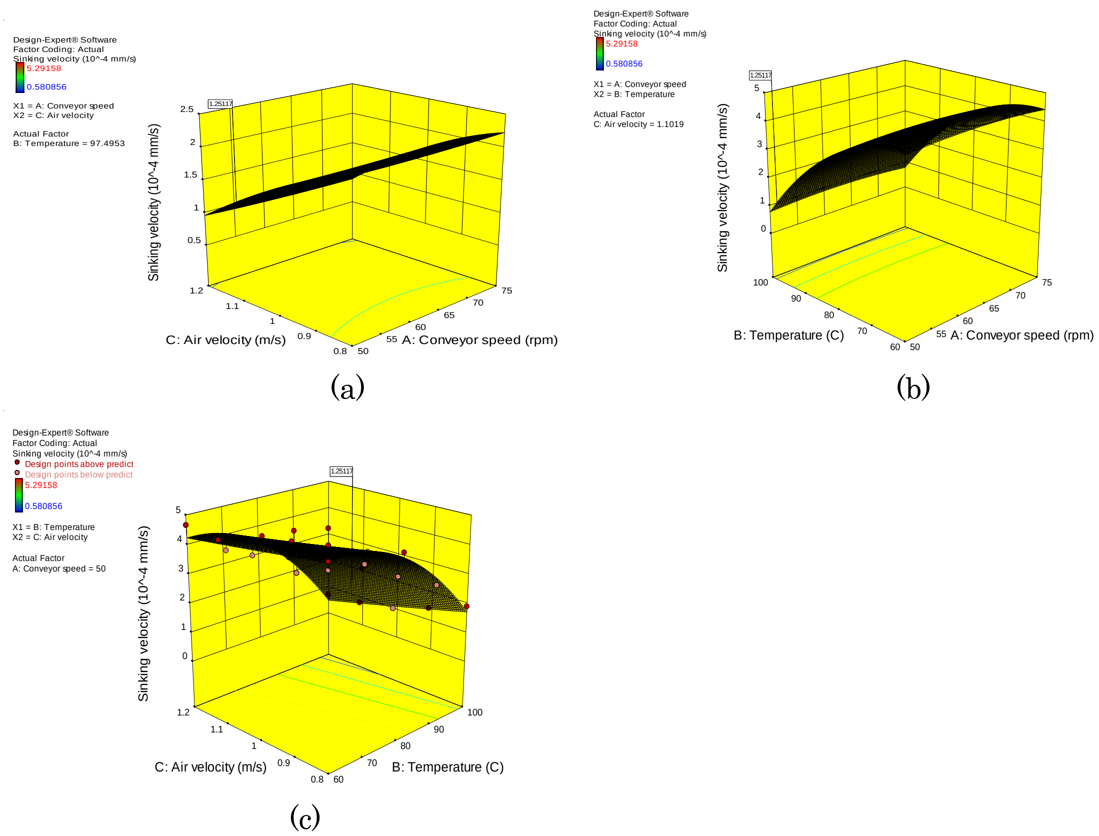
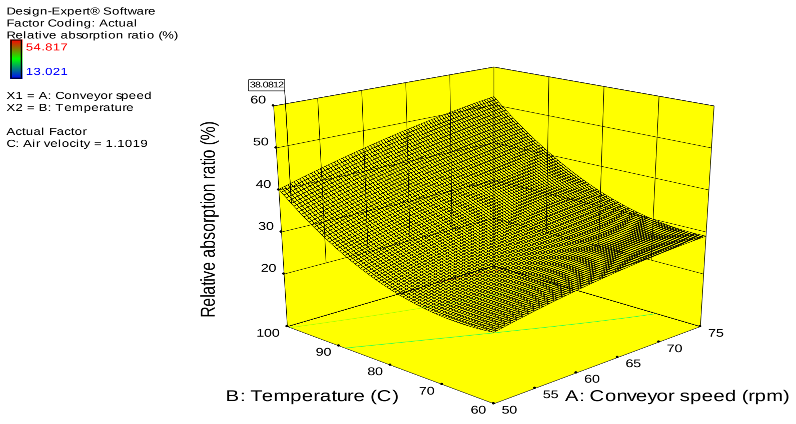


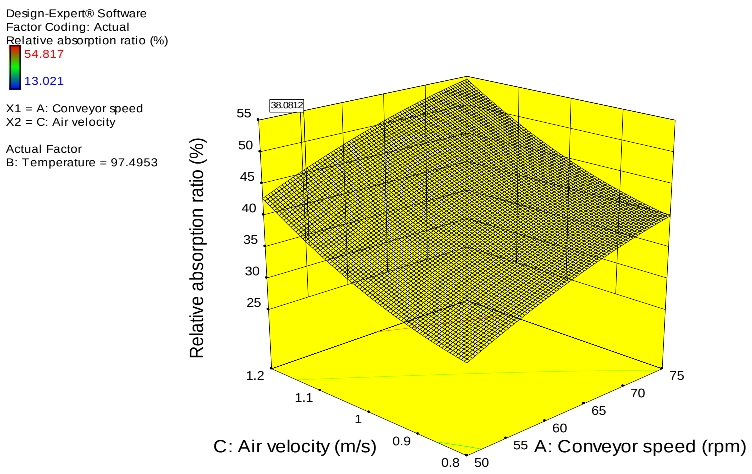
Figure 3(a – c). *Optimal surface plot of sinking velocity versus operational parameters of the machine.*

Estimate Response Surface of the Relative Absorption Rate

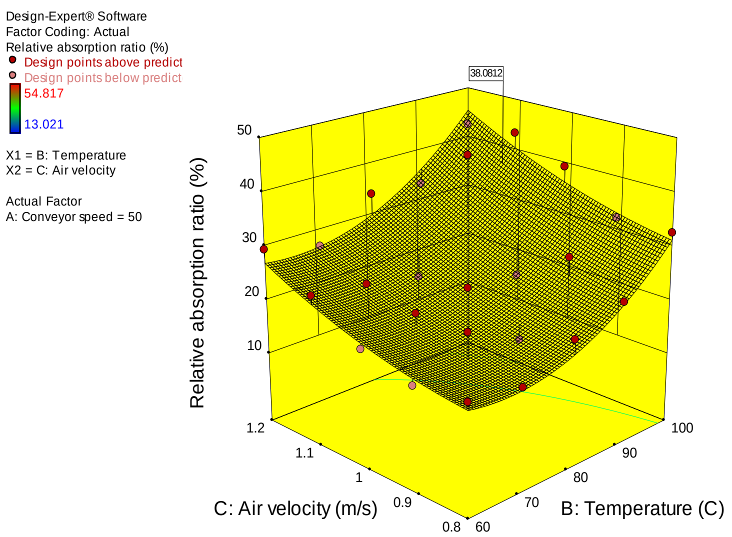
Figure 4a shows the optimal surface plot of the relative absorption rate as affected by the drying temperature and conveyor speed of the continuous flow belt dryer and Figure 4b shows the optimal surface plot of the relative absorption rate as affected by the conveyor speed and air velocity of the continuous flow belt dryer while Figure 4c shows the optimal surface plot of the relative absorption rate as affected by the air velocity and drying temperature of the continuous flow belt dryer. The optimal solution shows that the relative absorption rate exhibits a quadratic relationship with the operational parameter with the coefficient of determination value of 0.90 which shows that the operational parameter can optimally explain about 90.97% change in the relative absorption rate via quadratic function. Considering the experimental range of 60°C-100°C drying temperature, 0.8 m s^{-1} – 1.2 m s^{-1}, air velocity and 50 rpm-70 rpm conveyor speed as operational range of optimality, Also, taking the experimental output range of 13.02%–54.81% as the range of optimality and the optimal relative absorption rate of the extrudate was obtained by minimizing (Table 1) the quadratic function which resulted to 38.08% (Table 2) and this will be obtained when the continuous flow belt dryer was operated at the drying temperature of 97.49°C, conveyor speed of 50 rpm, and air velocity of 1.10 m s^{-1} with high value of desirability of 0.40 which shows that over 49% of the optimal goal will be attained if the machine was operated at the optimal operational condition.



(a)



(b)



(c)

Figure 4(a –c). *Optimal surface plot of relative absorption ratio versus operational parameters of the machine.*

CONCLUSION

This research provided valuable insights into the intricate relationship between various processing parameters and the resulting characteristics of the dried extrudate feeds' physical properties. This systematic exploration helps in optimizing the production, enhancing nutritional content and overall quality of fish feeds. The optimum predicted values for air temperature of 97.49°C, conveyor belt speed of 50 rpm and air velocity of 1.10 m s^{-1} were obtained for the dryer within the range of the input parameters. It is recommended that further research should be done on the response surface of buoyancy, expansion ratio and other physical properties of dried extruded fish feeds as this will contribute to sustaining the growth of the aquaculture sector.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Funmilayo Ogunnaike is responsible for the various parts of this paper including.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

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